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Feasibility study of Haffa Mini- hydropower plant in Bambasi Woreda (In the Case of Six Selected Kebeles)

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ABSTRACT

Currently; Ethiopia is one of the countries which is under developing and one of the strategies to be used to develop the country is to explore and develop the sector of energy. Ethiopia needs to develop the rural electrification sectors in order to provide illumination to the population living in those rural remote areas for rapid development in different sectors like schools; health centers; business centers and administrative officers. Hence the current energy regime in Ethiopia, that is heavily reliant on the burning of biomass, has had major implications for the environment.

In Ethiopia there is a fast depletion of renewable sources that is used in the past & in now days for the generation of electricity and the difficulty in reachability of the grid supply to the remote villages is a big challenge faced. The best possible remedial measure in this situation is to make use of the natural water resources available to generate electricity. In an endeavourance towards this end, the paper has been formulated for the electrification of six selected remote Kebeles in Bambasi woreda. This kebeles are kinds of locality in which there are a tribal settlement of about 600 families each that do not have opportunity of electrical energy supply. The present work focus on the feasibility studies carried out at the site for the assessment of mini hydro power plant potential of the selected site.

The results of the study reveal that there is a huge potential at the site to develop a mini hydro power plant which would meet the energy demand of the tribal settlement and thereby improving their living condition. But the river is intermittent so that it is recommended to construct dam for the purpose of storage of water.

Key words: Mini Hydropower, Energy generating potential, Haffa River, River flow

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INTRODUCTION

Background of the Study

Ethiopia is fortunate to be blessed with abundant water resources that can be tapped to meet its growing energy needs, despite being landlocked and non-oil producing country. Hydropower is one of the main energy sources that is recognized and given priority for poverty reduction and sustainable development in Ethiopia (Niguse Abebe, 2014)

The western region of Ethiopia has many permanent rivers and streams providing excellent opportunities for mini hydropower development. While large scale hydropower development is becoming a challenge due to environmental and socio-economic concerns and more recently its vulnerability to changing climates, mini hydropower development continues to be an attractive resource, especially in remote parts of the region. It is a proven technology that can be connected to the national grid, isolated grid or as a stand-alone option, or combined with irrigation systems. Mini hydropower can adequately contribute to the electricity needs of our country.

Ethiopia needs to develop the rural electrification sectors in order to deliver light to the population living in those remote areas for rapid development in different sectors like schools; health centers; business centers; administrative officers and others.

In Ethiopia the existing electricity network necessity high transmission lines and low load factor and this has a consequence of high cost of extending to grid extension. The future Haffa mini hydropower plant will be managed by the local population and we hope to have a rapid change and development of daily life from Kebele's people.

Sub-Saharan Africa (SSA) has the lowest energy access rates in the world. Electricity reaches only about half of its people, while clean cooking only one-third; roughly 600 million people lack electricity and 890 million cook with traditional fuels (*Jan Corfee-Morlot et.al.2019)*. Thirteen countries in SSA have less than 25% access, compared to only one in developing Asia (World Bank, 2018.) Economic growth in the region is also relatively low at an estimated a 2.8% percent in 2018, compared to 7.1% in South Asia (IMF, 2018). This dramatic lack of energy access stifles economic growth and sustainable development (World Bank, 2017).

Electric energy (electric light in particular) is still an extra appreciated only by a few in Ethiopia. The rate of electrification in the country is 42.9 %, for urban Ethiopia is 85.4% and for rural

Ethiopia it is 26.5 % in 2016 according to the World Bank collection of development indicators, compiled from officially recognized sources.

Ethiopia is a Federal Democratic Republic composed of 9 National Regional states: namely Tigray, Haffar, Amhara, Oromia, Somali, Benishangul-Gumuz, Southern Nations Nationalities and People Region (SNNPR), Gambella and Harari. From those regions we are focus on Benishangul-Gumuz which has 22woredassuch as Bambasi. There are about 43 kebeles and more than 50000 households in Bambasi woreda (CSA 2008). From those kebeles only 11 kebeles are get electricity. The remaining 32 kebeles doesn't get electricity because they are scattered and very far from national grid; so, they have very faraway chance to get electricity through the national grid. The only realistic method to electrify the rural villages seems therefore to be the stand-alone (self-contained) system like our proposed system.

Statement of the problem

The present energy regime in Ethiopia, that is heavily dependent on the burning of biomass, has had major implications for the environment. The use of traditional fuels as the main source of energy by rural households, which include the majority of Ethiopia's population, is especially an area of worry. Deforestation, land degradation, decreases in agricultural productivity, and increased greenhouse gas emissions have resulted from these patterns of unsustainable fuel consumption, and are further exacerbated by Ethiopia's growing population's increased energy demands. (Ethiopian Environment Review, 2010; Karakezi, 2003).

Most of the people of Benishangul-gumuz (around 86.49% of the population) live in rural areas where energy access is almost insignificant. Now covering the national grid to these remote areas is impossible because of the high cost of transmission and the very low load factor in these areas. But electrification of the rural communities is very crucial specially to ensure the socio-economic development of the community. To satisfy their energy needs, these people are using kerosene which is becoming difficult to afford because of the high and day-to-day increasing price of kerosene; and fire wood, cow dung and other traditional biomass resources which are causing health problem, deforestation and soil degradation leads to global warming which is one of the biggest issues in the world at this moment. So that in order to overcome these all problems the appropriate answer is allocating simple alternative renewable energy source for them.

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Therefore, from different alternative energy sources we are proposed mini hydropower plant to electrify the selected areas.

General Objective of the Study

Objective

The main objective of this work is identifying energy generating potential of Haffa River for mini hydropower site to electrify the selected six villages which are found around Haffa River.

Specific objectives

- To make survey on the hydrology of the area in the field
- To determine the head, flow rate and turbine type.
- To calculate the estimated power potential of the site.
- To make energy demand study and socio-economic survey.

Significance of the Study

Ethiopia is endowed with renewable energy resources such as wind, solar, biomass and small hydro. Demand for electricity is forecast to grow at an annual rate of 10% (MoEn 2012). The increase trend is due to the combined effects of expansion in the economy, growing population and higher disposable income, which provides a strong growth in energy demand. Increased utilization of renewable energy technologies such as small-scale hydropower will not only boost the energy supply use but also reduce advance environmental impacts of energy usage.

Again, investing in small-scale hydropower will invariably derive important benefits at the local level. The most important benefits would include among others:

1. Improved household food security through increased agricultural production.
2. Provision of electricity for small-scale industries and social services such as education and health care.
3. Electricity, will to some extent substitute the use of paraffin and diesel for cooking and heating.

It will also reduce the time spent on collecting wood fuel and this contributes to the reduction in drudgery. A study of this nature that promises to improve the quality of life among rural households cannot be overlooked.

Expected Outcomes

The benefits of rural electrification are theorized to be spanning a wide range, from increases in income due to new work opportunities to increased security and decreases in fertility. We summarize the expected outcomes as follows:

- Income benefits from access to electricity through new opportunities of work
- Leisure and domestic benefits from lighting and TV/radio.
- Time savings from household chores which can be used for leisure and productive activities.
- Education benefits through higher earnings for children living in electrified households that have higher educational attainment.
- Increased productivity of home business through higher revenues of existing businesses and the creation of new home business.
- Increased agricultural productivity through higher revenues.
- Improved health outcomes and reduced mortality through improved indoor air quality from changes in lighting source.
- Reduced fertility at lower costs, achieved through information channels that use electricity in lieu of reproductive health programs.
- Public goods benefits, such as increased security and lower environmental contamination.

The Study Area: Topography, Location and Climate

Bambasi is found in Benishangul Gumuz National Regional State at 39 km from the regional capital, Assosa and 637 kms asphalted road from the National capital Addis Ababa. According to the elders in the community Bambasi town is established in 1750s. In 1928 E.C. Bambasi was established as second Woreda capital. Now Bambasi is the Woreda capital for Bambasi Woreda with a municipal status and a town manager.

The study is located on Haffa River around 650km far from Addis Ababa and 50 km from Assosa in Bambasi woreda. The river is part of the Abay basin.

The source of the Haffa River, on which is the study is will takes place Mini hydropower study is being built, flows from the southwestern highlands southwards to Dabus river. Like most of Ethiopia's river basins, the Haffa sub basin is characterized by deep and steep sided valleys making it conducive to harnessing hydroelectric power at a number of locations along the river system. The Haffa mini hydropower study is located within the Abbay basin.

The climate of Haffa sub basin is classifiable as humidity with heavy rainfall from May to September of each year. The annual rainfall of the region ranges between 1,000 to 1,800mm while the mean temperature of the river sub basin and its surrounding area ranges from 20 to 30^0c.This climatic conditions are along with conducive nature of the soil in most parts of the hinterlands of the sub basin give more opportunity to promote development in the area in particular and in the region in general.

LITERATURE REVIEW

Introduction

Energy is considered to be a basic issue in the generation of prosperity, social development and improved quality of life in all countries in the world. Therefore, produced and consumed energy resources and especially renewable energy sources have a very important value (Capik et al., 2012). The use of renewable source is the most valuable solution to reduce the environmental problems associated with fossil fuels-based energy generation and achieves clean and sustainable energy development. Hydros, wind, biomass, solar and geothermal are among the most important renewable sources for energy generation (Nautiyalet al., 2011).

General Description of Hydropower

Hydropower, hydraulic power or water power is power that is derived from the force or energy of moving water, which may be harnessed for useful purposes. Hydropower is available in a wide range of study scales and types. Study's can be designed to suit particular needs and specific site conditions. As hydropower does not consume or pollute the water it uses to generate power, it leaves this vital resource available for other uses. At the same time, the revenues generated through electricity sales finance other infrastructure essential for human welfare. This can include drinking water supply systems, irrigation schemes for food production, infrastructures enhancing navigation, recreational facilities and ecotourism (Yuksel, 2008).

Classifications of Hydropower

Hydropower is a general term that covers a wide range of installations. Depending on the type, the services provided vary (Gaudard and Romerio, 2014). There are some classifications: into water head, storage capacity or size and facility type: run-of-river (RoR), storage and pumped storage hydropower (Kumar, et.al, 2011).

Power Potential

There is no international agreement on the limit of “small”, but most European and other countries accept 10 MW as the upper limit. Within the SHP category, the systems are further categorized into pico, micro, mini, and small systems. Most of the countries and organizations recognize pico as a system that generates less than 10 kW, micro (more than 10 kW but less than 100 kW), mini (more than 100 kW but less than 1 MW), and small (above 1 MW but less than 10 MW) (Chiyembekezo S. et.al, 2012).

Mode of discharge regulation

Hydropower plants are often classified in three main categories according to operation and type of flow. Run-of-river (RoR), storage (reservoir) and pumped storage hydro power plants (HPPs) all vary from the very mini to the very large scale, depending on the hydrology and topography of the watershed (Nasr Al Khudhiri et.al. 2018). In addition, there is a fourth category called in-stream technology, which is a young and less-developed technology (Kumar, et.al, 2011).

Run-of-River

A RoR HPP draws the energy for electricity production mainly from the available flow of the river. Such a hydropower plant may include some short-term storage (hourly, daily), allowing for some adaptations to the demand profile, but the generation profile will to varying degrees be dictated by local river flow conditions. As a result, generation depends on precipitation and runoff and may have substantial daily, monthly or seasonal variations. When even short-term storage is not included, RoR mini hydropower will have generation profiles that are more variable, especially when situated in mini rivers or streams that experience widely varying flows Kumar, et.al, 2012).

In a RoR HPP, a portion of the river water might be diverted to a channel or pipeline (penstock) to convey the water to a hydraulic turbine, which is connected to an electricity generator (Fig 2.1).RoR studys may form cascades along a river valley, often with a reservoir-type HPP in the upper reaches of the valley that allows both to benefit from the cumulative capacity of the various power stations. Installation of RoR PPs is relatively inexpensive and such facilities have, in general, lower environmental impacts than similar-sized storage hydropower plants (Kumar, et.al, 2012).

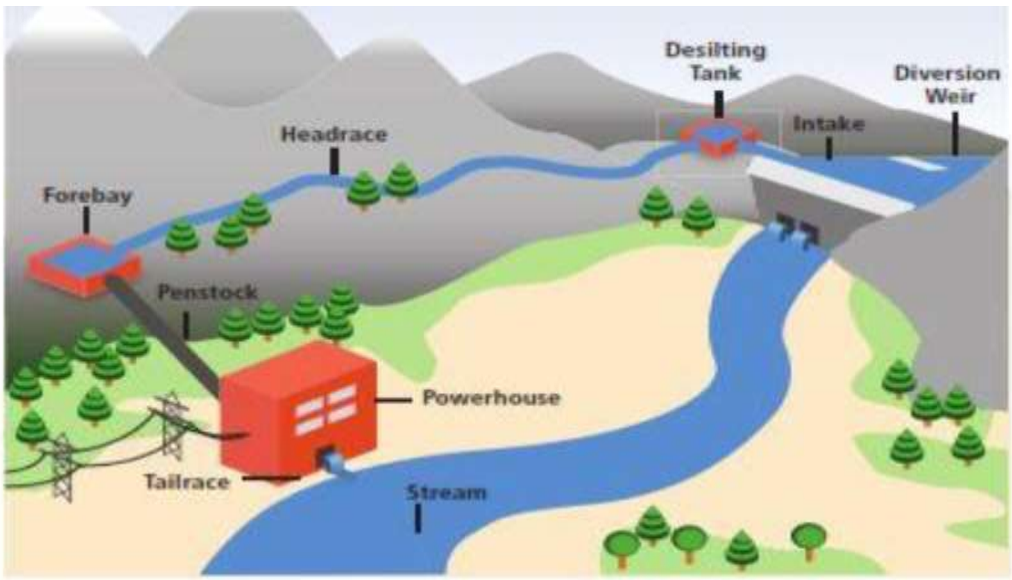

Figure 1 Typical ROR hydropower plant ***(Source: Kumar, et al., 2012)***

General layout of ROR type Mini Hydropower

A typical run-of-river mini hydropower system for electricity generation is composed of the following basic components: water intake structure (e.g., weir and settling tank), penstock, turbine, mechanical power transmission system to generator, generator, and electricity transmission system to load centers, and control system (Kaunda et al., 2012) (Fig.1). In RoR type only part of the river flow is diverted to a forebay through channels or pipes, from which it falls down a penstock to enter an electricity-generating turbine. After this process the water is returned to the river through a tailrace. These plants depend directly on natural water cycles, since their water supply is variable and cannot be controlled. The water head is practically constant, so that the power generated by the power plant will depend on the mass of water flowing along the river or stream.

SHP is a site-specific technology and as such not all locations on the river flow course are ideal for mini hydropower development except those that have considerable sizes of head such as sloping sections of the river and natural falls. This shows that most of the potential sites for mini hydropower are found in mountainous areas with perennial rivers (Kaunda et al.2012).

Importance of mini Hydropower

As an electricity generation technology, mini hydropower is a very efficient energy technology because electricity is generated directly from the shaft power. Mini Hydro Power system for power supply is a well matured technology as the case with solar PV and wind energy systems (Kaunda et al., 2012). Mini Hydro Power schemes have relatively low life cycle investment costs per kW of installed power and through their modular nature it is possible to size the system to meet specific power demand according to potential of the site and the available finance (Kaunda et al.,2012). As the system can be designed and installed using local resources: materials and labor, this also creates job opportunities and ability to use technology to advance standard of living in the area (Kaunda et al., 2012).

In Ethiopia, most of the villages/towns are remotely located and interconnected grid system if has to transmit electricity to these villages/ towns may not be that much techno-economic viable. Presently efforts are being made by Ethiopian Electric Power (EEP) through Universal Electric Access Program to electrify vast areas in Northern, Central & Southern, Western and Eastern parts of the country. Although expansion of the national grid for rural electrification is progressing fast, still there is a vast possibility to develop mini hydro schemes, particularly in those areas which are remotely located and are not covered presently under Universal Electric Access Program (AAU, 2014).

Advantages of hydropower

Small and large hydropower can have different effects. Mini hydro generation have no environmental effects to speak of as there are no large dams or reservoirs involved. Large hydro systems with sizable dams and reservoirs may cause one or more of the following in addition to large financial investments (Fritz, 1984);

- Relocation of an existing settlement;

- Reduction of farmland and grazing land;
- Disruption of the normal migration pattern of fish or the flow of traffic;
- The presence of a dam will probably cause the accumulation of silt which will, not only adversely affect power generation but also cause the level of reservoir water to rise, resulting in further inundation of the surrounding lands;
- Increased possibility for water-borne diseases;
- Disappearance of bird and animal sanctuary because of inundation, although other birds and animals can find sanctuary at the boundary of the reservoir.

A few general statements can be made about the environmental aspects of hydro energy generation systems:

- They are generally environment friendly; i.e., no air or thermal pollution;
- The energy source, i.e. water, is not, in the final analysis, consumed like fossil-fuel.

MATERIALS AND METHODS

Materials

The following materials had been used to conduct this research:

Contour Map (Topo Map): In order to successfully delineate a watershed boundary, it is needed to visualize the landscape as represented by a topographic map. This map helps to examine the elevation, determine flow direction and flow length of the catchment areas.

Tape meter: to measure the cross section of the site.

GPS: to measure the elevation of the site.

Data Types and Sources

This part contains the types and sources of data which were used in this study. Consequently, the qualitative as well as quantitative type of data has been used for this research. Flow data was used to develop FDC curve and data sources for this research were both primary and secondary sources.

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Primary data sources

Field survey/observation, interview of professionals and results were the primary data sources which were engage in this study.

Secondary data sources

Specific information for the selected site(s) was obtained from the following key government ministries, department and agencies: Ministry of Energy of Water Resources, Metrological Services Department, Statistical Services Department and Hydrological Survey Department. The major information that were collect from the above sources includes; Reconnaissance of the study area, Data collection such as hydrological data (stream flow data), Development of flow-duration curves for different exceedance levels based on available hydrologic data of the study area, GIS data collection in order to describe the topography of the site, checking of the consistency of the hydrologic data.

Sampling Procedure and Sample Size

The participants of this study are the six selected kebeles which are found under Bambasi woreda. Accordingly, there are over forty kebeles under Bambasi. Among the six kebeles which have more than 110 household in each kebele; using random sampling method the researchers have taken 10 household people, generally the total of 60 sampling size is concerned.

Data Collection

The report was prepared based on primary and secondary data source gathered through field assessment, household survey, key informant interview, site visits as well as problem and situation analysis. The data gathering was conducted in February 2021 and relevant information on the socio-economic situation of the area were collected from respective Woreda sector offices, kebele administrators, Development Agents, farmers, key informants, women group and other responsible partners and individuals.

a) Review of Reports And Secondary Data Source

Available national, regional and Woreda level secondary data sources were gathered. Although, this study has no previous study document, pertinent literature on policy issues and development strategic direction, line office reports and statistics were reviewed within the framework of the study objective.

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b) Key Informants & Discussion with Stakeholder Institutions

Primary data required for this study were generated through field assessment and site visits during which discussions were held with different stakeholders and focal groups including interview with individual households. Also, Woreda sector offices experts have been contacted that included Woreda water resource development office, Woreda agriculture and rural development office, Woreda Cooperative Office. Similarly, Officials and Development Agents of the six kebeles as well as representatives of the beneficiary communities were widely consulted in the study process.

c) Public Consultation and Focal Group Discussion

Separate public consultations were held in each kebele with community representatives of different segments of the society. The public consultation were facilitated and arranged by the kebele leaders and participants were drawn from different groups of the society (Elders, Women, Youth, beneficiary Farmers and Kebele executives). Discussions were also made with Kebele leader as well as in group in order to assess the attitudes, opinions and reactions of the community to the proposed study.

d) Household Survey

One of the various primary data collection methods utilized by the socio-economic study was sample household survey. Accordingly, a random sample of 100 households covering 5.1% of the total households in the kebeles has been selected in a random fashion for detailed interviews. Prior to data collection, enumerators were selected from the study area and thoroughly oriented for the survey.

RESULT AND DISCUSSION

Socio-Economic Profile of the Study Woreda

Haffa River is located in Benshangul Gumuz Region, Bambasi Woreda, which is located at a distance of 628 km from Addis Ababa town and 42 km from Assosa town. Bambasi Woreda is one of the seven Woredas in the Assosa zone..

Based on the 2007 Census conducted by the Central Statistical Agency of Ethiopia (CSA), Bambasi Woreda has a total population of 48,694 of whom 24,720 (50.77%) are men and 23,974 (49.23%) are women. While 9,146 (18.78%) of the total population is urban inhabitants, 39548

(81.22 %) lives in rural areas of the Woreda. With an area of 2,210.16 square kilometers, Bambasi Woreda has a population density of 21.4per sqkm. Berta, Amhara, Oromo, Tigray, Mao, Komo, Gurage and Agew are among the ethnic groups living together in the Woreda.

Bambasi town, which is the capital of the Woreda, is connected to Assosa and other parts of the country through an asphalt road. A network of all-weather gravel roads link Bambasi with other adjacent Woredas in the region. Water supply coverage of the Woreda is about 65%.

Population Size

According to the information obtained from the Administrative offices of the kebeles the combined total population size of the six kebeles 2798. Out of the total, 17.6% live in Mender 50, 20.9% live in Mender 55, 13.4% live in Sisa Kutr 1, 10.5% live in Sisa Kutr 2, 17.7% live in Budaselga and Ida 19.7% live in Dabus kebele. Of the total population of the command area 49.1 % are female while 50.9% are male.

Data from the indicated sources show that the total number of households in the kebeles is 694 of which 49 are female headed.

Table 1. Population Size of study Area by Kebeles

Kebeles	Total households			Population size		
	M	F	Both	M	F	Both
Mender 50	102	11	113	250	245	495
Mender 55	110	10	120	300	286	586
Sisa Kutr 1	101	8	109	190	185	375
Sisa Kutr 2	100	9	109	150	144	294
Budaselga	112	5	117	256	240	496
Ida Dabus	120	6	126	280	272	552
Total	645	49	694	1426	1372	2798

Source: *Household survey*

Electricity

The Kebele has no electric power supply that is connected to national grid system.

Health Facilities

Three health post run by a nurse is the only health facility currently available is providing health services to the communities of Buda selga & sisa kutir 1 & sisa kutir 2. There is no health facility in Mender 55, Mender 50, and Ida dabus kebeles. However, health extension workers stationed in the kebeles educate the communities on preventive health, such as hand washing, using mosquito nets, toilet construction, etc. Malaria is the major human health hazard in the kebeles followed by intestinal parasites.

Education Facilities

The educational institutes available in the kebeles comprise three Primary Schools (1-8) in Budasela, Ida dabus & Mender 55 and two first cycles (1-4) in sisa kutir 1 & Sisa kutir 2.

Water Supply

The sources of safe water supply in the kebeles are totally twelve hand pumps and two protected springs. However, the existing sources are not adequate for the population and as a result many families have no alternative but to consume unsafe water from Haffa River.

Road and Transport

The availability of effective transport network and commercial vehicle and road infrastructure is one of the most important aspects for speedy movement and marketing agricultural produce. It was observed during field assessment that the command area kebeles have a dry weathered road network that permits travel by motorized transport. The kebeles are hardly accessible during the rainy season as the rain in the area last for about six months (April-September). There is no public transport from aforementioned kebele to the market center. As a result, people of the area use pack animals and carry by them to sell their agricultural product and to transport purchased industrial output and other items from and to the market.

Climate and Hydrology

General

The objective of the climate and hydrological investigations were to establish and quantify climatological and hydrological aspects of the study region and derive parameters and hydro meteorological series required for analysis of crop water requirements, dimensioning, design and evaluation of the Study area.

The geographical area of interest was defined to cover the catchment of the Haffa River and adjacent catchments in regard to data collection and analysis for this hydrological study.

The scope of the hydrological investigation comprised the following activities:

- Field visit to study area and to the different locations within the catchment,

- Review of previous hydrometric and water resources development studies carried out in the Region,
- Compilation, update, and qualitative and quantitative analysis of all pertinent meteorological and hydrological data,
- Determination of climatological and hydrological characteristics of the study area,
- Determination of design floods

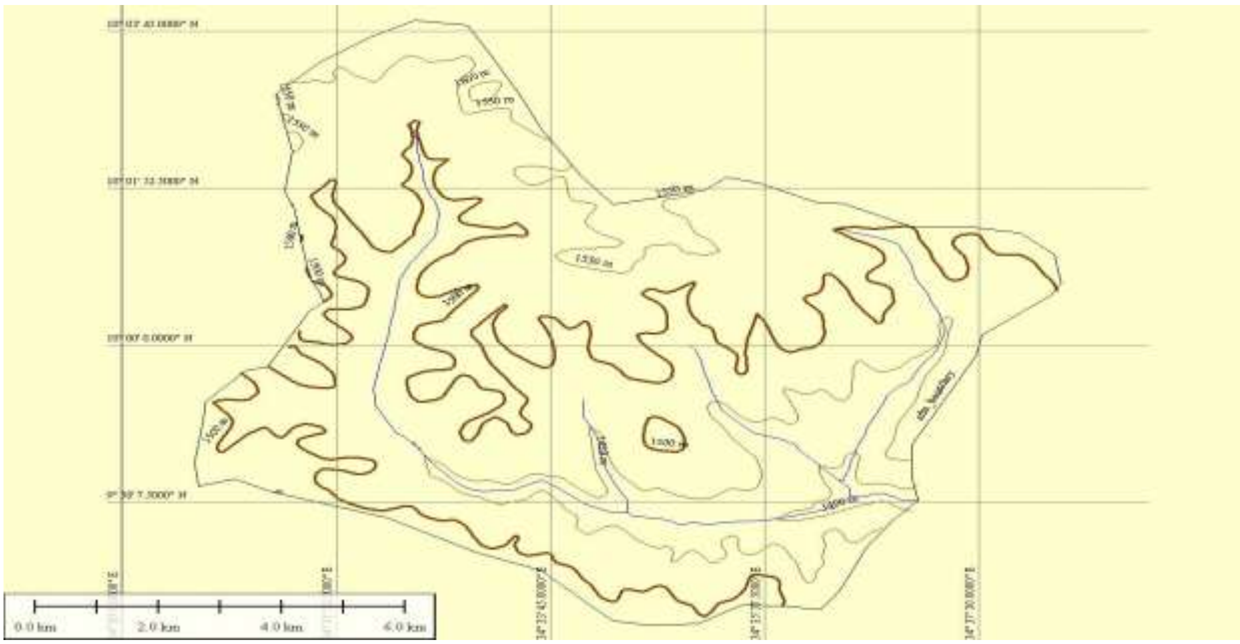


Figure 2: Haffa River Catchment

Meteorological Data

For the Haffa feasibility study, stations located in and near to the study were identified and a data set was assembled from the database comprising the following records.

- Monthly rainfall from Assosa station
- Monthly Meteorological data from Assosa station with data types: evaporation, relative humidity, sunshine duration, and wind speed.

Climate of the Study Area

The seasonal variation of typical climatic parameters recorded at the principal station at Assosa station is shown in Figure 2. Although situated just outside the study catchment area, this station holds the longest and most complete climatological records and can be used to represent conditions near to the study sites.

Mean monthly profiles of temperature show only a slight variation from month to month. In contrast evaporation varies quite considerably throughout the year, being conditioned to some extent as well by other climatic factors, particularly rainfall. Evaporation rates are thus highest in the dry season months between October and May.

Table 2: Monthly Profile of Climatic variables at Assosa

Month	MaxTemp (deg.C)	MiniTemp (deg.C)	Humidity (%)	Wind Sp. (Km/d)	Sun Shine (Hours)	Solar Rad. (MJ/m2/d)	ETo (mm/d)
January	29.9	14.5	54	147	9.3	20.9	4.66
February	31.5	15.7	53	147	8.5	21.1	5.03
March	31.8	17	54	121	6	18.5	4.62
April	31.5	17.2	56	147	8.7	23	5.43
May	28	16.7	79	147	6	18.4	4
June	25.2	15.5	86	121	4.7	16.1	3.23
July	23.9	15.1	87	121	4.1	15.3	3.01
August	23.9	14.9	88	121	2.3	12.9	2.67
September	25.6	14.8	83	121	6	18.5	3.64
October	25.8	14.9	78	121	7.2	19.5	3.79
November	27.4	14.4	72	121	7.7	18.9	3.81
December	29.3	14.6	63	147	8.3	19	4.2

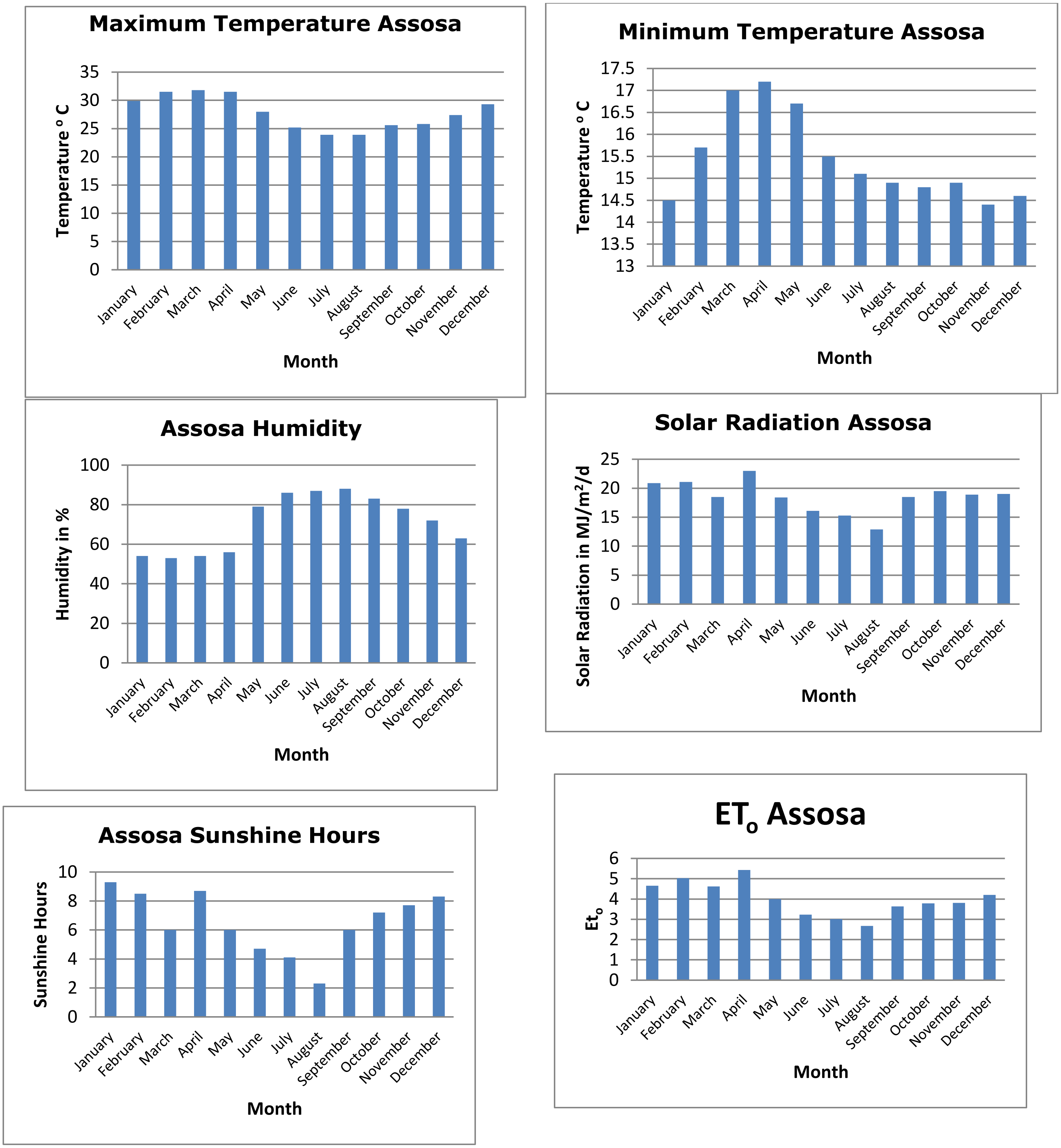


Figure 3: Monthly Profiles of Climatic Variables at Assosa

Rainfall

Mean monthly rainfall profiles are generally uni -modal with peak in August. Rainfall is conditioned principally by migration of Inter-Tropical Convergence Zone which accounts for almost 100% of annual rainfall on average between March and November. Rainfall variation at Assosa station adjacent to Haffa River catchment is shown in Figure 5.

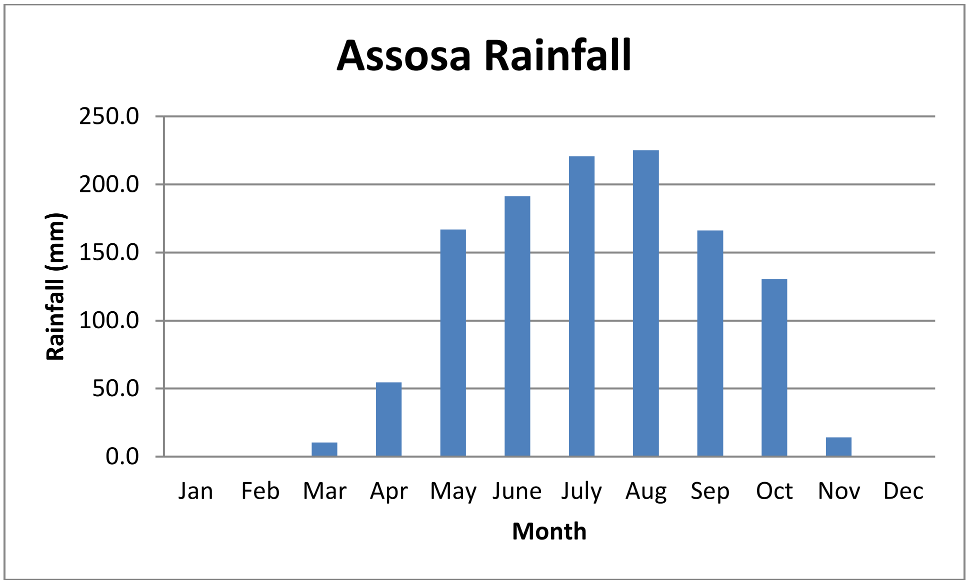


Figure 4: Monthly Rainfall at Assosa

Table 3: Inventory of Rainfall Stations and Data

Station	Class	Latitude	Longitude	Elevation (m.a.s.l)	Mean Annual Rainfall (mm/a)	Period of Measurement		Number of Complete Years
						From	To	
ASSOSA	1	$10^0$4’	$34^0$32.39	1560	1090	1994	2013	20

Estimation of Missing Data

Before using a river flow record of a station, it is necessary first to check the data for continuity. The continuity of a record may be broken due to the following reasons.

- Absence of the observer
- Broken or frailer of instrument

The missing data can be estimated by using the data of the neighboring station. There are different methods of filling missing data such as arithmetic average method, normal ratio method or other approximation methods. However, all the above methods require more than one nearby station and concurrent records. These problems force to adopt simple correlation between runoff and rainfall value for the determination of this missing data. The missing data can be estimated by using the following methods by considering the data of the neighboring station. The following are commonly used method of estimating missing data. These are:

A. Arithmetic mean method

B .Graphical Correlation Method

C. Normal Ratio Method

D. Linear Regression Method

Among all these method we use linear regression method of estimating missing data. For this method consider a line between rainfall and runoff. If the correlation coefficients are in the range 0.6 < r<1.0 indicates good correlation (Ray k. Linsley. JR).The equation for linear regression between runoff and rainfall is:

Y = a*X+b

And the values of the coefficient and b are given by:

$$a=\frac{N\sum_{i=1}^{N}XY-\sum_{i=1}^{N}X*\sum_{i=1}^{N}Y}{N\sum_{i=1}^{N}X2-\left(\sum_{i=1}^{N}\right)2} \qquad b=\frac{\sum_{i=1}^{N}Y\sum_{i=1}^{N}X^{2}-\sum_{i=1}^{N}X\sum_{i=1}^{N}Y}{N\sum_{i=1}^{N}X^{2}-\left(\sum_{i=1}^{N}X\right)^{2}}$$

$$r=\frac{N\sum_{i=1}^{N}XY-\sum_{i=1}^{N}X\sum_{i=1}^{N}Y}{\sqrt{\left(\left(N\sum_{i=1}^{N}X^{2}-\left(\sum_{i=1}^{N}X\right)^{2}\right)\left(N\sum_{i=1}^{N}Y^{2}-\left(\sum_{i=1}^{N}Y\right)^{2}\right)\right)}}$$

Where, a and b are constant

Y =monthly average runoff

X = monthly average rainfall

r = correlation coefficient

For this particular project we will use linear regression method for 0.6<r<1.0. After filling the missing data the following table is obtained below:

Table 4: Computed discharge after filling missing data

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1994	0.542	0.409	0.325	0.332	0.475	0.584	1.930	0.081	2.560	2.800	1.975	1.044
1995	0.583	0.463	0.428	0.474	0.831	1.198	2.350	0.099	2.947	2.661	2.029	1.350
1996	0.821	0.588	0.474	0.449	0.444	0.767	0.579	0.031	0.925	1.001	0.540	0.484
1997	0.453	0.389	0.388	0.365	0.574	1.026	1.000	0.054	2.331	2.067	1.096	0.611
1998	0.431	0.496	0.410	0.354	0.420	1.677	1.477	0.069	2.480	2.649	2.103	1.241
1999	0.890	0.641	0.591	0.485	0.822	0.743	1.960	0.100	4.037	3.579	2.147	1.086
2000	1.301	0.793	0.433	0.308	0.342	0.461	0.934	0.072	2.750	1.834	1.004	0.524
2001	0.315	0.204	0.135	0.958	2.275	2.439	3.638	0.108	3.171	2.233	1.395	0.563
2002	0.072	0.000	0.001	0.538	1.044	1.007	2.729	0.109	2.773	2.891	2.289	1.172
2003	0.730	0.459	0.360	0.287	0.674	2.141	3.150	0.134	3.853	2.889	1.880	0.933
2004	0.605	0.405	0.257	0.231	0.526	0.630	1.590	0.062	2.859	2.336	1.354	0.682
2005	0.429	0.288	0.293	0.155	0.645	1.045	2.317	0.121	3.917	3.097	1.179	0.585
2006	0.328	0.182	0.602	0.333	0.926	3.095	3.225	0.118	5.813	4.353	1.975	1.088
2007	0.696	0.420	0.278	0.346	0.950	2.664	2.758	0.096	4.471	3.087	2.538	1.215
2008	0.740	0.478	0.339	0.259	0.803	1.068	1.009	0.083	4.815	4.743	3.040	1.430
2009	0.851	0.552	0.352	0.316	0.953	1.213	2.137	0.146	5.227	6.561	3.496	1.805
2010	1.008	0.609	0.378	0.380	0.784	2.411	3.200	0.121	4.892	5.099	3.732	1.966
2011	1.094	0.677	0.442	0.369	0.422	1.104	1.516	0.082	4.393	5.595	3.361	1.752
2012	0.974	0.604	0.401	0.284	0.308	0.879	3.345	0.110	4.621	3.400	1.823	0.932
2013	0.579	0.377	0.257	0.199	0.428	1.416	0.878	0.046	2.967	1.993	0.990	0.555

Computation of Flow Duration Curve

A flow duration curve of a stream is a plot of discharge against percent of time the flow was equaled or exceeded.

It also answers the question concerning normal flow, the length of the time (duration) that a certain river flow is expected to be exceeded and also to decide whether storage is required or not.

There are two different methods for constructing flow duration curve; namely the

1. Total Year Method
2. Calendar Year Method

Therefore, for our project the total year method is used to plot the flow duration curve for this particular project. When studying stream flow variability through flow duration curve, it requires detail knowledge of the different plotting position formula. A comparative study among different empirical formulae revealed that, on the basis of theoretical sampling from extreme values and normal distribution the following formula (m/n) provided the estimate that are consistent with the experience.

$$\text{Where, } Pi = \frac{m}{n} X100\%$$

Pi = plotting position

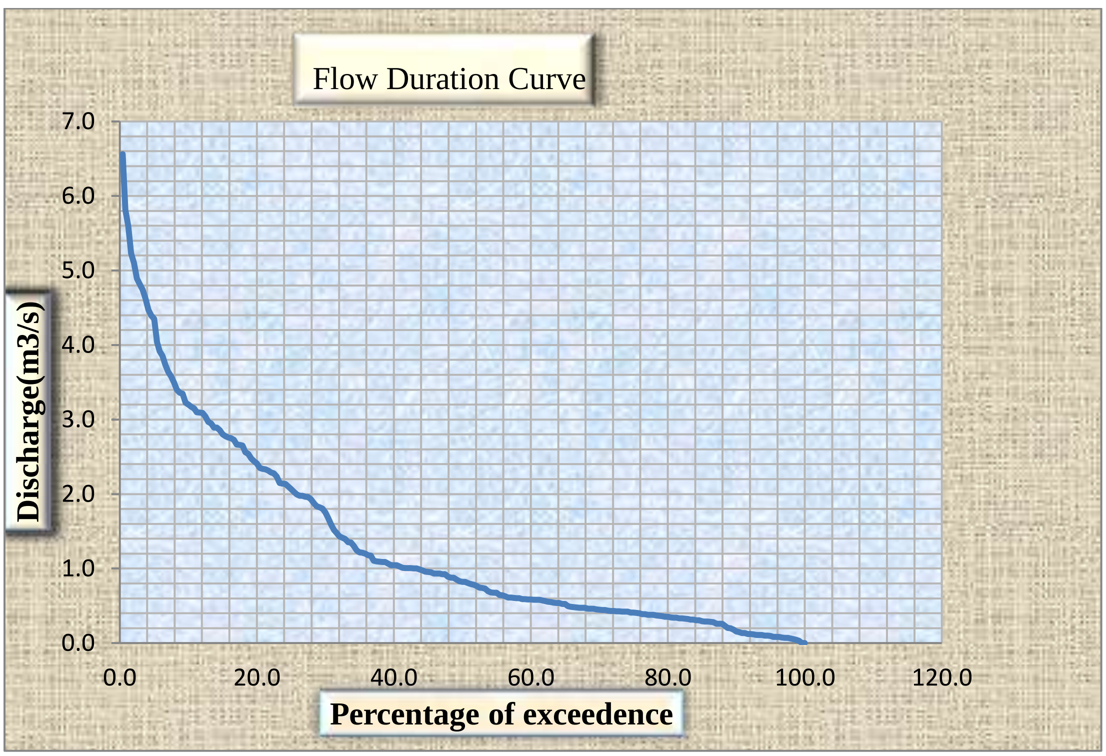
m = rank

n = length of records

Since total year method incorporates all the data in the record it gives more correct results than the calendar year method. Therefore, the total year method is used to plot the flow duration curve for this particular project.

In general, the flow period curve is very useful in hydrological analyzes, particularly in hydroelectric studies. The flow length curve (FDC) can be used in the hydroelectric study to calculate the expected power of a planned hydroelectric installation (Fritz 1984).

Figure 5: Flow duration curve



Estimation of Energy Production

The procedure estimating the capacity for energy production and the assessment of financial productivity (Du et al. 2017) is as follows, although only the first step is considered in this paper. The sites' power potential was calculated from a reliable average monthly flow and heads for different time scales. The generation potential energy depends mainly on the available flow and topographical hydraulic head (Kaunda et al. 2012).

$$P = Q\rho\eta g H$$

Where, p is the power; ρ is the water density, g is gravity, η-overall efficiency Q is discharged equally to 75% effective flow, and H (m) is the net head (Fraenkel etal.1991).(Table 5) Hydroelectricity is the power generated by flowing water using the potential energy it contains.

The available water head and flow conditions are the criteria for selecting the appropriate turbine's type. The related efficiency curves of the turbine depend on the rated head, runner diameter, turbine specific speed, and the turbine manufacturer/design coefficient. Since the estimated head of the selected site is 2m cross flow turbine is the appropriate one.

Table 5: Power at different discharge flow

Discharge (Q)	Power (kw)
Maximum (Q=6.5m^3/s)	127.53
Minimum (Q=0.5m^3/s)	9.81
Average (Q=1.34m^3/s)	262.9

4.7. Selection of best type of turbine

Selection criteria;

- ✓ The net head available for power generation
- ✓ The range of discharge passing through the turbine
- ✓ Rotational speed
- ✓ Cavitation problem
- ✓ Cost

In this project the best fit of turbine type to meet the power requirement is across flow turbine which is mostly used in many small scale hydro power projects however its efficiency is low as compared to other types of turbines.

Characteristics of Cross flow

- ✓ This impulse turbine is used for a wide range of heads overlapping those of Kaplan, Francis and Pelton.
- ✓ It can operate with heads between 5 and 200m
- ✓ it has low efficiency compared to other turbines
- ✓ High head cross-flow runners may have some troubles with reliability due to high mechanical stress.

But

- it is an interesting alternative when one has,
    - enough water,
    - defined power needs and
    - Low investment possibilities, such us for rural electrification programs.

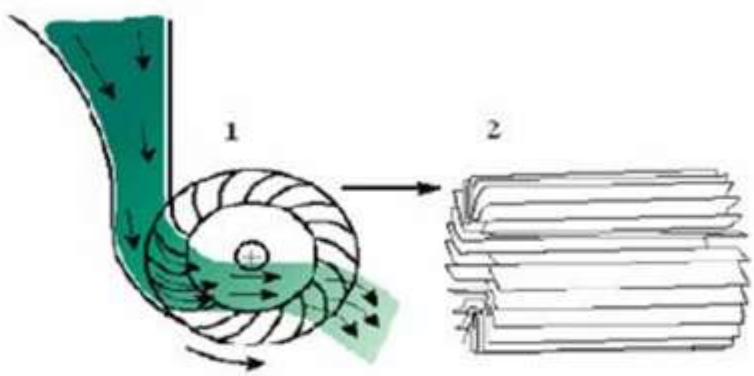


Figure 6. Cross flow turbine (1) cross section through the turbine and (2) arrangements of cross flow turbine blades

CONCLUSION

This paper presented a preliminary feasibility study of mini hydro energy potential in Haffa River. Based on the research findings the feasibility of MHP potential sites of Haffa River were obtained. The missing data were filled by using linear regression method and the discharge for the site was estimated. Based on the available gross head, estimated discharge, and by determining turbine characteristics; the amount of annual energy generation was produced from the selected site.

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According to the annual energy generated the most efficient configuration for the site is recommended. Out of this study, it can be concluded that: the most suitable mini-hydro turbines used for this site is Cross flow turbines. The expected average energy that can be produced from the site is about 262.9 kW. Finally Haffa River is intermittent and it has been observed that dependable flow in the basin without storage is low. Therefore, run-of-river plants are not feasible. This is because, though there is suitable gross heads for MHP development, there is high variability of stream flows.

RECOMMENDATION

This study is about the feasibility study of mini hydro energy potential in Haffa River, and recommends the development of water resources for multiple purposes. Further, the recommendation of such hydroelectric dams will benefit the country want sustainable development. To be effective and efficient in programming rural electrification by developing mini hydropower plants, it must be combined with the broader objectives of other rural development programs at local and national levels. The top most priority has to be given among the various factors that influence the cost of capital, the choice of site and the simple layout. Develop and modernize legacy conventional recording systems for hydraulic data in incorporate modern technology to improve data recording operations.

In general, the Haffa River is irregular and it has been observed that dependable flow in the basin without storage is low. Therefore, run-of-river plants are not feasible. Because there is high variability of stream flows. So it is recommended to construct dam to store water.

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