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Impact of Climate Conditions on the Water Potential of the River Ansegmir Watershed (Morocco)

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ABSTRACT

The aim of this study was to assess the impact of climatic conditions on the water potential in the watershed of river Ansegmir (WRA) over the period 1970–2018. The processing and exploitation of the climatic data acquired has made it possible to carry out an evolution of the climatic conditions at the level of the aforementioned basin. Interpolation of the precipitation data, using the inverse distance weighting (IDW) method, has produced a precipitation map for the catchment area. Combining this with temperature and Emberger's bioclimatic stages will make it possible to define the bioclimate of the WRA. Statistical processing of Oued Ansegmir flow data and its combination with climatic conditions will allow monitoring climatic trends and their impact on the water potential of the WRA. As a result, the climate of the WRA can be characterized by low rainfall, less than 396 mm/year, which is very poorly distributed in time and space. Rainfall has very high intra- and inter-annual variability, which stimulates thunderstorms in the catchment area, particularly in summer. Thermal amplitudes are high, exceeding 33 °C, which justifies the cold that is fairly frequent in winter. The bioclimate is semi-continental, very cold to cold semi-arid. Therefore, the climate is a natural constraint on the development of vegetation, particularly for rain-fed agriculture. This climatic summary provides an introduction to the surface context of the water potential of the WRA. However, further research will be needed to determine the state of the groundwater in the WRA in order to define the different forms of input and the factors causing a drop in the water table in the context of climate change, as well as to assess changes in the piezometry of water sources with the establishment of farms over the said period.

Keywords: water potential, climate conditions, watershed of river Ansegmir.

INTRODUCTION

Water is certainly the most important resource that the Earth can provide to humanity. Today, water is strongly threatened by multiple constraints, making it increasingly vulnerable [Iglesias et al., 2007]. In addition to pollution and the strong increase in water demand due to population growth and economic development [Schilling et al., 2020], there is also the global climate change, which is greatly affecting the distribution of precipitation, causing a decrease in the mass of ice caps and the major natural risks associated with it [Mizyed et al., 2009]. In fact, all these factors worsen the situation of water resources as well as accentuate current and future stresses, which heavily impact the water availability worldwide, especially in the Mediterranean countries [Milano et al., 2012; Noto et al., 2023].

These effects lead many countries to adopt national action plans in dealing with climate change such as enhancing water supplies through water harvesting methods and artificial recharge of groundwater, adopting efficient irrigation systems [Mizyed et al., 2009; Kmoch et al., 2018]. In Morocco, water management became a concern when the first crises appeared, following the over-expansion of agricultural activities, low groundwater recharge and long drought periods especially between 1980 and 1985 [Bekri et al., 2021; Khaffou et al., 2022].

In this context, the conducted study focused on linking the effects of climatic conditions and the available water resources in the Ansegmir river. The watershed of river Ansegmir, with an area of 1060 km^2, is the right bank of the Upper Moulouya, which in turn is considered part of the large Moulouya basin. It gives the Upper Moulouya basin an excellent water potential, even with the high rainfall deficits observed in Morocco between the periods of 1980–2008 [Rochdane et al., 2012]. In fact, water potential in this region is strongly linked to climate, rainfall and natural recharge of groundwater [Karmaoui et al., 2014; Aouragh et al., 2016].

Upper Moulouya basin is supposed to play a key role in the socioeconomic growth on both regional and national scales in the production of apples, especially after the launch of the Green Morocco Plan (GMP) by the government. This implies an increase in water demands as well as competition for water use, which affect water sustainability and management within this region [Schilling et al., 2020; Chebli et al., 2021; El Bouazzaoui et al., 2022]. Therefore, it becomes imperative to manage the water resources sustainably.

MATERIALS AND METHODS

Study area

The watershed of river Ansegmir (1060 km²), in the province of Midelt (Fig. 1), is bordered by the upstream part of Oued Moulouya watershed to the west and Oued Bel Lahcen tributary of Outat River to the east. It is considered part of the Upper Moulouya basin, which constitutes the western extremity of the Meseta Oranaise. This watershed extends from west to east between the High Atlas in the south and the Middle Atlas in the north and northeast.

At the forestry level, this watershed belongs to the Provincial Directorate of Water and Forests and the fight against Desertification (PDWFD) of Midelt. The bioclimatic conditions, the geological formations as well as the topography offer a great diversity of forest groups in the watershed of river Ansegmir, which extends for nearly 96900 hectares. This watershed is characterized by several major forest species, such as Atlas cedar (*Cedrus atlantica*) and Holm Oak (*Quercus rotundifolia*); and other secondary species, either pure or mixed with the major forest species, such as Aleppo pine (*Pinus Halepensis*), prickly juniper (*juniperus oxycedrus*), esparto (*Stipa Tenacissima*), white wormwood (*Artemisia Herba Alba*) and shrubland. The watershed of river Ansegmir is located between two main structural areas, the Southern High Atlas and the Western Middle Atlas. It is characterized by various geological formations ranging from the Paleozoic to the Quaternary (Fig. 2).

A Paleozoic basement represents the main geological formations of the watershed of river Ansegmir, it is manifested by schists, pelitic sandstones formations and amphibolite, and intersected by Hercynian granitic intrusions (i.e. granites of Zaida, Boumia and Ahouli).

In unconformity on the Paleozoic bedrock, the Mesozoic terrains are represented by altered conglomeratic, clay and basaltic facies from the Triassic, followed by deposited dolomitic carbonates and limestones from the Jurassic. Moreover, at the end of the Mesozoic, the Cretaceous

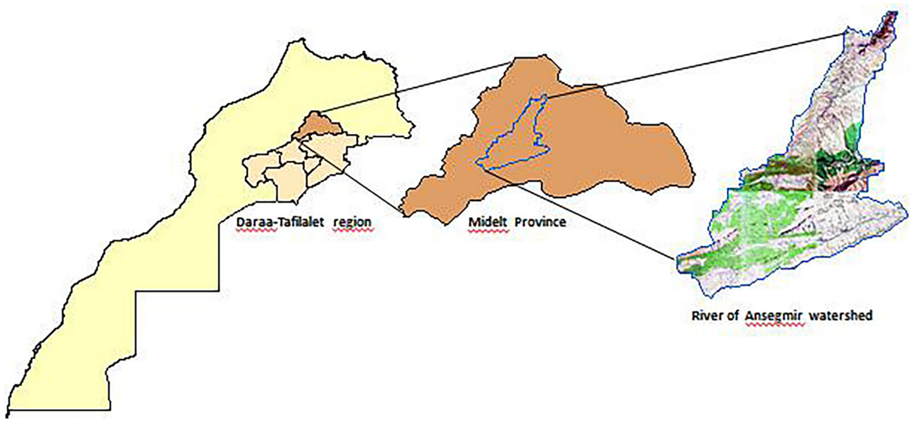

Figure 1. Geographical location of the river of the Ansegmir watershed

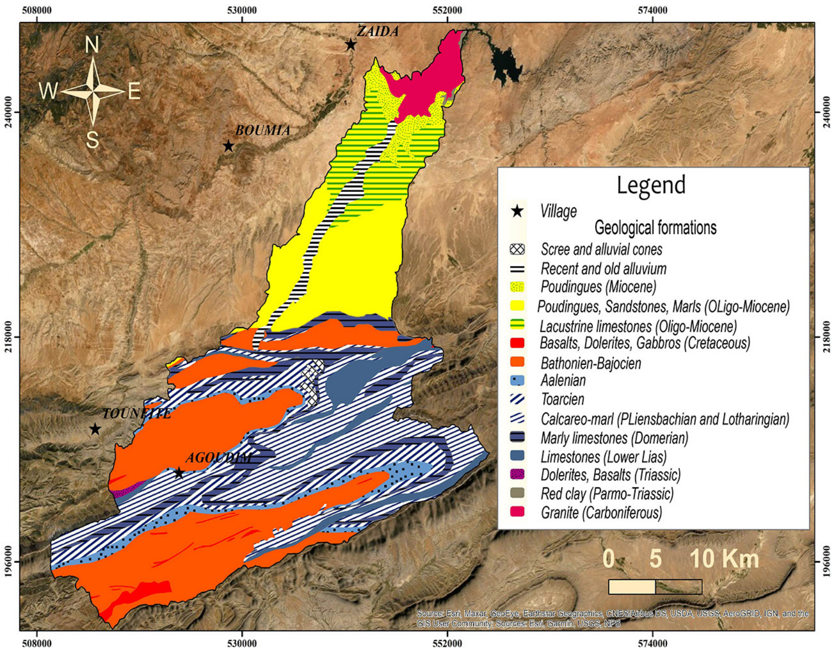

Figure 2. Geological map of the watershed of river Ansegmir

is characterized by basalts, dolerites and gabbros. On the other hand, the Cenozoic is characterized by dolomitic limestones, lacustrine limestones and marls surmounted by Quaternary terrains which are represented by alluvial fans, alluviums and conglomerate (Fig. 3).

The watershed of river Ansegmir consists of several tributaries, including:
- Ait Bou Arbi River, which drains the upstream part of the right bank;
- Ait Moussa River, which drains the upstream part of the left bank;
- Jaafar River, which drains the central part of the right bank;
- Ansegmir River, which drains the central and the downstream parts.

The primary network is well developed throughout the watershed, which promotes a fast downstream runoff capacity (flashing flow) and

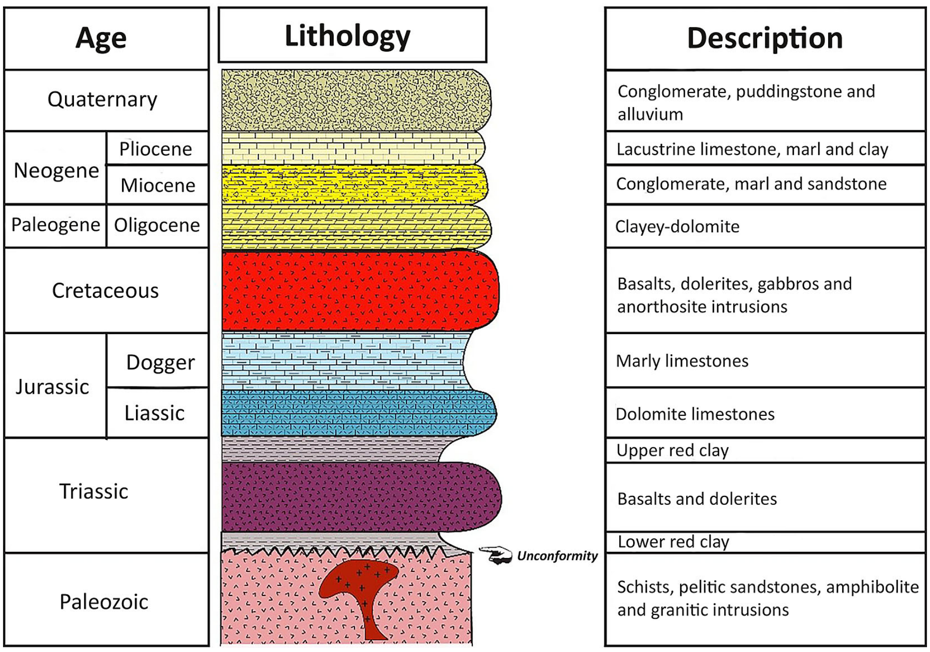

Figure 3. Stratigraphic column of the watershed of river Ansegmir

consequently a higher runoff coefficient, especially in the areas without vegetation. This primary drainage density may be explained by low substrate permeability, steep slopes and low plant cover.

Data

In the current study, the climate data of the studied region were collected, specifically: rainfall (P), temperature (T), evapotranspiration (EVP) and flow (Q). In order to assess the evolution of climate, these parameters were used to produce all graphs: ombrothermic diagrams, climatogram of Emberger and the spatiotemporal mapping of precipitation. These data were collected from the databases of the Hydraulic Basin Agency of Moulouya of Midelt (ABHM), Provincial Directorate of Water and Forests and the fight against Desertification of Midelt, the Provincial Directorate of Agriculture of Midelt (PDA), the Boumia Works Center (CT) and the National Agricultural Advisory Office of Midelt (NAAO). Collected climate data, from the period 1970–2018, are those related to the watershed of river Ansegmir stations (Table 1). This study uses a dataset of multiple sources, such as:

- two topographic maps of 1:100000 scale (maps of Riche and Tounfit) and three topographic maps of 1:50000 scale (maps of Ait Iloussane, Boumia and Ait Oumghar);
- two geologic maps of 1:200000 scale (High Atlas map of Midelt and Northern Middle Atlas map);
- digital elevation model (ASTGTM) with a spatial resolution of 28.54 m (downloaded from Google Earth Pro);
- A Landsat 8 OLI/TIRS L1TP image acquired in June 30, 2021;
- ground surveys;
- other data collected during the field site visit including coordinates of studied sites, photographs, observations, farmers declarations, etc.

Exploration, processing and analysis of data were performed using the following tools: digital mapping and geographic information system (GIS); remote sensing; statistics; GPS surveying techniques.

Methodological approach

The aim of the present study was to assess the impact of climate change on the water potential of the watershed of river Ansegmir. To address this issue, all spatial data cited above were used to produce the hydrographic network map and land cover map. In fact, the processing and exploitation of climatic data allowed studying the evolution of climatic conditions of the watershed.

The interpolation of precipitation data, using the inverse-distance weighting (IDW) method allowed producing a precipitation map of the studied region. In addition, by combining this latter with the temperature and the Emberger's bioclimatic stages, the bioclimatic zone of the watershed of river Ansegmir was determined.

Moreover, statistical analysis of Oued Ansegmir watershed data as well as their combination with climatic conditions were used to monitor climate change and its impact on the water potential of the watershed of river Ansegmir.

RESULTS AND DISCUSSION

Precipitation

In the watershed of river Ansegmir, the rainfall regime is Mediterranean. Moreover, monthly and annual precipitation at the watershed of river Ansegmir hydrographic stations (Fig. 4) fluctuates according to altitude.

In fact, the highest average monthly precipitation (> 40 mm) in the upstream (South) and central parts of the studied area and at Agoudim and Tounfit stations, occurred in February, March, April, September, October, November and December. However, the lowest average monthly precipitation (< 10 mm) occurred in June and July (Fig. 5a). On the other hand, the downstream parts (North) of the watershed and Ansegmir station are characterized by low precipitation levels and did not exceed 36 mm in October, while the driest month is always July. In addition, the

Table 1. Climatological stations at the BV of River of Ansegmir

Stations	X	Y	Z
Ansegmir	551416.37	242414.78	1413
Tounfit	514226.47	209033.48	1977
Agoudim	523299.91	204664.79	2037

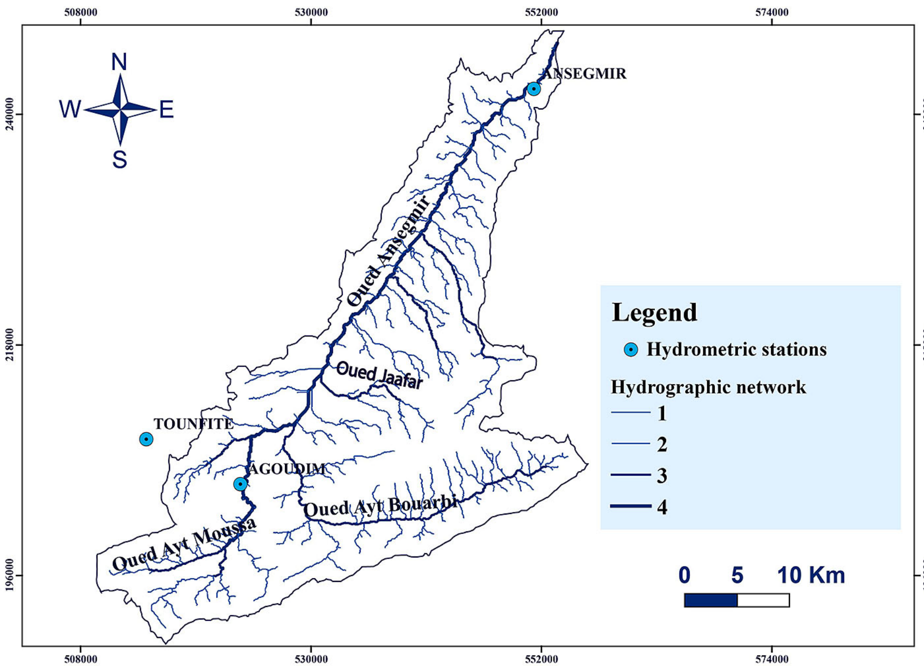

Figure 4. Watershed of river Ansegmir hydrographic stations

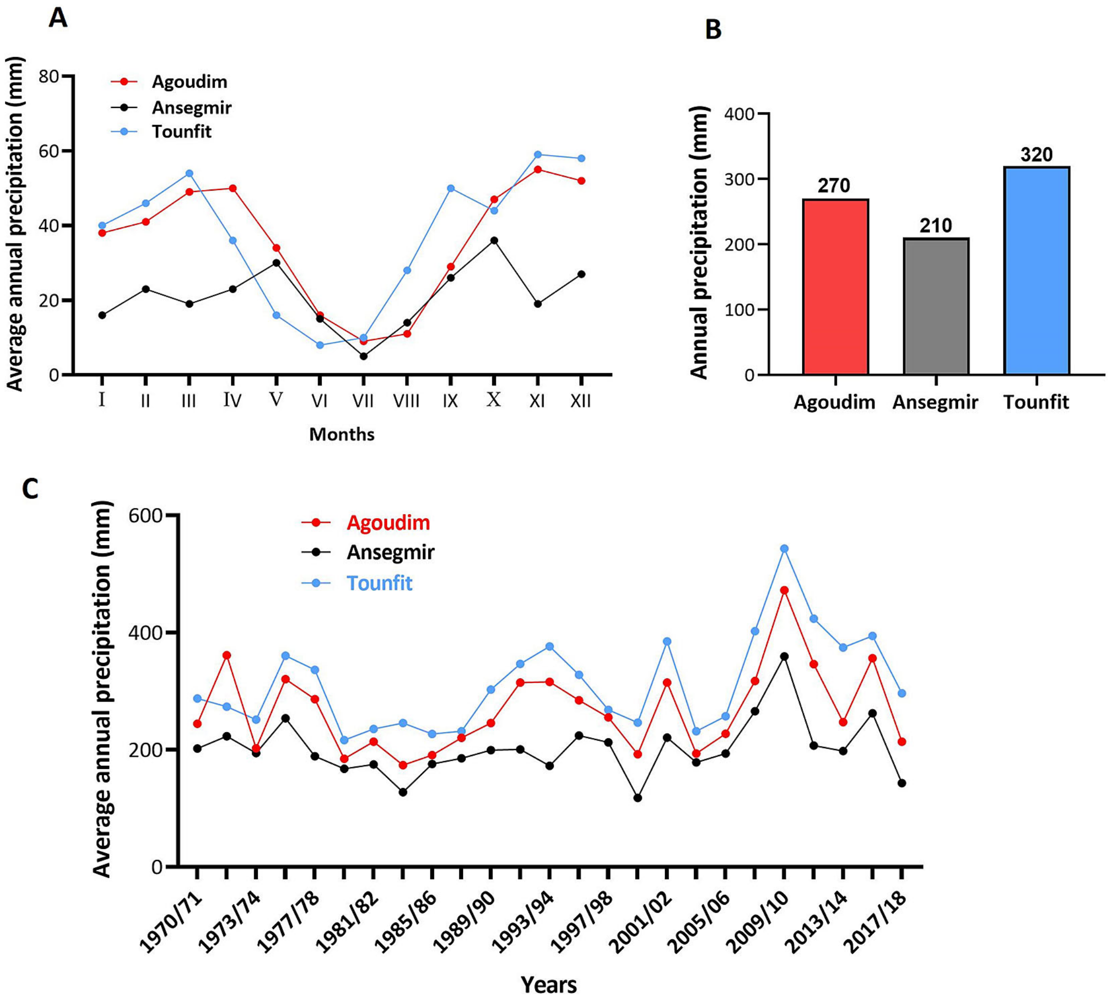

Figure 5. Precipitations at watershed of river Ansegmir during 1970–2018: A) Average annual precipitation (mm) per months; B) Total annual precipitation (mm); C) Average annual precipitation (mm) per years

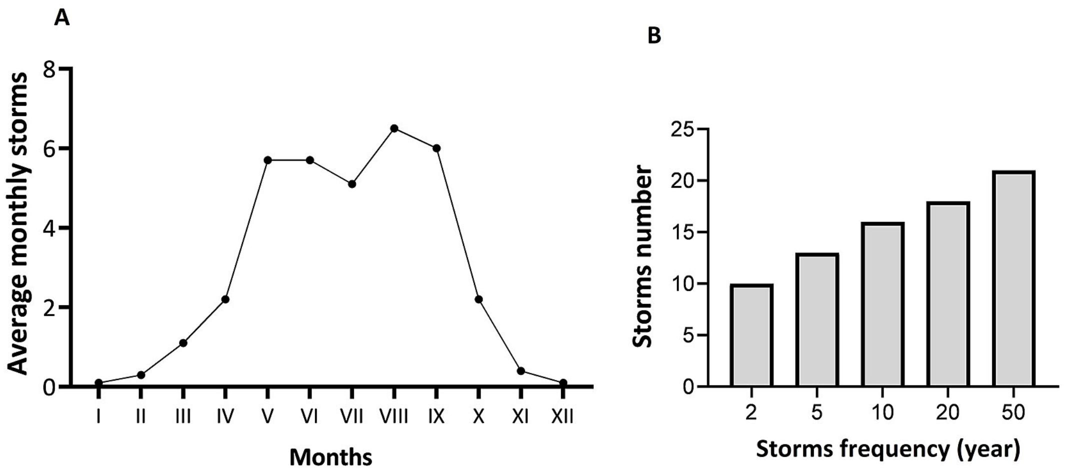

Figure 6. (a) Average monthly storms at watershed of river Ansegmir during 1970–2018; (b) frequency of storms per years

watershed of river Ansegmir is also characterized by stormy rains (from May to September) which sometimes cause significant damage.

Frequency analysis in Midelt shows that on average 10 storms could take place every 2 years (Fig. 6), which is relatively debilitating for arboriculture, especially Rosacea. In the same area, the maximum daily precipitation recorded varies from 43 to 80 mm. It should be noted that the downpour which generated the catastrophic flooding of Midelt in 1992 was 60 mm for 24 hours. At annual time-scales, spatial rainfall patterns indicated that the average annual rainfall in the watershed showed a clear decrease from upstream (320 mm/year at Tounfit) to downstream (210 mm/year at Ansegmir) (Fig. 5b).

Moreover, the analysis of long-term precipitation data from surrounding stations indicates fluctuations between the period 1970–1971 and 2017–2018 (Fig. 5c), although a downward trend appears in the watershed, these are inter-annual variability that are particularly obvious.

The largest rainfall levels were recorded during the period 2007–2010 while the lowest were recorded in 1999–2000. In fact, annual rainfall showed severe fluctuations between the period of 1970 and 1980 with a maximum of 362 mm recorded in the Tounfit station and a minimum of 167 mm in the Ansegmir station.

Moreover, annual rainfall in the watershed of river Ansegmir during the period of 1980–1990, was relatively stable with an annual average of 210 mm. However, a trend of decreasing annual precipitation value was observed during the period 1990–2000. In fact, this decade is characterized by the lowest rainfall levels in the watershed (117 mm in Ansegmir station) over the study period (1970–2018). A trend of increasing annual rainfall was observed during the period 2000–2010. Indeed, this period recorded the highest value of annual rainfall (543.26 mm in Tounfit station) during the study period (1970–2018).

However, a decreasing trend in annual precipitation was observed throughout the period 2010–2018, with a minimum value of 143 mm recorded in the Ansegmir station and a maximum of 424 mm in the Tounfit station. During the periods 1970–1971 and 2017–2018, and by considering the coefficient of variations (CV = the ratio of the standard deviation to the mean) our data indicated a severe precipitation irregularities in the three studied stations (CV = 27% in Agoudim, CV = 26% in Tounfit and CV = 24% in Ansegmir).

Snowfall

In addition to rainfall, another water source may come from melted snow. However, there is no quantitative data regarding snow in the study area. Snowfall duration varies from a few days to 4 months per year. Moreover, snowfall occurs on average 8.3 days/year according to the Moulouya River basin Agency of Midelt.

Temperature

Maximum and minimum temperatures data from the three stations of the watershed of river Ansegmir (Fig. 7A–C). Regarding temperatures, July is the hottest month with a maximum exceeding 32 °C. Moreover, the temperature of the

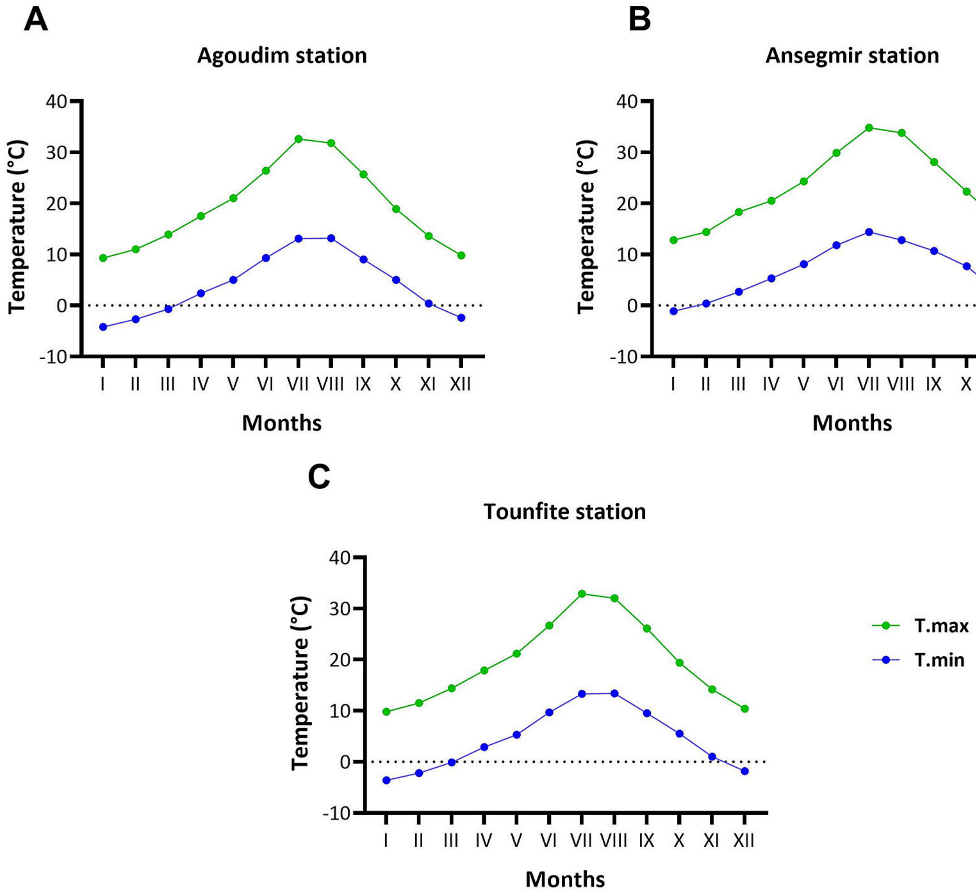

Figure 7. Maximum (T_{max}) and minimum (T_{min}) average monthly temperatures (°C) during the period 1970–2018 in (a) Agoudim station; (b) Ansegmir station and (c) Tounfit station

coldest month (i.e., January) is near 0 °C. Thermal amplitudes from the three stations of the watershed of river Ansegmir (Table 2).

Thermal amplitudes indicated that the climate of the watershed of river Ansegmir could be considered semi-continental to continental, while the temperature 35 °C is considered the limit between these climate types.

Evapotranspiration

The estimation of evapotranspiration (ET) is linked to the potential evapotranspiration (PET) and the actual evapotranspiration (AET). PET represents the rate at which ET would occur from a large area, which has access to unlimited water supply, while AET is the actual evapotranspiration of the land surface. Both PET and AET are determined by classical empirical formulas such as Turk, Coutagne and Thornthwaite.

The studied data indicated that estimating ET using the Thornthwaite formula showed a strong atmospheric water vapor in the watershed of river Ansegmir. In fact, the estimated AET of Ansegmir, Tounfit and Agoudim stations are 2350, 1896 and 1864 mm/year, respectively.

High PET with more than 2 m/year in downstream parts and near 2 m in upstream parts of the watershed is considered to present a handicap to agriculture, especially in wastelands.

Table 2. Annual precipitation in the watershed of river Ansegmir stations

Stations	Min. (mm)	Max. (mm)	Average (mm)	Median (mm)	SEM[1] (mm)	Extend (mm)
Ansegmir	174	472	270	247	72	299
Tounfit	216	543	320	296	80	327
Agoudim	118	359	210	198	49	241

Note: [1]SEM: standard error deviation.

Streamflow of the Ansegmir station

Maximum and minimum of monthly streamflow data of the Ansegmir station during the study period (1970–2018) (Table 3). Streamflow of the Ansegmir River generally vary throughout the months of the year (Fig. 8). According to the Moulouya River basin Agency of Midelt, the highest degree of river flows were recorded in May and June, which were found to correspond to about 21.4 m^3/s and 17 m^3/s, respectively. However, the lowest values were recorded in July and August, which were near to 0 m^3/s.

Bioclimate

In order to determine the bioclimatic stage of the studied area, the Emberger Q2 index was calculated as follows:

$$Q_2 = 2000 \times P / (M_2 - m_2) \quad (1)$$

where: P – average annual rainfall, M – maximum temperature of the warmest month (T + 273 K), m – average minimum of the coldest month (T + 273 K) (Table 4).

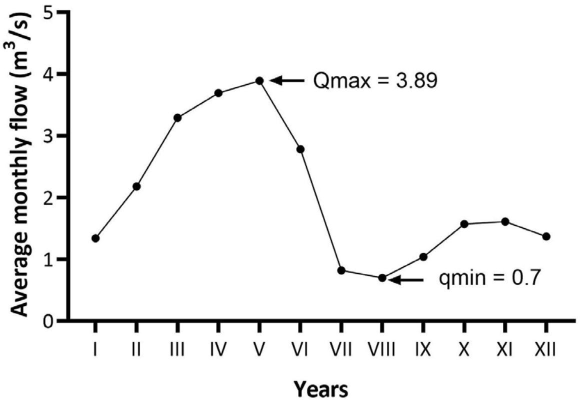

Figure 8. Streamflow of the Ansegmir River

The aridity is more pronounced in downstream parts of the watershed (Fig. 9). Moreover, this bioclimatic evolution controls the spatial distribution of natural ecosystems from upstream to downstream parts of the watershed. For instance, Cedrus, Juniper and Holm oak characterized upstream parts while lower downstream parts are characterized with steppes.

The average annual water inputs from precipitation are relatively low in the downstream (North) part of the watershed (253 mm/year at the Ansegmir station) and high in the upstream (South) part (460 mm/year at the Tounfit station).

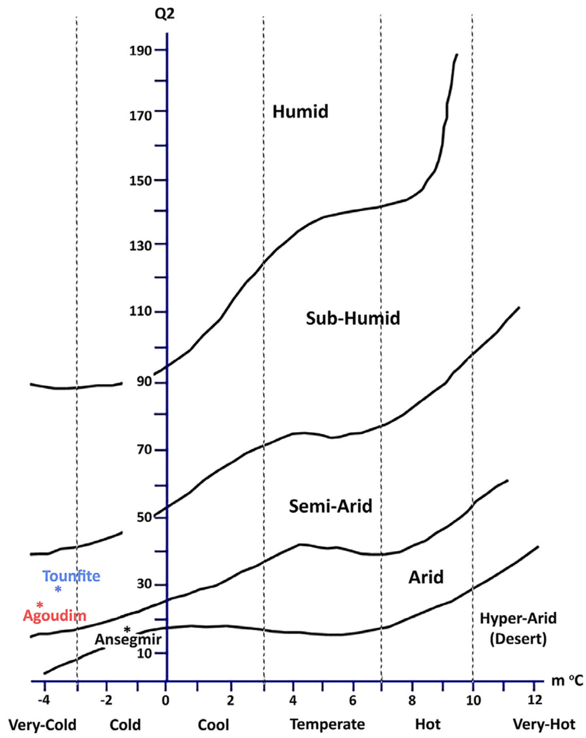

Figure 9. Emberger climagram of the watershed of river Ansegmir

Table 3. Average monthly flow (m3/s) of the Ansegmir River during the period 1970–2018

Station	Flow (m^3/s)	January	February	March	April	May	June	July	August	September	October	November	December	Mean
Ansegmir	Average	1.34	2.18	3.29	3.69	3.89	2.78	0.82	0.70	1.04	1.57	1.61	1.37	2.08
	Max	4.24	6.48	13.4	13.6	21.4	17.0	4.73	3.30	4.61	9.70	8.79	4.71	6.90
	Min	0.13	0.11	0.13	0.13	0.12	0.03	0.00	0.00	0.01	0.01	0.01	0.02	0.37

Table 4. Bioclimatic synthesis in the watershed of river Ansegmir during the period 1970–2018

Stations	Altitudes (m)	M (°C)	m (°C)	P (mm)	Bioclimat
Ansegmir	1413	34.8	-1.1	253	Lower semi-arid to cold winter
Tounfit	1977	32.9	-3.6	459	Lower subhumid to very cold winter
Agoudim	2037	32.6	-4.2	431	Lower subhumid to very cold winter

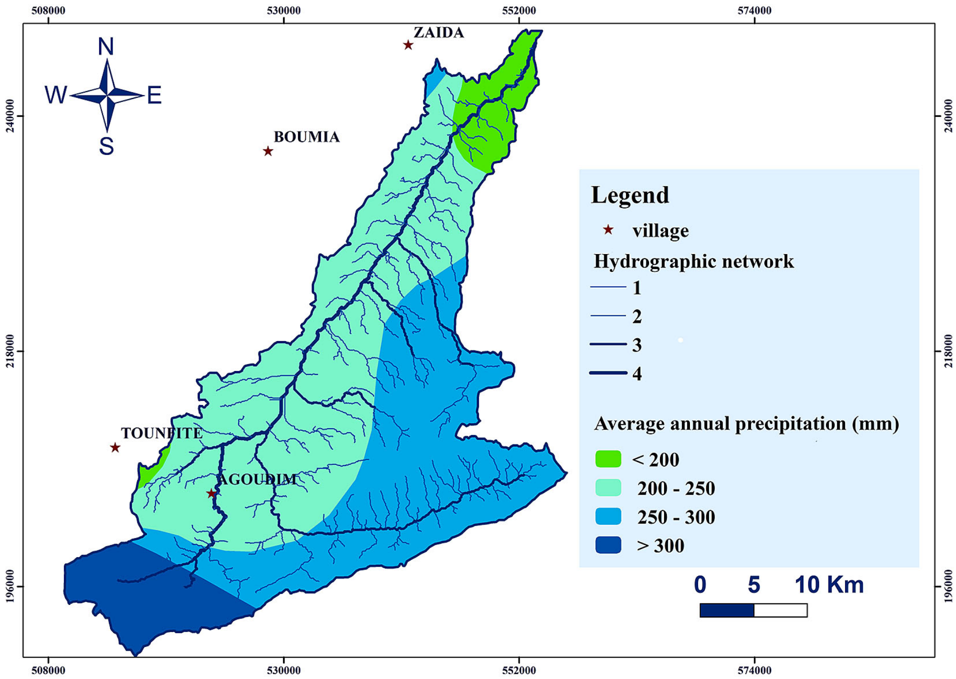

Figure 10. Spatial distribution of average annual precipitation in the watershed of river Ansegmir in the period 1970–2018

However, the precipitation varies considerably intra and inter-annually (Fig. 10). By using the Thiessen polygon method (Jiang et al., 2007), we calculated the mean area rainfall. Results indicated that the average of annual rainfall in the watershed of river Ansegmir is about 395.6 mm. However, rainfall constitutes a limitation for the development of agriculture activities based on it such as dried agricultural products. In fact, cereal production requires on average 600 mm/

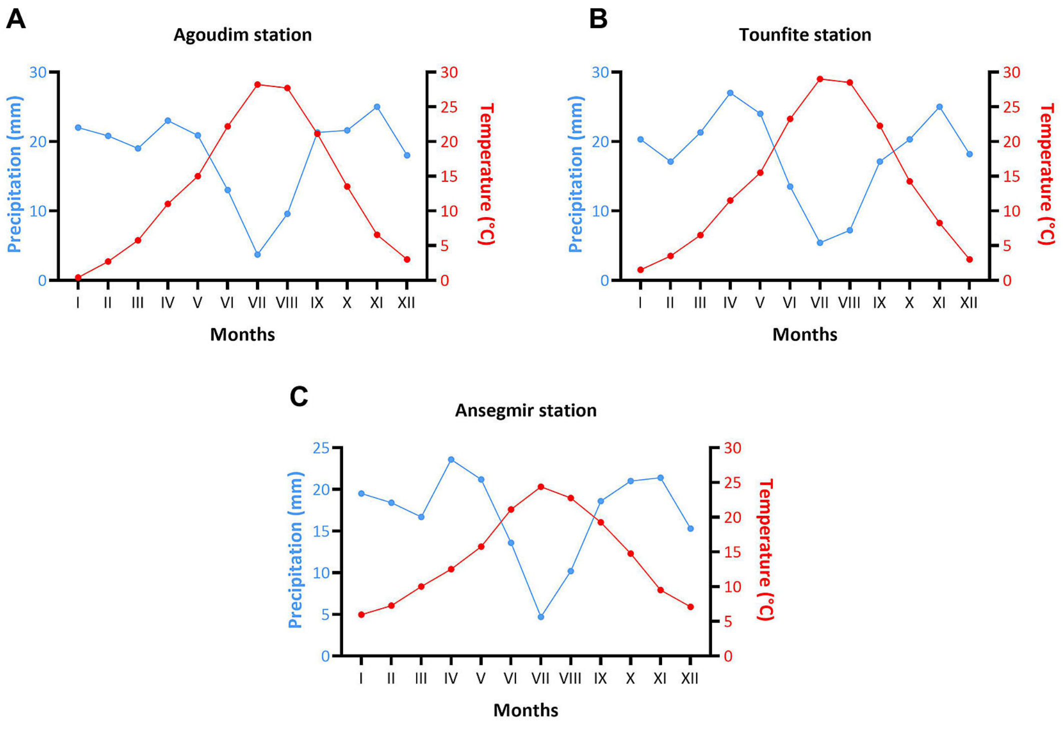

Figure 11. Ombrothermic diagram during the period 1970–2018 of: (a) Agoudim station, (b) Tounfit station and (c) Ansegmir station

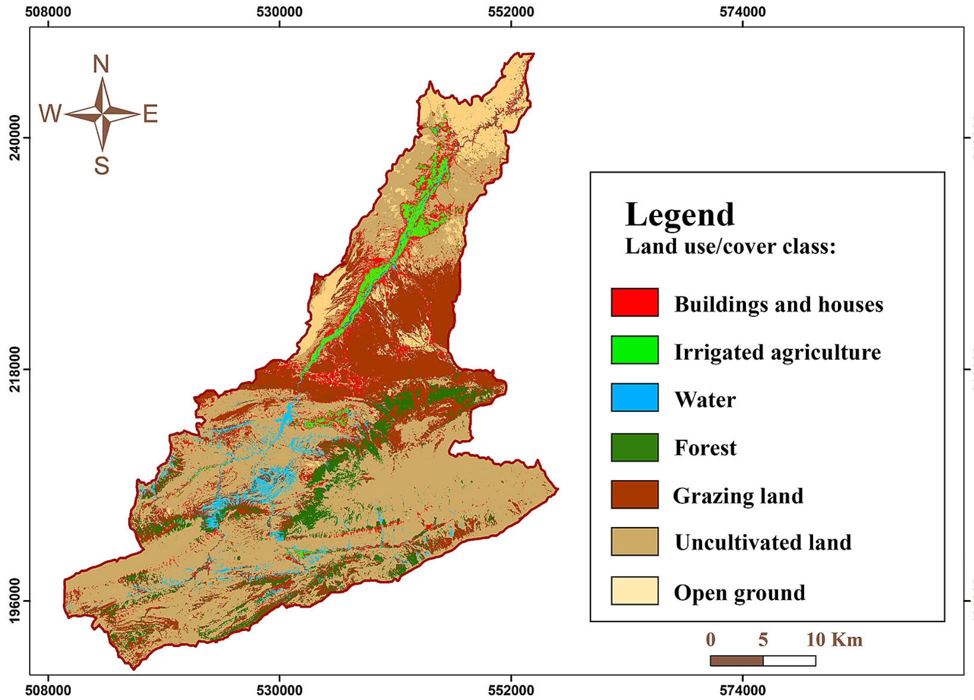

Figure 12. Land use and land cover map of the watershed of river Ansegmir

year evenly distributed over the year. Moreover, temperature data indicated that July is the hottest month with a maximum exceeding 32 °C while the coldest month is January with minimum temperatures near to 0 °C (Fig. 11). In addition, the watershed of river Ansegmir is characterized with higher values of thermal amplitude exceeding 35 °C. Therefore, temperature could as well present a handicap for the development of an interesting rain-fed agriculture since this condition favors frost occurrence in the winter and evapotranspiration in the summer. In addition, optimum vegetative growth durations are very short (Fig. 12).

Cold, as a physiological factor, represents a main factor for the development of Rosacea fruit trees including apple trees. The watershed of river Ansegmir is very sensitive to the effects of climate conditions. In fact, the occurrence of deficits in rainfall and snowfall may induce hydrological drought that contributes to water deficit and consequently on water potential, which sometimes goes as far as the drying up of the main River of Ansegmir.

Among the hydraulic schemes designed to mitigate the negative effects of climatic conditions on the water potential of the Oued Ansegmir watershed area, the construction of two dams is considered, namely:

- The "Hassan II" dam with a capacity of 400 mm^3 to regulate 100 mm^3/year;
- The "Tamalout" dam, whose average annual inflow is estimated at 60 mm^3. To meet the irrigation needs of the Ansegmir perimeter.

CONCLUSIONS

The following conclusions were drawn after conducting effects of climatic conditions on water potential of the river Ansegmir watershed:

The climate in the watershed of river Ansegmir is characterized by low rainfall inputs with 396 mm/year, very poor distributed in time and space. In fact, the precipitation varies considerably intra and inter-annually, which can stimulate storms in study area, particularly in the summer.

In addition, the watershed of river Ansegmir was characterized by high thermal amplitudes exceeding 35 °C, which justifies the extreme cold in winter. This region has a semi-continental with a very cold/cold semi-aride bioclimate. Consequently, temperature constitutes natural constraints for the development of an interesting rain-fed agriculture.

The present study provides an overview on the potential of surface water in the watershed of river Ansegmir. However, future studies are greatly needed to determine the state of groundwater in the watershed of river Ansegmir to identify the different forms of contribution (i.e., inputs and outputs) in groundwater recharge/discharge in order to assess the interactions between groundwater and climate change. On the other hand, future studies integrating piezometric data will clarify the evolution of water sources following farms installation in the watershed of river Ansegmir, particularly after the launch of the Green Morocco Plan.

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