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ASSESSING THE INFLUENCE OF THE AL WAHDA DAM COMMISSIONING ON FLOOD FLOWS AND LOW WATER LEVELS IN THE GHARB PLAIN, MOROCCO

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Abstract: The Sebou Basin is one of the most important hydrographic basins in Morocco. When the Wadi Sebou enters the Gharb Plain, it encounters difficulties in evacuating its waters during wet years due to its flattening, resulting in risks of floods. Its flow decreases during drought years and in August and September. For the purpose of this research, we were granted authorization to utilize the hydrometric station located in Bel-Ksiri. This station is most suitable for the study as it was designated as a reference point for the Wadi Sebou's flooding in the lower basin. This study is based on detecting floods in the Wadi Sebou from 1976 to 2020, dividing this period on pre and post 1997, corresponding to periods before and after the construction of the Al Wahda dam, examining the mean daily flow rates. Identifying discontinuities within the maximum daily flow series from 1967 to 2020 was achieved in Microsoft Excel. Additionally, determining flood return periods and examining low water flows are integral aspects of the study. The findings indicate a relative decrease in the frequency and intensity of floods within the Wadi Sebou's basin, coupled with effective control of low water levels. These changes are attributed to the construction of the Al Wahda dam, which guarantees a stable water supply for irrigation purposes in the plain. To ensure the long-term sustainability of water management practices, the adoption of innovative irrigation technologies is deemed necessary.

Keywords: maximum daily flows; return periods; breakup; low flow; Gharb Plain

1. Introduction

Floods are considered one of the most dangerous natural disasters that kill humans, with the number of victims annually reaching more than 20,000 (Simona & Cedric, 2007). Today, the world is witnessing rapid climate changes that translate into a rise in temperatures and changes in the amounts of precipitation (Hakam, Baali, Ait Brahim et al., 2022; Hakam, Baali, Azennoud et al., 2022; Jasman et al., 2023; Valjarević et al., 2022). This has a major impact on food security, which is considered one of the main challenges for the world's population. Therefore, the United

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Nations set its 17 goals to achieve sustainable development such as those linked to climate change (United Nations, n.d.). An increase in temperature of 0.5 to 1.2 °C, whether natural or due to human intervention, decreases the short-term flood frequency by 25 to 50% (Wilhelm et al., 2022). Coastal areas and lowlands are also more vulnerable to the effects of climate changes (IPCC, 2001a, 2001b). These climate changes therefore negatively affect the flow of valleys in the humid, semi-humid, dry, and semi-arid environments found in the Mediterranean basin, where the flow of the rivers is characterized by a precipitation regime (Wadi Sebou). The lowest throughput values are recorded during August and September, while the highest is recorded during November, December, and January (Haida et al., 1999; Réméniéras, 1976).

Floods pose a persistent threat to Morocco, with devastating consequences evident from past catastrophic events. The 1963 flood stands out as among the most perilous occurrences in the Gharb Plain, extending from December 31, 1962 to February 23, 1963, submerging 180,000 ha of agricultural land (Le Coz, 1964). Morocco remains highly vulnerable to floods, with the 2010 disaster being particularly severe, claiming 11 lives and inundating an area of 180,760 km^2 across multiple regions (Centre for Research on the Epidemiology of Disasters, 2024).

Morocco is among the countries affected by these climate changes that result in consecutive years of drought, alongside occasional sudden floods in the northwest region of the country, which is particularly susceptible to weather disturbances originating from that direction. Additionally, the Gharb Plain in the lower section of the Sebou Basin experiences similar vulnerabilities (El Karfa et al., 2023a). This situation caused a haphazard extraction of water from the Sebou which creates a big challenge for water management.

Floods left considerable human and material damage, mainly in the Gharb region (Banque Africaine de Développement, 2009). Several hectares of cultivated land were submerged, a lot of inhabitants were displaced and several roads and railways were cut off. Damage to infrastructure and land use has reached colossal sums. Moreover, the overflowing water cannot return to the riverbed in the same way and spreads out across the plain, covering tens of thousands of hectares and stagnating for weeks or even months. The impermeability of the clay soil covering almost all the lowlands of the plain favors this stagnation.

This plain is esteemed as one of the most fertile in Morocco because it holds significant potential for utilizing the surface water resources originating from the Sebou Basin, which are provided by the main river, ensuring promising prospects for agriculture and regional development. However, when the Sebou River entered the Gharb Plain, it frequently flooded it, so the most of the plain were meadows. Therefore, drainage process was difficult (Combe, 1975; Le Coz, 1964). Significant precipitation was recorded in the Rif mountains (2,000 mm in the Katama region; Fejjal, 1982), where the river overflows with a flow rate of up to 1,600 m^3/s (Le Coz, 1964).

These floods have negative effects on farmers' investments in this plain. Therefore, the state carried out agricultural reform within the framework of the Sebou project in partnership with Food and Agriculture Organization (Troin, 1996). Its goal is to control the floods of the Wadi Sebou and reduce the danger, in addition to reclaim meadowlands and distribute them to small farmers.

Despite all these, and despite the construction of the Garde dam in the central plain of the Gharb basin, which began to be used in 1992 to ensure the sustainability of irrigation water, the flow decreased to the concerning minimum levels, posing significant implications for irrigated agriculture. Low flow is defined as a period during which flows are very low and

little variable because they come only from groundwater in the process of being exhausted or drying up (George & Verger, 2000), which is due to long periods of drought and hydrological drought (Abi-Zeid & Bobée, 1999). This is why the position of the Bel-Ksiri hydrometric station in the Gharb Plain is very important.

2. Study area

The Al Wahda dam is located in north-west Morocco (Figure 1), and was built and commissioned in 1997. It covers an area of 12,300 ha and retains a normal volume of 3,800 mm^3. The dam plays a vital role in irrigating the Gharb Plain and protecting it from the devastating floods of the Wadi Ouergha (Sebou Hydraulic Basin Agency, 2021). The absence of sufficient gradient in the plain inhibits the river's capacity to effectively discharge its water, thereby precipitating significant flood occurrences. The profile of the riverbed is shown in Figure 2. The Bel-Ksiri hydrometric station is used as a referenced one for the flooding of the Wadi Sebou, according to the fact that this is the only station on the Wadi Sebou on this plain and it has sufficient data for this study. Data from this station have also been utilized by several researchers (Igouzal & Maslouhi, 2003; Le Coz, 1964).

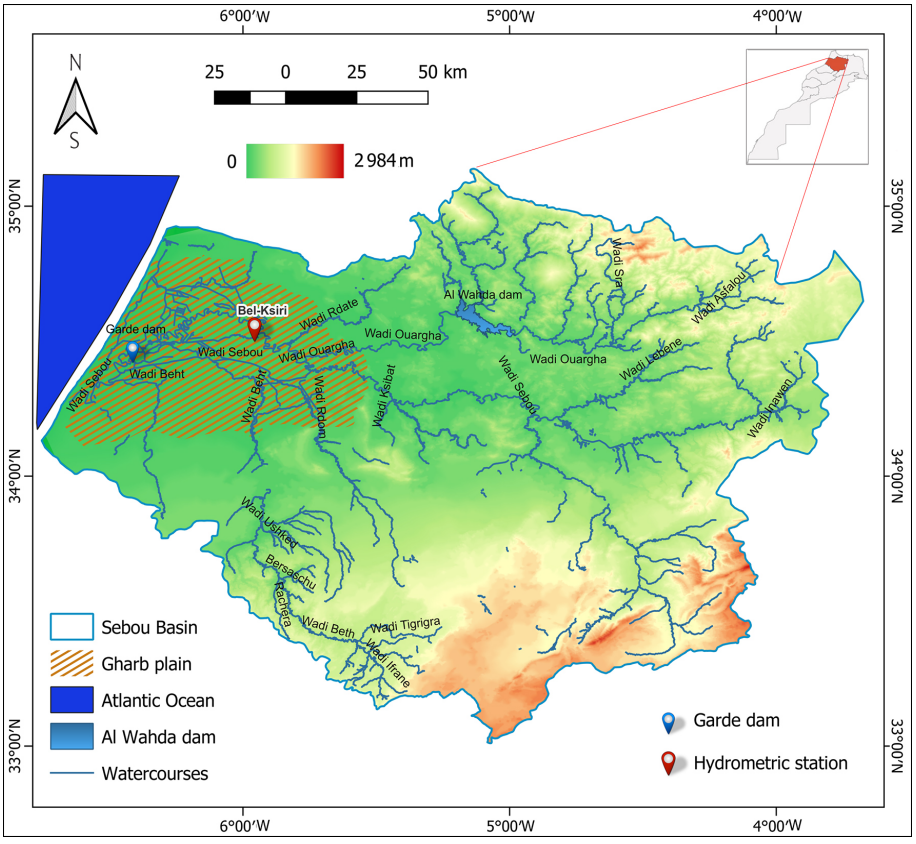

Figure 1. Location of the study area.

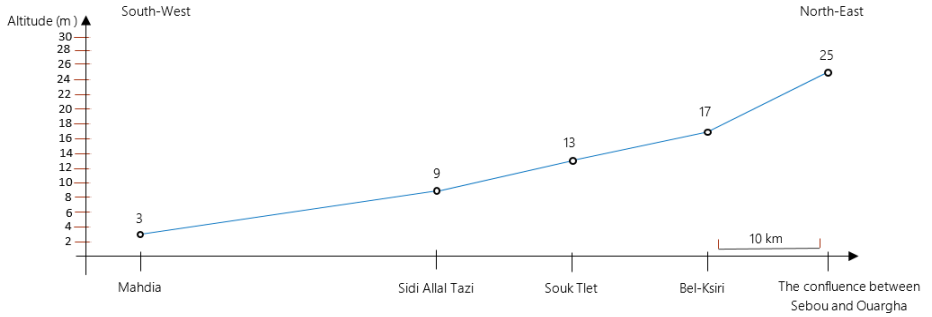

Figure 2. The profile of the slope of the Sebou River riverbed in the Gharb Plain.

3. Data and methods

The average daily flow values for the Wadi Sebou at the Bel-Ksiri hydrometric station from the 1975–1976 season to the 2019–2020 season, and the annual maximum daily flow values from 1967 to 2020 were obtained from the Wadi Sebou Water Basin Agency (Sebou Hydraulic Basin Agency, 2023). In this study, aimed at assessing the influence of the Al Wahda dam on flooding and low water levels in the Gharb Plain, the following methods and techniques were employed:

- determining the days of rise and fall of the flow, from the maximum values of the daily flow, two seasons before the construction of the dam and two others after it to show the impact of the dam;
- the detection of return periods of the daily maximum flow values by adjusting these values using a Gumbel's law (Gumbel, 1958); and
- the detection of the average monthly low flow rate during the year and the lowest low flow rate during the year, in addition to identifying the lowest low flow rate throughout the period studied.

4. Results

4.1. Study of the floods of the Wadi Sebou

Figure 3 illustrates the impact of the Al Wahda Dam on the Sebou River maximum flows. On January 24, 1977, the peak daily flow reached 2,080 m^3/s, persisting for four days, indicating a severe flood year. Previously, before the construction of the dam on the Wadi Ouargha, the lower plain endured hazardous floods. In February 2009, the daily flow peaked at 1,123 m^3/s for over eight days, followed by a nine-day decline. The dam construction influenced on reducing the values of extreme flow, which also had an impact on flood risk reducing. Additionally, it has formed an important reservoir of water resources that is utilized during periods of drought.

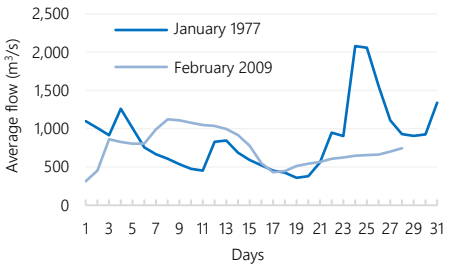

Figure 3. Average daily flow (in m^3/s) in January 1977 and February 2009.

4.2. High flow study

From Figure 4, on which the 54 experimental points corresponding to each of the annual floods have been plotted, it can be concluded that the Gumbel fitting method gives results relatively close to the peak flows recorded in the study area during the floods affecting the Gharb Plain (1969, 1970, 1971, 1974, 1977, 1979, 1984, 1986, 1987, 1990, 1991, and 1996).

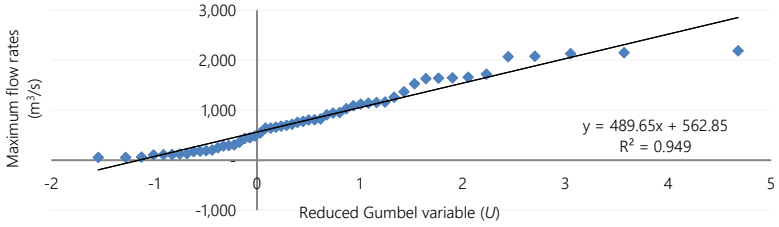

Figure 4. Adjustment of the maximum daily flow values according to Gumbel's distribution between 1967 and 2020 at the Bel-Ksiri hydrometric station.

According to the data shown in Table 1, a significant increase between the five-year flood (1,334.09 m^3/s) and the twenty-year flood (2,161.62 m^3/s) have been noticed. The intensity of the five-year flood is essentially due to the rainfall in the central Rif. In Figure 5, the 31 experimental points corresponding to each of the annual floods are plotted. It clearly shows that the risk of flooding in the Gharb Plain was much greater in the years 1969, 1970, 1971, 1977, 1979, and 1986 prior to the construction of the Al Wahda dam.

Table 1. Probable maximum daily flows (Q) for return periods after Gumbel's distribution for period 1967–2020

Return periods (years)	5	20	50	100
Q (m^3/s)	1,334.09	2,261.62	2,686.06	3,079.04

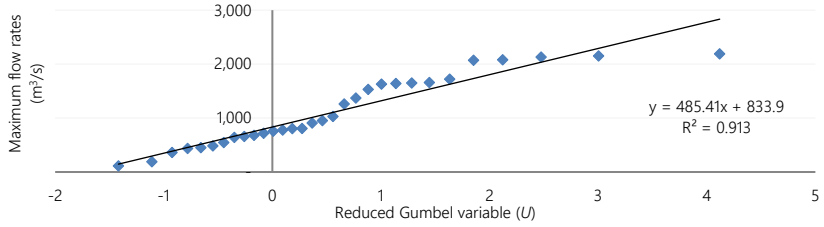

Figure 5. Adjustment of the maximum daily flow values according to Gumbel's distribution between 1967 and 1997 at the Bel-Ksiri hydrometric station.

The values shown in Table 2 justify the risk of five-year floods (1,736.21 m^3/s). The intensity of the five-year floods is mainly due to heavy rainfall concentration in the central Rif. In Figure 6, on which the 23 experimental points corresponding to each of the annual floods have been plotted, a decrease in peak flows compared with those in Figures 4 and 5 was recorded, generally due to the construction of the Al Wahda dam in 1997. The major floods are those recorded in the years 1998, 1999, 2009, 2010, and 2013.

Table 2. Probable maximum daily flows (Q) for return periods after Gumbel's distribution for period 1967–1997

Return periods (years)	5	20	50	100
Q (m^3/s)	1,736.21	2,962.26	3,739.24	4,321.47

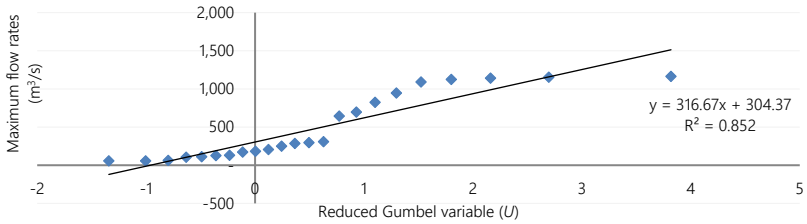

Figure 6. Adjustment of the maximum daily flow values according to Gumbel's distribution between 1998 and 2020 at the Bel-Ksiri hydrometric station.

Table 3. Probable maximum daily flows (Q) for return periods after Gumbel's distribution for period 1998–2020

Return periods (years)	5	20	50	100
Q (m³/s)	773.21	1,221.71	1,504.30	1,716.82

In Table 3, 773.21 m³/s for the five-year flood and 1,716.82 m³/s for the 100-year flood was recorded, with a very low ratio of 2.22. Therefore, the construction of the Al Wahda dam has reduced the severity of flooding in the Gharb Plain.

4.3. Low flow study

The role of low water flow is of paramount economic importance, which led to the intervention of planners in 1992 to build the Garde dam to counter the adverse effects of drought periods (El Karfa et al., 2023b). However, this action did not solve the problem of low water flow, which is recorded at 0 m³/s during two agricultural seasons, as shown in Figures 7 and 8. Additionally, the State built the Al Wahda dam in 1997, playing a crucial role in ensuring the sustainability of low water flow in the Gharb Plain.

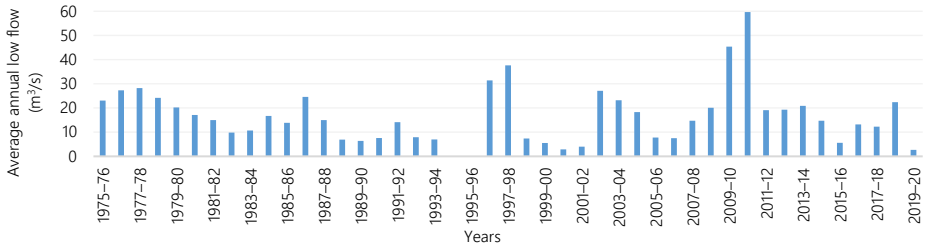

Figure 7. Average annual low flow of Bel-Ksiri in period 1975–2020.

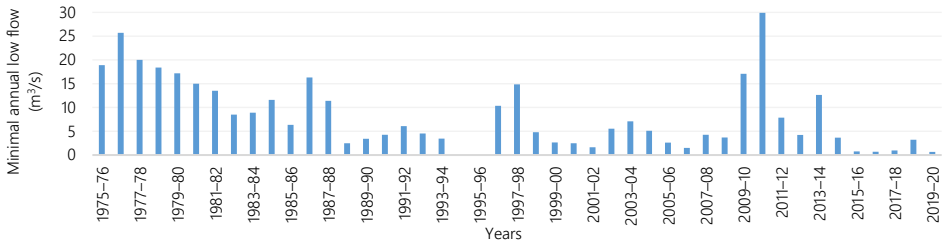

Figure 8. Minimal annual low flow of Bel-Ksiri in period 1975–2020.

5. Discussion and conclusion

Before the construction of the dam, the study area of the Gharb Plain experienced frequent floods, exemplified by the 1977 event shown in Figure 3, on the strength of the Wadi Sebou floods. Situated in a semi-arid climatic zone, the area consistently faced years of drought, adversely impacting the river's flow regime (El Karfa et al, 2023a). However, previous research indicates that climatic drought has intensified since the break in rainfall patterns observed since 1975 (Sebbar et al., 2011). This pressure became stronger by higher temperatures and fewer wet days, as noted by Driouech (2010). Before the dam construction, the flow rate decreased to 0 m^3/s, as depicted in Figures 7 and 8. Presently, Morocco faces a water deficit across all its hydrographic basins, excluding the Sebou Basin, albeit experiencing a decline in water capacity. However, challenges persist due to traditional and erratic irrigation practices, as well as water supply to the Bouregreg basin. This has led to a reduction in irrigated land, compelling local stakeholders to tap into groundwater without adequate controls, thereby raising concerns about sustainability in the region. It is crucial to highlight that this study focuses on floods and low water levels specifically within the lowlands of the Sebou Basin. The Gharb Plain holds significant importance in Moroccan agriculture and regional development. Considering the region's reliance on water resources, particularly in a climate influenced by limited precipitation affecting both surface and ground water sources, there is a pressing need to prioritize research in water resource management. Future investigations should explore the incorporation of innovative irrigation technologies to ensure the sustainable utilization of water resources in the Gharb Plain and upgrade its resilience against environmental challenges.

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