The determination of energy production potential of traditional water mills in the district of Kalkandere in Turkey

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Abstract

A county in the province of Rize in Turkey, Kalkandere is topographically hilly and sloping terrain. Therefore, the stream is available in large amounts. In addition, Rize is the province of Turkey's highest rainfall and the average rainfall in region is 712.5 kilograms per square meter. River water flows in region are large, and flow velocity is high. In Rize, there are a lot of traditional water mills for grinding grain because of abundant rainfall and rugged terrain. Many of them are inactive, and their functionality is lost. Recently, the traditional water mills have come to the fore due to the increasing need for green and renewable energy. There are approximately 2000 water mills in the region of Eastern Black Sea (between province of Carsibasi in Trabzon and province of Kemalpaşa in Artvin). In this study, 23 traditional water mills in Kalkandere have been discussed. The water flow rate, the channel cross-sectional area and height of drop were measured. In addition, the technical characteristics of watermill have been investigated. Energy production levels have been determined to use the collected data. Then, the energy potential of water mills has been calculated and the results are expressed in tables and graphs. As a result of this study, electric generation capacity of traditional water mill has been proven, and the applicability of all the water mills has been discussed.

Keywords: Traditional Water Mill, Potential Energy, Water Power.

1. Introduction

Located in Eastern Black Sea Region, Rize is the province of Turkey's highest rainfall. This region is rich in water resources, and the hydro-power is highly utilized. Due to the fact that the region has a topographically rugged structure, a height of drop is composed of short distances. Because there is abundant water in this area, getting the height of drop is easy. This region is rich in water resources and the height of drop in short distances can be obtained.

However, the construction of the traditional water mills is difficult due to terrain conditions. Rize has become one of the places where the most traditional water mills exist. As a result of research conducted in the Kalkandere district, 23 traditional water mills were selected.

In this study, 23 active or inactive traditional water mills were checked, data were obtained and the sustainable energy potential was calculated. While reviewing literature about Traditional Water Mills (TWM) in different parts of the world, it was seen that most studies were made in far-eastern states like India, Nepal, Pakistan, Myanmar, and China. In Turkey, the most comprehensive research about TWM was done in Eastern Black Sea Region. Sume and Kocyigit investigated 2000 TWM in Rize. Aras [1] made a comparison between the hydropower energy and nuclear energy. Kocaer and Ahiskali [2] made an emphasis on importance of hydropower resources in Turkey. Kirtay [3] mentioned about the role of renewable energy sources. Ibrahim et al. [4] mentioned about the traditional water wheel with simple construction coupled with a basic concept of technology can be utilized as a renewable rural energy system. Demirbas and Bakis [5] investigated the water

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sources in Turkey. Sume et al. [6] investigate 17 watermills in Guneysu, Rize, Turkey on determination of the potential of electrical energy production and selection of micro hydro-electrical power plant. Other studies on TWM are described in [7-10].

Section 2 gives a method mentioned about the study area, the climate characteristic of Kalkandere, TWM and the calculation of energy potential. In section 6, some discussions are given and some conclusions are drawn.

2. Method

2. 1. Study area

2. 1. 1. Geographical characteristics

The Province of Rize located in Eastern Black Sea Region in Turkey (Fig.1). The town of Kalkandere in Rize in Eastern Black Sea Region was chosen as the study area and the boundaries are approximately between 40° 55' 41" north latitude to 40° 26' 31" east longitude (Fig. 2). The district is surrounded by central Rize, İyidere, İkizdere, and Of and has an area of 95 km². 13 km distant from the sea coast, Kalkandere has a very rugged terrain with almost no flat land and all of the land is covered with trees and green vegetation (Fig. 3). In the region, many large and small streams flow through the valleys between them. Within the boundaries of the district, many of the peak heights are available under the 1000 meters. The average altitude is 500 meters from center to village. City center is surrounded by hills and as one goes two or three kilometers away from center, this altitude can reach even several times of this value. Within the boundaries of the district, 21 villages and dozens of streams of various sizes are available.

There are a total of 39 units of water mill streams. In time, due to transportation problems, unused traditional water mills have increased considerably.

2. 1. 2. Climate characteristics of Kalkandere

Kalkandere, which has a temperate climate-four season's climate in terms of features- is a zone of continuous rainfall. As far as 41-year-data gathered from Turkish State Meteorological Service is concerned, Precipitation in April and May is seen to be the minimum (Table 1).

Climate characteristics of 41-year-data (Fig.4) are as follows:

a) Annual average temperature is 14 degrees Celsius.
b) Average sunlight is 4 hours 14 minutes per day.
c) Average humidity is 75%.
d) The average annual rainfall is 2327 kilogram per square meter.
e) The average annual number of rainy days is 172.

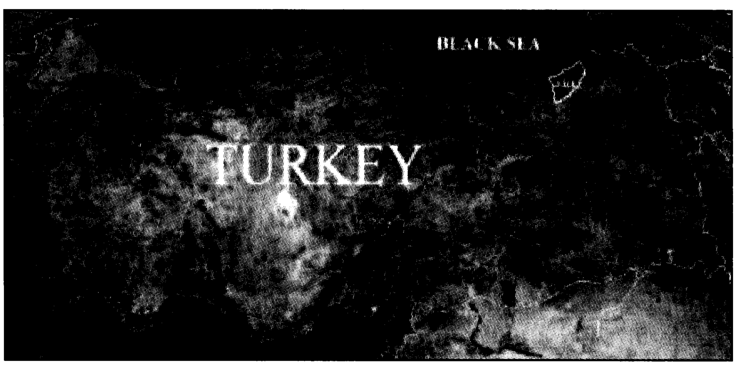

Fig. 1. Geographical Position of Rize in Turkey [10].

2. 3. The traditional water mills

The traditional watermills' resources of water are obtained either from direct stream or bunds constructed in water course with simple stones or brush wood weirs. Earthen channel is extended and led towards water mill through a wooden chute. A turbine with wooden blades, fitted to a thick vertical wooden shaft tapering at both ends. A wedge is inserted to the end of the chute to direct the water to the runner. The traditional and modern watermills are illustrated in Figs. 5 and 6.

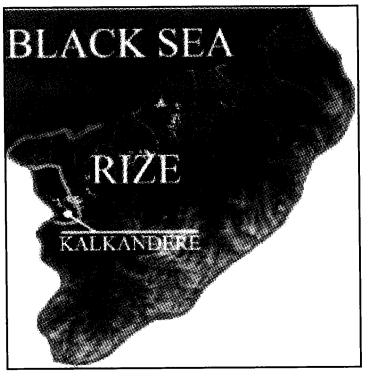

Fig. 2. The Province of Rize [10]

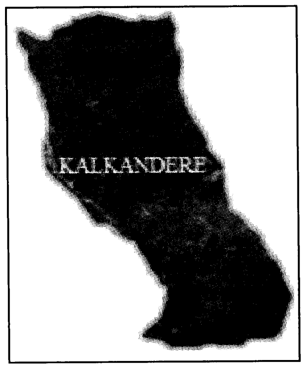

Fig. 3. The district of Kalkandere [10]

Table 1. Annual total rainfall data in Rize [11]

Period of Average Rainfall (kg/m^2)	January	February	Marc	April	May	June	July	August	September	October	November	December	Annua l Total
2009-2011	212.0	178.1	144.1	93.9	99.1	138.6	148.9	182.1	251.8	305.1	256.0	243.2	2252,9

The water chute consists of an open channel either made from wooden planks or carved from a large tree trunk or earthen, stone, stone veneer. The chute is narrowed down toward the lower end forming a nozzle.

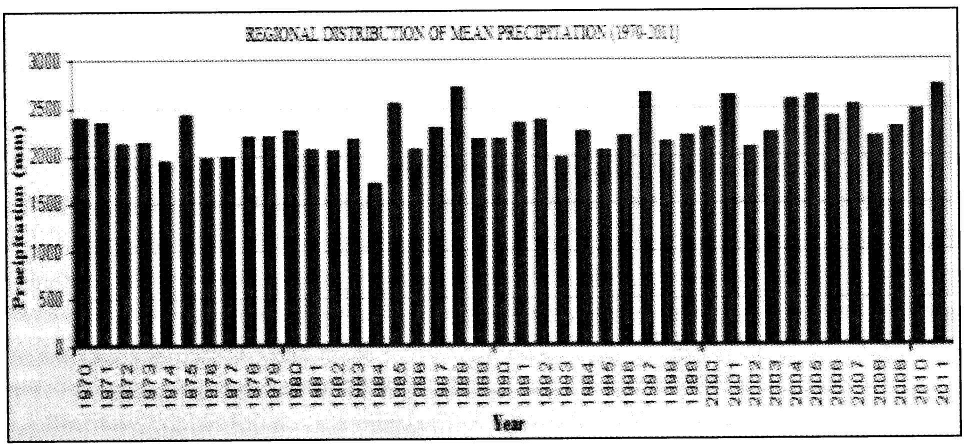

Fig. 4. Regional distribution of mean annual precipitation [11].

Dressing of stones is very important to increase the output of the water mills. Stones grooving are necessary to be made scientifically. It is very necessary that grooves should be maintained from time to time and properly. The wooden shaft of the turbine is supported on a stone pivot through a steel pin and held in the sliding bearing at the top. The sliding bearing is a wooden bush fixed in the lower stationary grinding stone (Fig. 7). The top grinding wheel rests on the lower stone and is rotated by the turbine shaft through a straight slot coupling. The gap between the stone is adjusted by lifting the upper stone with the help of lift mechanism. The turbine runner wooden blades are tightly driven by the boss. The boss is coupled to its counterpart with wooden wedge and then led to the shaft and key at the top. The whole runner rests on a steel plate with conic depression. The key exactly fits at the slot in the upper grinding stone and runs (Fig.8).

Turkey is rich in water resources in this region of the water flow rate of traditional water mills ranging from 0,040 to 0,327 cubic meters per second. The velocity of water in channel vary from 0,28 to 0,85 meter per second. The head varies vary from 3,50 to 12,00 meters and the grinding capacity ranges from 16-39 kgs corn, wheat, barley and other grains per hour.

2. 4. The calculation of energy potential

To determine the power potential of the water flowing in a river or stream it is necessary to determine both the flow rate of the water and the head through which the water can be made to fall. The flow rate is the quantity of water flowing past a point in a given time. Typical flow rate units are liters per second or cubic meters per second. The head is the vertical height, in meters, from the turbine up to the point where the water enters the intake pipe or penstock. For calculating the theoretical power of the water, the volumetric water flow rate is known in advance.

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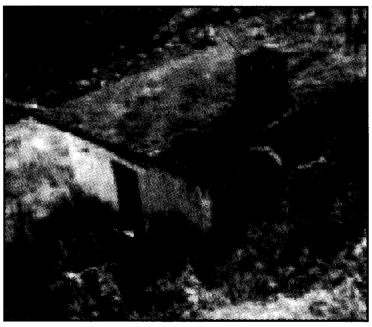

Fig. 5. The old traditional water mill.

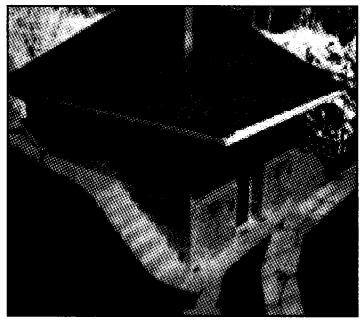

Fig. 6. The modern watermill.

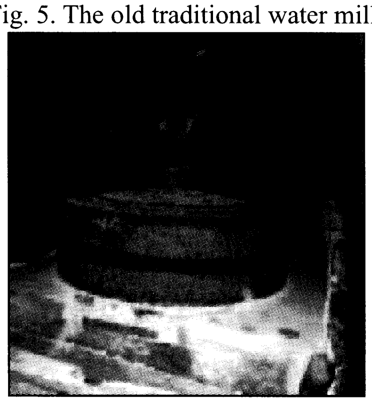

Fig.7. The grinding stone.

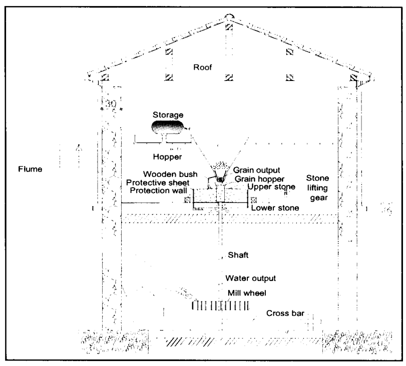

Fig.8. The cross-section of modern watermill.

meters per second. The head is the vertical height, in meters, from the turbine up to the point where the water enters the intake pipe or penstock. For calculating the theoretical power of the water, the volumetric water flow rate is known in advance.

For the volumetric water flow rate is defined as follows:

(1)

where, is cross-sectional area of running water and is velocity of water. The theoretical power of the water *P (W)* is defined as follows:

(2)

where, (m^3/s) is the volumetric water flow rate which is calculated by using Eq. (1), ρ (kg/m^3)

Table 2. The Potential energy of traditional watermills in Kalkandere

Sıra No	The name of watermill	Distance of seaside (km)	Daily Grain Production (kg)	Size of canal in rectangular shape (m)			Water velocity (v) (m/s)	Flow Rate (Q) (m^3/s)	Head (H) (m)	Energy Potential (P) (kW)
				length	width	depth				
1	Yenikoy-1	47	500	25	0.70	0.40	0.45	0.126	12	14.833
2	Yenikoy-2	47	500	25	0.70	0.40	0.45	0.126	12	14.833
3	Bodursirt-1	46	380	35	0.50	0.33	0.3	0.050	5	2.428
4	Bodursirt-2	46	380	35	0.50	0.33	0.3	0.050	5	2.428
5	Findikli-1	45	400	30	0.47	0.30	0.62	0.087	4	3.430
6	Findikli-2	45	400	30	0.47	0.30	0.62	0.087	4	3.430
7	Motorun	44	450	60	0.70	0.70	0.28	0.137	5	6.730
8	Aksu	45	350	30	0.20	0.36	0.75	0.054	10	5.297
9	Tascilar	43	400	20	0.40	0.35	0.39	0.055	8	4.285
10	Dogan	42	600	15	0.95	0.15	0.4	0.057	6	3.355
11	Kizilktoprak	40	550	55	0.70	0.15	0.6	0.063	4	2.472
12	Bagyaka-1	41	300	30	0.80	0.30	0.7	0.168	5	8.240
13	Bagyaka-2	44	350	26	0.45	0.45	0.63	0.128	8	10.012
14	Bagyaka-3	42	450	33	0.60	0.50	0.82	0.246	5.5	13.273
15	Bagyaka-4	37	400	22	0.50	0.35	0.23	0.040	7	2.764
16	Bagyaka-5	40	370	20	0.60	0.25	0.29	0.044	5	2.134
17	Dulgerli-1	43	420	25	0.40	0.35	0.4	0.056	3.5	1.923
18	Dulgerli-2	45	280	24	0.50	0.50	0.53	0.133	6.5	8.449
19	Dulgerli-3	42	320	32	0.65	0.30	0.55	0.107	5	5.261
20	Unalan-1	40	350	30	0.60	0.35	0.66	0.139	6	8.158
21	Unalan-2	45	290	28	0.80	0.40	0.7	0.224	4	8.790
22	Unalan-3	48	410	30	0.70	0.55	0.85	0.327	7	22.472
23	Unalan-4	45	350	50	0.90	0.50	0.6	0.270	6	15.892
									TOTAL	**170.889**

2. 5. Determination of energy potential

In this study, the determination of energy potential is calculated by using Eq. (2). However, energy is always lost when it is converted from one form to another. Because of frictional losses, power will also be lost in the pipe carrying the water to the turbine. A rough guide used for small systems of a few kW rating is to take the overall efficiency.

The estimated power of the water power is defined as follows:

(3)

where, η is the productivity coefficient.

The data of the traditional water mills in Kalkandere is given Table 2. According to first line of Table 3, the output power of the traditional water mills ranges from 1.923 kW to 22.472 kW.

These values were calculated by using Eq. 3. For example, a turbine generator in Yenikoy-1 set operating at a head of 12 meters with flow of 0.45 cubic meters per second will deliver approximately 15 kilowatts of electricity. This calculated value reduces to lower value, due to the productivity coefficient.

The classification of hydropower by size varies from one country to another. In this study, this classification is considered that large hydropower plants have a capacity of more than 15-20 MW, small hydropower plants have a capacities in the range of 0.1 to 20 MW, and the micro hydropower have capacities of less than 100 kW. According to above, the micro hydropower in the scale of hydropower is suitable for the territory of Kalkandere.

3. Conclusion

As micro-hydro power continues to grow around the world, it is important to show the public how feasible micro-hydro systems actually are in a suitable site. Micro-hydro is a very
site-specific resource. Without the proper head or flow, the system does not function properly. At least a 1m head height is necessary in sites, and the water must be moving to activate the turbine. Areas that are flat or have stagnant water must install costly canals to move the water. So, micro-hydro power can be used for generating electricity in Turkey. For rural areas, which cannot be included in normal power grids, this provides a small amount of electricity that can make a large impact on where it reaches. Less than 1 kW of power is sufficient for power of an entire house in most situations.

Micro-hydro power is generally a more cost-effective source of energy, which after a while, pays its way, and it is also environmentally-friendly. Since it is renewable and does not harm the environment, many homes and companies are beginning to look into installing turbines into their own local streams. Turkey and the rest of the world can begin to look towards new sources of energy which are better for everyone. Through researching the scientific, historical, and sociological background of micro-hydro power, our group has realized the potential that hydroelectric power has raised the importance of water in the world. As non-renewable resources are being used up daily by the transportation industry, powering homes, and the industrial world, it is obvious that newer, more efficient, renewable sources of energy must be found, and hydropower, specifically micro-hydro power, is a great alternative.

There are a lot of traditional water mills in the study area. However, most of them could not stand the time and were destroyed as the time passed and lost their functions. Therefore, this article has studied only 23 traditional water mills since they are easily accessible and the data retrieval is easy.

The data have been evaluated and tabulated. Thus, potential energy of each watermill has been calculated. The calculated data are shown in the table. According to the data from Table 3 Total 170.889 kW of energy can be obtained.

It is shown that unused traditional water mills as a source of renewable electrical energy can be obtained, and they can continue the grinding function. In addition, energy and environmental capacity of the traditional water mills can be increased by using modern techniques.

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