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Prospective study: Choice of the potential sites intended for the new renewable energy approach

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Abstract: Morocco since the year 1929 has given great importance to the construction of dams and to ensure their sustainability. 128 large dams currently operational, totaling nearly 17.2 billion m3 of capacity, are the result of the efforts made in the deployment of dams strategy. As part of our new approach of renewable energy production from dams, this article aims to explore the application of this concept. Several criteria are fixed to make the most advantageous location choice to get an efficient power production.

Keywords: Renewable Energy, Wind Generated Waves, Dams, Power, Multiple-Criteria Decision-Making

1. Introduction

It was demonstrated in our previous article [1] the potentiality that presents the wind generated waves on the surface of stored water on dams as a new source of renewable energy. This fact leads us to go further in our research in order to explore all its aspects.

Given that any technical conception of the mechanism to convert this power to useful one is necessarily related to the well-known of the in situ variables; it is evident that we have to fix a short list of appropriate dams in order to have a real evaluation of the input data.

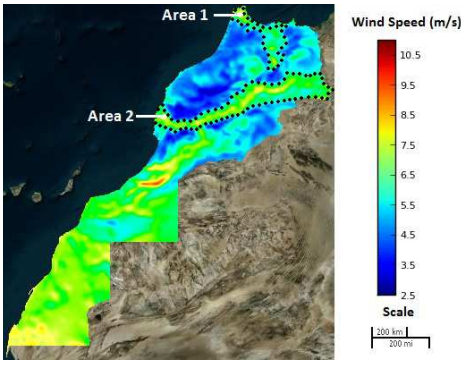
In this context, we have to notice that the Multiple-Criteria Decision-Making applied to the choice of the site location is restricted only to the technical aspects; therefore the different stakeholders (institutional or private) are not involved in the analysis process.

2. Overriding Criteria in Site Selection

We present on the following the criteria on which the optimal location will be selected:

- It is clear that the wind speed will constitutes one of the main parameter to take in consideration for the site selection. The more the wind speed is important the more the height of the wind generated waves is important and the more the swept area is increasing what automatically enhances the generated power.
- The second one is the wind direction. Indeed, to get optimal conditions of the power extraction, we need to have a regular and dominant wind direction.
- The third one is the area of the surface of the stored water. In the present study, its evaluation will be combined by double parameters: the area of watershed and the volume of reservoir capacity.
- Another point which should be considered is the availability of hydroelectricity plant in the dam, in order to benefit from the direct injection of the generated electrical power in the network.

3. Data Processing



Map 1. *Wind speed map.*

Initially, we take in consideration the wind speed on *Map 1*, in order to provide us the potential geographical area which can host such installation.

As it can be inferred, the exploitable wind speed range is between 4 and 8 m/s, corresponding to spectrum of colors from blue to yellow including the green one.

Based on what precedes, we can identify at least two locations:

- Area 1: corresponding to the north-west and Rif regions;
- Area 2: corresponding to the geographic zone delimited by the high Atlas Mountains and those of the anti-Atlas and from the Atlantic sea to the west border.

Even if the south region is under the effects of a significant wind speed field and as it was mentioned in [1] the arid climate at this area can't promote a successful results.

Taking in consideration this geographical segmentation in respect to the wind speed, we select a list of existing dams which can eventually satisfy the criteria exposed in Chap. 2.

Table 1. *Selected dams informations.*

Dam	City attachment	Height (M)	Location		Area of watershed (Km2)	Reservoir capacity (Mm3)	Existence of hydroelectricity plant
			Latitude	Longitude			
Abi El Abbess Sebti	Marrakech	75	31°10'16.6"N	8°29'06.0"W	N.A(*)	25	N.A(*)
Al Hassan Addakhil	Errachidia	85	32°00'16.1"N	4°27'35.1"W	4400	347	No
Aoulouz	Taroudant	79	30°42'31.6"N	8°06'57.6"W	4450	110	No
Hassan II	Errachidia	115	32°47'39.9"N	4°47'23.8"W	3300	115	No
Ibn Batouta	Tangier	30	35°38'10.6"N	5°43'00.7"W	180	38,5	No
Imin Lhad	Essaouira	23	31°21'05.5"N	9°34'22.7"W	0,4	N.A(*)	No
Joumoua	Al Hoceima	57	34°55'51.9"N	4°19'05.5"W	N.A(*)	6,5	No
M. B. A. El Khattabi	Al Hoceima	40	35°05'16.9"N	3°48'31.4"W	790	33,6	No
M. Slimane Jazouli	Essaouira	60	31°06'02.6"N	9°38'09.6"W	403	17	No
Ouirgane	Marrakech	70	31°10'52.0"N	8°05'16.1"W	1200	70	N.A(*)
Tangier Med	Tangier	80	35°52'08.9"N	5°28'26.9"W	34	25	No
9 April 1947	Tangier	52	35°32'12.6"N	5°48'32.5"W	220	300	No

(*): Not Available

The informations[1] summarized on *Table 1* can be defined by what follows:

1 The "*City attachment*": presents the city on which the dam is administratively attached.
2 The "Height": is the measurement of the dam high, taken from the foundation level.
3 The "*Location*": is spotted by both latitude and longitude coordinates.
4 The "*Area of watershed*": the watershed is a unit of natural or disturbed land on which all the water that falls collects by gravity and fails to evaporate and runs off via common outlet. Its area is calculated based on this definition by the use of the appropriate method Cf. [4].
5 The "*Reservoir capacity*": presents the volume of the stored water in the dam.
6 Finally a check is done regarding the existence of hydroelectricity plant in the dam.

In order to have more accurate information on the wind characteristics (speed, direction) we will focus on the nearest cities to the above dam location and for which these data are available, namely: Agadir (instead of Taroudant), Al Hoceima, Errachidia, Essaouira and Tangier.

For Abi El Abbess Sebti and Ouirgane dams (Cf. [5]) they are both administratively attached to the city of Marrakech which represents a lowest wind speed performance. Nevertheless based on *Map 1* they are located in Area 2. This is why they will be excluded from the rest of this study due to the absence of the corresponding information.

The following are data[2] based on observations taken between 03/2001 - 08/2014 daily from 7am to 19h local time:

Table 2. *Monthly wind speed statistics.*

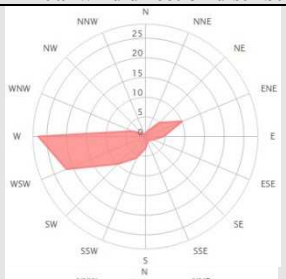
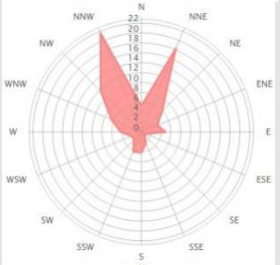
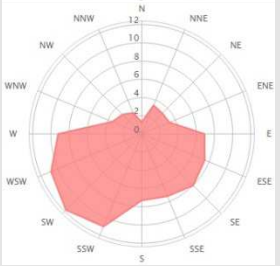
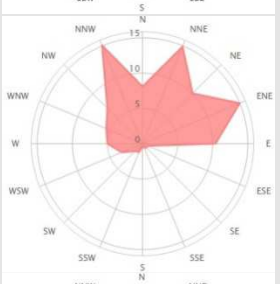
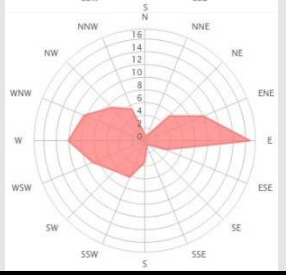
	Wind speed (m/s)				
Mounts	Agadir	Al Hoceima	Essaouira	Errachidia	Tangier
1	4	3	5	3	5
2	4	4	6	4	6
3	5	4	5	4	6
4	5	4	8	4	6
5	5	5	6	5	7
6	4	5	5	5	7
7	4	5	7	5	6
8	4	4	5	4	6
9	5	4	3	4	6
10	4	4	7	4	6
11	4	4	3	3	6
12	4	3	4	3	6

Here after we present also the annual wind direction distribution:

1 www.water.gov.ma

2 www.windfinder.com

Table 3. *Wind direction distribution.*

City	Annual wind direction distribution (%)
Agadir	
Al Hoceima	
Errachidia	
Essaouira	
Tangier	

It may be tempting to wait, to collect additional data and clarify same aspects before starting any analysis at all. However, we choose to conduct the analysis in an iterative manner and insure adjustment during the project evolution.

4. Analysis and Recommendations

As we can deduce from the *Table 3*, the wind distribution is widely variable. We can reveal two categories: a dominant wind orientation (at most two directions concentrate approximately the half of the whole wind direction distribution) and dispersed wind orientation.

The first category includes:

- Agadir: 48.9% (W 27.2%, W-S-W 21.7%);
- Al Hoceima: 40.1% (N-N-W 21.7%, N-N-E 18.4%);
- Tangier: 38.8% (E 16.7%, W 12.1%).

In the opposite of this category, the remaining sites are spread over several directions with a low distribution percentage.

On the other hand, to have an idea concerning the annual wind speed behavior, we calculate the average value for each city and also their standard deviation.

Table 4. *The annual wind speed performance.*

	Agadir	Al Hoceima	Essaouira	Errachidia	Tangier
Annual Average Speed (m/s)	4	4	5	4	6
Standard Deviation	0,48	0,64	1,49	0,71	0,49

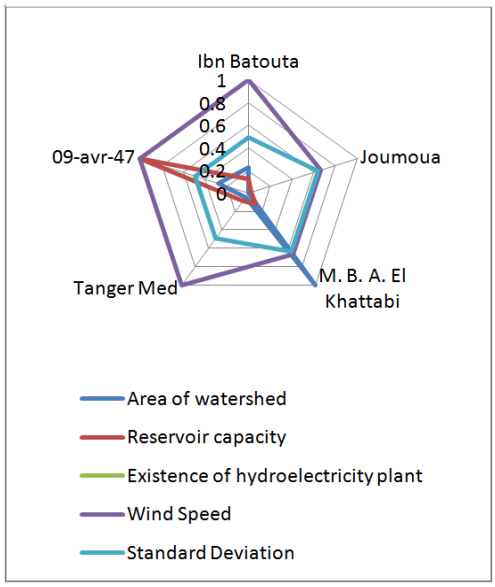
The *Table 4* shows that even if some cities have a favorable annual average wind speed, the relative standard deviation is unpropitious. For example Essaouira city is second in term of the annual average speed (5 m/s) but its standard deviation is about 1,49 which means that a huge fluctuation occur regarding the wind speed during the year.

We propose to synthesize the most pertinent criteria in the following graphs, in order to allow us a better analysis with respect to the segmentation specified at Chap. 2.

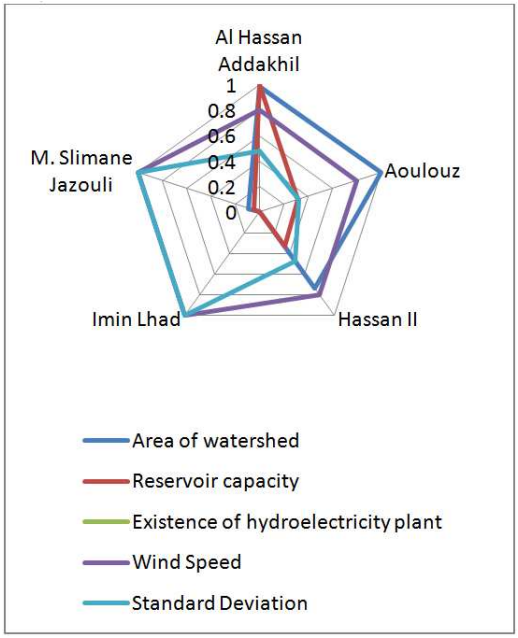
To have a profitable reading of these graphs, the representation of criteria: area of watershed, reservoir capacity and standard deviation, were appropriately rescaled.

The existance of hydroelectricity plant was quantified by a binary test.

Given that none of these dams contain a hydroelecticity plant, fact which can probably lead us to consider that it don't have to be mentioned as pertinent criterion. Nonetheless it will have a great importance in the reduction of the amount of investment related to the power transportation.



Graph 1. *Star rating of the Area 1.*



Graph 2. *Star rating of the Area 2.*

Therefore, in accordance to the geographical segmentation established previously, we have:

- For Area 1: 09 April 1947 and M. B. A. El Khattabi dams are selected.
- For Area2: Al Hassan Addakhil dam is selected.

5. Conclusion

Based on the elements of the present study, we can identify a short list of dams selected for the in situ experimentation.

For this prospective study, we consider that all the criteria are weighted equally. The need is to first estimate the data with some acceptable accuracy, and later estimate more critical data with higher accuracy.

In this way, we don't overestimate non critical data. The above considerations will improve the sensitivity of our analysis.

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