Impact of climate change on surface water resources in arid zones - the case of the Ykem watershed in the central plateau of Morocco

Mohamed Gramz1*, Mouhcine Batchi1, Jamal El Bouziani2, Moulay Hicham Azagane1, Adnane El-boukhari3, Ayoub Nafii4, and Youssef Elharrari1

1 Ibn Tofail University, Territory, Environment and Development Laboratory, Morocco
2 National Department of Planning Territory, Morocco
3 Ibn Tofail University, Literature, Arts and Pedagogical Engineering Laboratory, Morocco
4 Hassan II University, Process and Environmental Engineering Laboratory, Morocco

Abstract. Given the importance of natural resources for integrated development, it is necessary to adopt adaptation strategies to face disturbances affecting the globe. Particularly, climate change, with a particular impact on water potential. The aim of this article is to highlight the impact of this world phenomenon on surface water resources in the Ykem watershed situated in the northwest of the central Moroccan plateau, which is characterized by predominantly arid conditions. In order to monitor the spatiotemporal evolution of surface water, a methodology based on geospatialization techniques was used. This involved mapping the evolution of surface water resources in time and space, providing a variation between reference years, specifically 2012–2021, from 132 ha to 32 ha, and of course interpreting the results by climate elements based on rainfall in the study area and temperature readings in this geographic location. Remote sensing was employed to acquire satellite images available between 1992 and 2021. The area covered by water rose from 10 ha to 126 ha between 1992 and 2012, but the amount of land covered by water shrank to 32 ha between 2012 and 2021.

Keywords: Climate change, arid zone, GIS, water resources, Ykem watershed

1. Introduction

Earth's water supply is essential. Compared to the water in the seas and oceans, there is remarkably little freshwater on the surface [1]. Ever since water resources are essential to all living things, including humans, safeguarding this potential, guaranteeing its availability and sustainability over time and space, and assessing water resources as an essential element in preserving the ecological and environmental balance of the natural environment become challenges [2–3].

* Corresponding author: mohamed.gramz@uit.ac.ma

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Earth’s water supply is essential. Compared to the water in the seas and oceans, there is remarkably little freshwater on the surface [1]. Ever since water resources are essential to all living things, including humans, safeguarding this potential, guaranteeing its availability and sustainability over time and space, and assessing water resources as an essential element in preserving the ecological and environmental balance of the natural environment become challenges [2], [3].

The study of the changes affecting the water, namely climate change, is essential for a better understanding of the functioning of hydraulic regimes in the hydrosphere, and for taking measures aimed at the equitable management of water resources. This study looks at changes in the surface area covered by water in the Ykem watershed, which is in the northwest of the central plateau of Morocco, between 1992 and 2021. The methodology is based on geospatialization tools [4], mainly remote sensing techniques that use publicly available data from Landsat and Sentinel satellite images. Second, data collected is analyzed by a GIS geographic information system [5], which quantifies spatio-temporal variations in water resources [6] using the Land Use index. Finally, mapping the results is done for interpretation.

The Ykem watershed on Morocco’s central plateau is characterized by a Mediterranean climate, its geographical location in the north-west, bounded topographically to the north by the Bouragrag watershed, to the south by the intermediate part of the central plateau, to the east by the Cherrat watershed and to the west by the Atlantic Ocean, with altitudes varying between -8 m and 465 m from the coastal part towards the mainland (Fig1). Average annual rainfall (1992-2021) is around 418 mm, according to rainfall data. Precipitation is characterized by monthly and daily irregularity, except in 2018 when precipitation reached 785.74 mm how a maximum value of the data series used, at the pluviometric station of located at the Ykem watershed. Temperatures are moderate on the Atlantic coast and higher inland. The temperature parameter shows intra-annual variability, with little variation from one year to the next. The mean annual temperature calculated for the study period covering the last 28 years is 18.80°C. The temperature values indicate mild winters and warm summers, and are relatively homogeneous in the part overlooking the Atlantic, and heterogeneous towards the south of the study area.

Water sustainability in terms of quantity and quality requires equitable management of water resources [7], in order to ensure the availability of this natural potential, which is essential for human activities (agriculture, industry, tourism), especially given the particular climatic context characterized by the dominance of a semi-arid climate, with the aim of highlighting the current state of surface water resources, is to monitor the spatio-temporal evolution of water resources, and to help decision-makers take the necessary measures to preserve water, through medium- and long-term adaptation strategies, in addition to actions to mitigate the extreme phenomena that affects this geographical area of the globe.

2. Materials and methods.

2.1 Study area

The Ykem watershed is located in the lower part of the central plateau in Morocco, covers an area of 29628 hectares, bounded to the north by the Bouregrag watershed, to the south by the Cherrat watershed, to the east by the intermediate part of the Central plateau and to the west the Atlantic Ocean. The morphology of the area of our study is characterized by a varied topography, with altitude classes between -8 and 50m near the coastal area where the dunes are designated, towards the middle the heights reach 270m covering more than half of the area of the Ykem watershed, while the rest is between 270 and 465m, especially in the
southwest (Fig.1). In climatic terms, it is a semi-arid region where the average annual rainfall is almost 423.5 mm per year. The average temperature varies is 18.81°C, with variability between summer and winter. In addition, this area is characterized by vegetation cover in the form of forests located in the west.

2.2 Methodology

The method employed is tracking the changes in surface water resources in the Ykem watershed, which is situated in the northwest of Morocco’s central plateau (Fig. 2) and has an arid climate from 1992 to 2021. The monitoring of spatiotemporal variations is predicated on the examination of satellite image data using a geographic information system (GIS) and the Land Use Index. The results are first mapped, and an interpretation is subsequently provided based on the study area’s rainfall and temperature. Images from satellites were used to collect the data obtained through the open access website (https://www.usgs.gov/).

Fig. 1. Localisation study area with GIS based in digital elevation model.

Fig. 2. Framework of the methodology adopted for this study.
2.3 Land Use index

By using the land use index via a GIS, we can analyze the types of land use in the Ykem watershed. The advantage of this index is to combine several bands of data (table 1), such as land cover, vegetation, water bodies, roads and urban areas, from satellite imagery data as well, then to carry out a supervised classification from the samples in terms of pixels, over the entire surface of the study area.

<table>
<thead>
<tr>
<th>Year</th>
<th>Satellite Image</th>
<th>Band Used</th>
</tr>
</thead>
<tbody>
<tr>
<td>1992</td>
<td>Landsat 5</td>
<td>B03 B02 B01</td>
</tr>
<tr>
<td>2002</td>
<td>Landsat 7</td>
<td>B03 B02 B01</td>
</tr>
<tr>
<td>2012</td>
<td>Landsat 8</td>
<td>B04 B03 B02</td>
</tr>
<tr>
<td>2021</td>
<td>Sentinel 2</td>
<td>B04 B03 B02</td>
</tr>
</tbody>
</table>

Source: [https://www.usgs.gov/](https://www.usgs.gov/)

3. Results & discussion.

Based on the analyses that were conducted, the Land Use index results allow us to map the evolution and variability of water resources. These results were produced using the methodological approach and the processing that was done during the reference years 1992, 2002, 20112, and 2021 (Fig.2). With regard to the results of the Land Use index [8], over the period from 1992 to 2021, the results of analysis divided into four categories, bare land, matorral, agricultural land and water surface, marked by an increase in the hectare area of agricultural land from 6148 to 16601 and water surface from 10 to 126 over the period from 1992 to 2012, with a decrease between 2012 and 2021 to 15082 for the agricultural area and 32 for that of the water surface, on the other hand the values obtained for bare land decreased from 20424 to 8323 between 1992 and 2012, and are increased to 11298 towards the year 2021, for the area of matorral characterized by an increase from 3046 to 5741 between 1992 and 2002, on the contrary the decrease of the area to 3216 hectares towards 2021 (Table 2).

<table>
<thead>
<tr>
<th>Year</th>
<th>Bare land in ha</th>
<th>Water in ha</th>
<th>Agricultural land in ha</th>
<th>Matorral in ha</th>
<th>total surface in ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>1992</td>
<td>20424</td>
<td>10</td>
<td>6148</td>
<td>3046</td>
<td>29628</td>
</tr>
<tr>
<td>2002</td>
<td>14535</td>
<td>18</td>
<td>9334</td>
<td>5741</td>
<td>29628</td>
</tr>
<tr>
<td>2012</td>
<td>8323</td>
<td>126</td>
<td>16601</td>
<td>4578</td>
<td>29628</td>
</tr>
<tr>
<td>2021</td>
<td>11298</td>
<td>32</td>
<td>15082</td>
<td>3216</td>
<td>29628</td>
</tr>
</tbody>
</table>

Source: results of using geospatial techniques.

The evolution of the surface area occupied by surface water resources is mapped [9] for the years 1992, 2002, 2012 and 2021, a scale of 10 years almost to follow the spatio-temporal variations of surface water (Fig.3), this chronology shows an increase in the surface area of water between time, but also a diminition.

Surface water resources are related to climatic conditions in terms of precipitation and temperature [10] in the Ykem watershed, which is why we focus on the series of meteorological data between 1992 and 2021 extracted from the website [https://power.larc.nasa.gov/data-access-viewer/](https://power.larc.nasa.gov/data-access-viewer/) open source, to determine wet and dry years, in order to compare the spatio-temporal evolution of water resources with the impact of climate on variations in water surfaces, using the following equations for precipitation and temperature respectively:

\[
D_{ap} = \left(\frac{P_{a} - a_{p}}{a_{p}}\right)\times 100
\]
\[ D_{at} = \left( \frac{T_a - a_t}{a_t} \right) \times 100 \]  

With:  
- \( D_{at} \): deviation from average temperature  
- \( D_{a.p} \): deviation from average precipitation  
- \( P_a \): total annual precipitation  
- \( T_a \): total annual temperatures  
- \( a_p \): average precipitation of data series used  
- \( a_t \): average temperature of data series used

The results obtained for the two equations show an interannual variability on the series of rainfall data as well as those of temperatures, with from 1992 is recognized as a dry year, with a dominance of wet years between 2002 and 2012, a climatic situation is changed to the year 2021 despite in 2018 is characterized by a high value of precipitation in addition to the minimum value of average temperature (Fig 4).

![Fig. 3. Land Use results for the years 1992, 2002, 2012 and 2021 via a GIS system based on open access data from https://www.usgs.gov/](image)

Deviation values from the annual average for precipitation (\( D_{a.p} \)) and temperatures (\( D_{a.t} \)) are shown in the following graph:

![Fig. 4. Deviation from the mean of precipitation and temperature according to meteorological data for the Ykem watershed from the open source website https://power.larc.nasa.gov/data-access-viewer/](image)

4. Conclusions

In this paper, we analyze how the Ykem catchment our study area has changed in relation to surface water resources between 1992 and 2021 as a result of climate change. Based on the monitoring of time series, our analysis of the spatiotemporal evolution of surface water shows notable variability in terms of decrease, especially between 2012 and 2021 when low rainfall values were recorded, especially with the succession of drought years. The meteorological series utilized from open access sources support this analysis. According to this perspective, maintaining the water potential at the surface as well as ecosystem and environmental
stability while meeting human needs for water and related activities present a significant challenge for the equitable management of surface water resources. Ykem catchment, which saw a rise from 10ha to 126ha between 1992 and 2012 and a precipitous drop in water surface area to 32ha by 2021, is being observed in relation to climate change. For decision-makers to be able to take the appropriate action and adopt global water strategies in this geographical situation where aridity influences surface water, they must be aware of the state of water potential in particular and manage the scarcity of rainfall.

Acknowledgements: Special thanks to the entire work team, as well as the open-access sites that provided the data for this study.

References


