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Hydrological Profiles in the Ouaoumana River Basin in the Middle Atlas of Morocco (November 2021-May 2022)

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ABSTRACT

Today, in the context of climate change and intensive over-exploitation by humans, Morocco's water resources have become very fragile. The water resources of the Ouaoumana catchment area, which forms our study area and is considered a tributary of the Oum Er-Rabia catchment area, play several important roles in the area. The aim of this study is to assess these water resources using a qualitative hydrological method based on flow measurements over the period (November 2021-May 2022) at 7 measurement points in order to produce hydrological profiles. The main results obtained show that the longitudinal evolution of the flow of the Ouaoumana river is characterized by a large variation on a spatial and temporal scale, as the population uses a large quantity of water from the river for irrigation (drawing water from motor-driven pumps), this consequently leads to a reduction in surface and groundwater.

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المقاطع الهيدرولوجية في حوض واد واومنة الأطلس المتوسط، المغرب (نوفمبر 2021-مايس 2022)

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الملخص

اليوم وفي سياق التغيرات المناخية والطلب والاستغلال المفرط من طرف الإنسان، أصبحت الموارد المائية في المغرب جدا هشة، تلعب الموارد المائية في حوض واد واومنة الذي يشكل مجال الدراسة ويعتبر رافدا من روافد أم الربيع عدة أدوار. تهدف دراستنا إلى تقييم هذه الموارد المائية بالاعتماد على منهجية هيدرولوجية كمية ترتكز على قياسات الصبيب خلال الفترة الممتدة ما بين (نوفمبر 2021 ومايس 2022) في سبع نقاط موزعة من العالية نحو السافلة، من أجل إنجاز المقاطع الهيدرولوجية. تبين النتائج التي تم الحصول عليها أن التطور الطولي لصبيب الواد يتميز بتباين كبير على المستوى المكاني والزماني، حيث يستخدم السكان كمية كبيرة من مياه النهر للري (سحب المياه بالمحركات الآلية والمضخات وغيرها)، مما يؤدي إلى انخفاض في المياه السطحية والجوفية.

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Introduction

Water resources management is one of the major issues of the 21st century. Numerous natural and man-made phenomena have an impact on water resources, and more particularly the water cycle (Garcia, 2016). And due to climate change, there is a continuous increasing real risk of water shortages as needs. Indeed, the increasing numbers of uses of water, which resort to direct abstraction from the river or pumping out the groundwater, aggravate low water situations (Lang, 2007).

Morocco is located in northwestern Africa on the edge of Europe continent, and is bordered by the Atlantic Ocean to the west, Algeria to the east, Mauritania to the south and the Mediterranean Sea to the north. Four mountain chains dominate the topography and divide the country into three geographic regions: the mountainous interior, including plateaus and fertile valleys; Atlantic coastal lowlands; semi-arid and arid areas of eastern and southern Morocco, where the mountains descend gradually into the Sahara Desert. In the north, the Rif Mountain range runs parallel to the Mediterranean Sea. South of the Rif mountains, a series of three Atlas mountain ranges somewhat overlap one another across the country on a generally ENE–WSW axis that separates the Mediterranean and Atlantic coastal regions from the Sahara Desert. Presently, Moroccan climate is mainly controlled by three different climate systems, the humid Mediterranean and Atlantic climates in the north and northwest and the arid Saharan climate in the south (Hssaisoune *et al.*, 2020). Over the last three decades, hydrologically speaking, Morocco has experienced a notable reduction in river flows, especially low-water flows. In the forthcoming decades, water will be one of the key factors in Morocco's development. The main reasons for this concern are climate change and the growing need for water as a result of demographic, industrial and agricultural development. Consequently, water is becoming an economic, social, and political issue. Therefore, the control and proper management, through specialized studies, are proving useful and even necessary (Qadem *et al.*, 2020).

Hydrological profiles correspond to a curve-type graph show the evolution of gross flows (l/s) and specific flows (l/s/km2) of the watercourse from upstream to downstream. The spatial criteria being the surface area of the catchment basin or kilometer stations. They can be used to visualize flows from the main drain according to the emptying of aquifer reservoirs via tributaries, springs and groundwater-river exchanges (concept of draining or drained aquifer) (Lejeune *et al.*, 2004). Hydrological profiles are drawn up for watercourses with at least three gauging points. Analysis of these hydrological profiles, with regard to the geology of the outcrops crossed by the watercourse, makes it possible to supplement the information on land yield already obtained by previous approaches (Lebaut, 2000). The aims of this study are:

1. To determine the spatial and temporal variation in river flows (upstream-downstream).
2. To determine the relationship between the water table and human activity.
3. To evaluate the quantity of water at several stations.
4. To give managers an idea of surface water variations, emergence zones and water losses.

Study Area

The Ouaoumana River basin belongs to the Oum ER-Rabia basin and is located in the Middle Atlas between longitudes 5°43' and 5°50' and latitudes 32°33' and 32°36'. It is a small basin with a surface area of approximately 176 km2 with a perimeter of 94 km, this basin is also characterized by significant relief (the maximum altitude is 2235m and the minimum is 663m).

Administratively, it belongs to the rural municipality of Ouaoumana in the Beni Mellal Khenifra region, this municipality is located 40 km from the town of Khenifra on national road no 8. Its administrative boundaries are as follows (Fig. 1):

- To the north: The commune of Aït Ishak and Sidi Lamine
- To the south: The municipality of Tizi Nisli
- To the east: The commune of Aït Ishak and Sidi Yahya Ousaad
- To the west: The commune of Ait Oum El Bekht

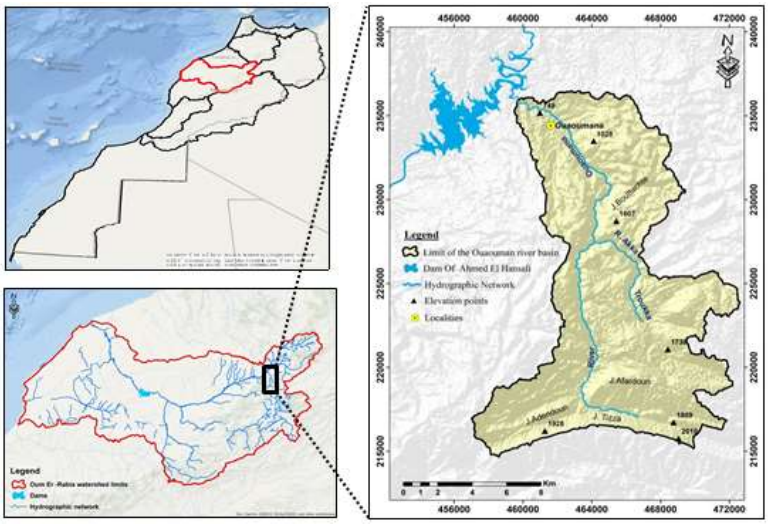


Fig. 1. Location of the Ouaoumana River basin

The studied area belongs to the Middle Atlas, which separates from the High Atlas in the Beni-Mellal region and extends in a north-easterly direction as far as Taza. The Middle Atlas comprises two different structural entities the "Tabular Middle Atlas", to the north-west. This is the limestone Causse, karstic plateau at an altitude of 1800-2000 m (Fig. 2), dotted with volcanic cones and recent flows, and the "Folded Middle Atlas", to the south-east. Synclinal basins are separated by ridge lines where the highest peaks are Jbel Tichoukt (2796 m), Jbel Bou-Iblane (3190 m) and Jbel Bou-Naceur (3340 m) (Piqué *et al.*, 1994). The Middle Atlas is a major component of the Moroccan terrain. It runs about 450 km from the southwest to the northeast and covers a total area of 27,550 km^2, which is 15% of the country's total mountain area. The Middle Atlas is 100 km wide in the North and only 30km wide in the south. In addition to its topographic boundaries (around 1,000 m), the Middle Atlas is characterized by the ubiquitous Jurassic, mostly limestone outcrops that makes this mountain the main water reservoir of Morocco, whose inputs are affected by ongoing climate change (El Jihad, 2016).

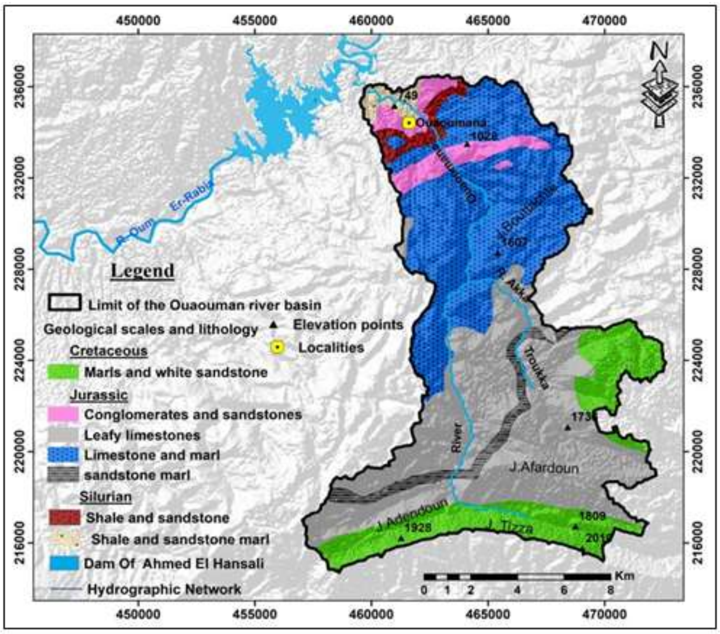


Fig. 2. Geology of the Ouaoumana River basin

The permeability factor is linked to the nature of the rock and plays an important role in hydrological studies. Permeable areas lead to an increase in infiltration, a decrease in runoff and the subsequent recharge of groundwater, and reduce the possibility of certain hydrological extremes (such as low water and flooding).

The zones formed by conglomerates and sandstones and the relief zones formed by foliated limestones are therefore the most favorable for surface water infiltration and therefore for groundwater recharge for 83%. The areas formed by white marl and sandstone and sandstone marl, plus the limestone and marl formations in the middle section, are moderately favorable (13%). The downstream part of the basin, formed by shales and sandstones and sandstone shales and marls, is unfavorable to infiltration (4%) (Figs. 3 and 4); so there is a dominance of permeable and non-permeable rocks, which play a very important role in infiltration.

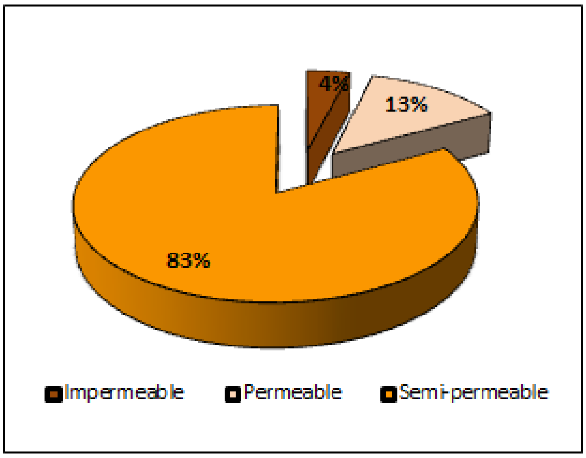


Fig. 3. Percentage of permeability of the Ouaoumana River basin

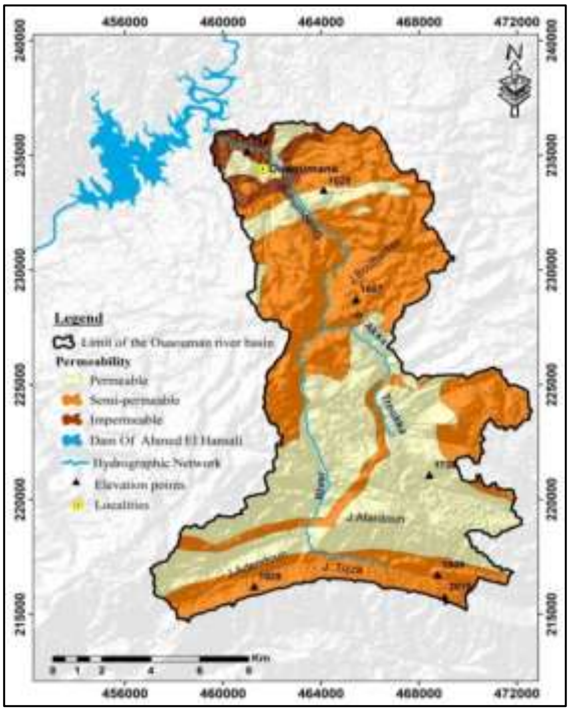


Fig. 4. Permeability of the Ouaoumana River basin

Materials and Methods

Hydrological profiles are a method based on spot monitoring of river flows at several points from upstream to downstream. Generally, the choice of measurements stations is based on the geology of the zone, the slope, the visits of area which shows several things (such as human extraction of water from the river), the distribution of the sources feeding the river, knowing that we chose other stations but their access was difficult (Elkbichi *et al.,* 2022).

We have selected (7) measurement stations distributed in the main stream from upstream to downstream (Fig. 5). These points are characterized by a wide variation in the natural parameters of the watershed, for example station (1) is located in the upstream part of the watershed and is characterized by a very strong slope which contributes to the acceleration of the flow, then stations (2, 3, 4, 5, and 6) which are located in the middle part of the watershed and are characterized by the presence of all the springs, and finally station (7) which is located in the watershed outlet.

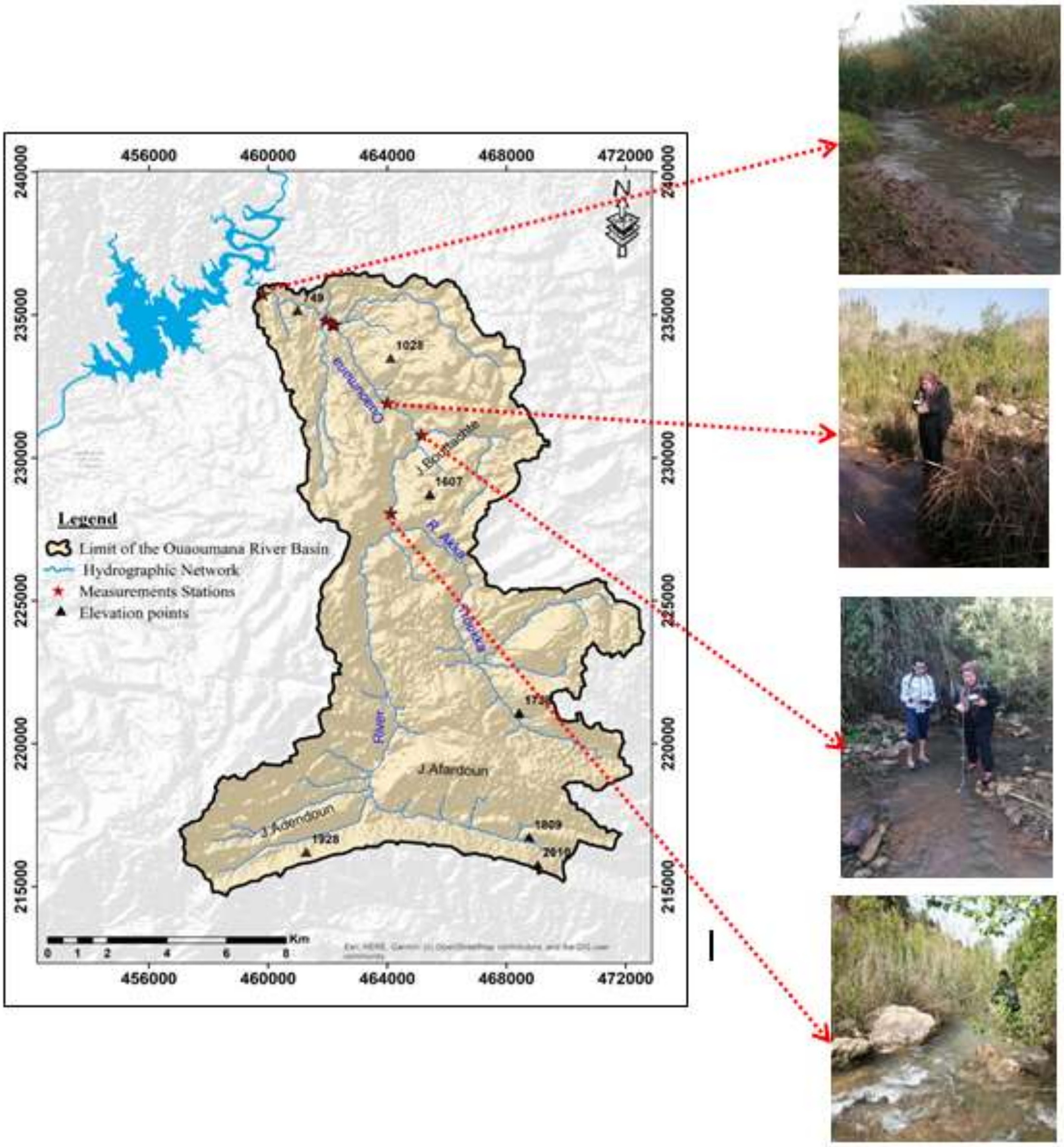


Fig. 5. Points of flow measurements in the Ouaoumana River basin

Measurement stations

There are several methods for measuring flow rates, which vary from one river to another depending on a number of criteria (such as flow velocity and depth). We chose a gauging method considering two criteria: the availability of suitable equipment, given our background in humanities and social sciences, and the fact that our study does not require sophisticated devices. We plan to carry out gauging during low flow periods, with low flow rates. We collaborated with a technician from The Oum Errbia River Basin Agency who has the necessary equipment. We opted for the complete gauging method with a micro-current meter (Photo panel .1). This approach involves measuring the flow depth using a rod, simultaneously measuring speeds with the micro-current meter, and determining the widths of the cross-section. By combining this data, we can calculate partial flows for each segment and determine the total flow (Ghadbane, 2024).


Photo panel. 1. Measurement of River flow using the micro-current meter

Data used

To create the hydrological profiles of the Ouaoumana River, we utilized the data produced in the field during several flow measurement campaigns over the period November 2021 - May 2022 (Table 1).

Table 1: Results of gauging campaigns (November 2021-May 2022)

Measurement stations / Date	station (1) Flow in (l/s)	station (2) Flow in (l/s)	Station (3) Flow in (l/s)	station (4) Flow in (l/s)	station (5) Flow in (l/s)	station (6) Flow in (l/s)	station (7) Flow in (l/s)
14/11/2021	52	70	49	43	24	53	60
19/12/2021	112	133	109	153	127	137	146
26/01/2022	47	56	37	35	46	39	52
20/02/2022	50	61	20	37	33	44	85
02/03/2022	45	49	30	31	29	40	68
01/04/2022	246	259	204	181	227	192	323
15/05/2022	178	238	170	153	178	173	201

Source: personal fieldwork

Result and Discussion

Monthly flow coefficient for the taghzoute station (1975-2018)

To determine the hydrological regime of the River Ouaoumana, we calculated the monthly flow coefficient using hydrometric data from the taghzoute station which is located downstream of the basin (X: 461400 /Y: 235500 /Z: 690) which has been awarded by the Oum Er rbia River Basin Agency and applied the following formula (Equation 1) (Layati *et al.*, 2024):

$$\textbf{monthly flow coefficient} = \frac{\textbf{Average monthly flow (1975} - \textbf{2018)}}{\textbf{Average flow (1975} - \textbf{2018)}} \qquad (1)$$

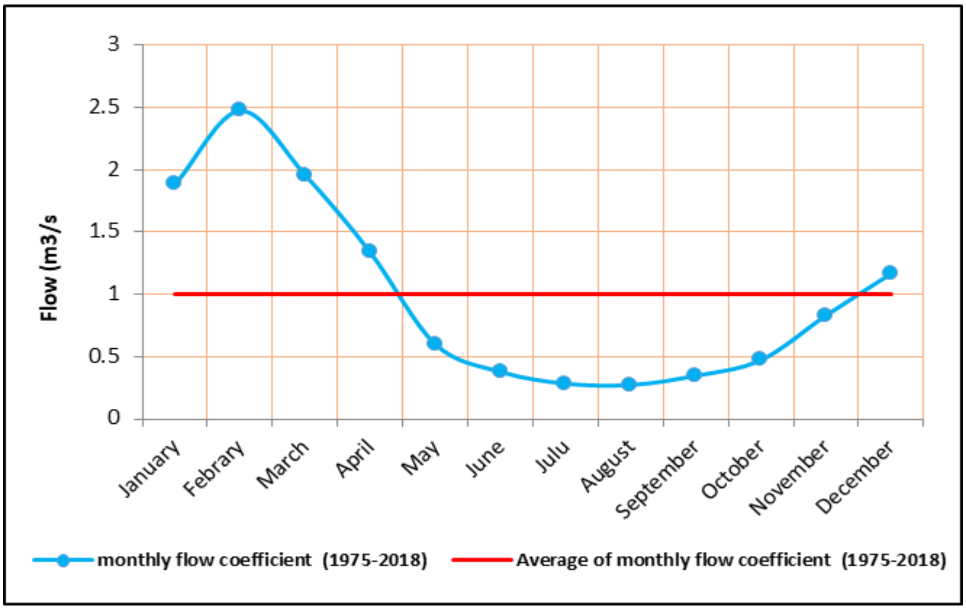


Fig. 6. Monthly flow coefficient at the Taghzoute station (1975 -2018)

Source: Oum Er Rbia River Basin Agency

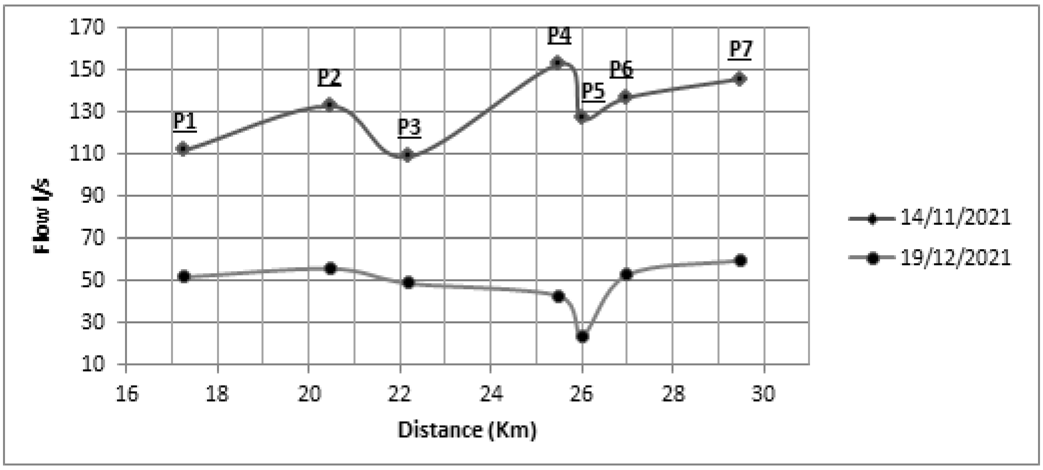
Analysis of the figure above reveals two periods:

The high-water phase: starts from December to April, with the highest value (2.47 m3/s) recorded in February, which shows that the high-water period generally corresponds to the winter and spring seasons.

The low-water phase: composed of 7 months, the low value of the flow recorded in August (0.27 m3/s) and this is due to the decrease in rainfall and the increase in evaporation.

Monthly hydrological profiles of the Ouaoumana River (November 2021-May 2022)

Hydrological profiles correspond to a curve-type graph showing the evolution of gross flows (l/s) and specific flows (l/s/km2) of the watercourse from upstream to downstream (with spatial criteria being the surface area of the catchment basin or kilometre points. These profiles show the flow of the main drain according to the emptying of aquifer reservoirs via tributaries, springs and groundwater-river exchanges (concept of draining or drained aquifer) (Lejeune *et al.,* 2004).



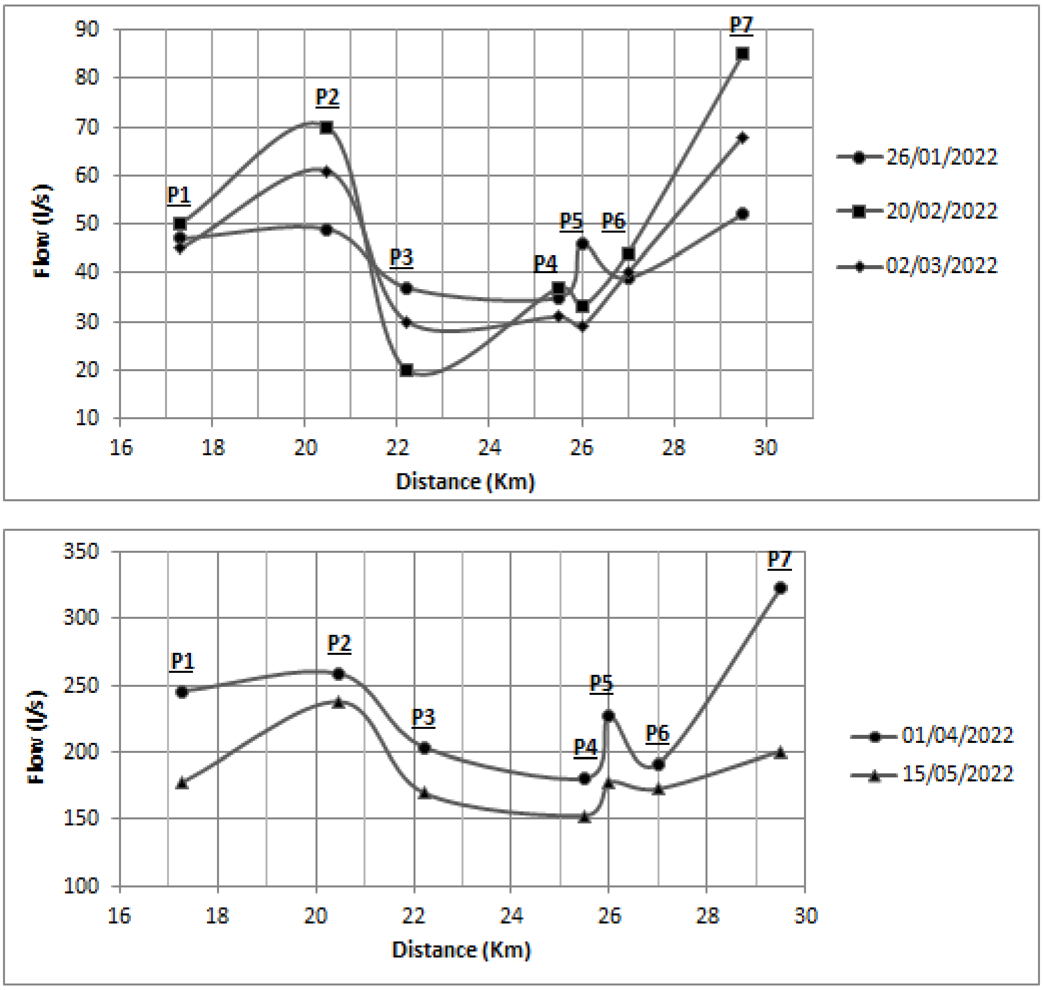


Fig. 7. Hydrological profiles of the Ouaoumana River in terms of gross flow from upstream (p1) to downstream (p7) (November 2021-May 2022)

Source: personal fieldwork

The hydrological profiles (Fig. 7) below are produced using data from 7 gauging campaigns (November 2021 May 2022). These profiles show the evolution of gross flows from upstream to downstream. There is a large variability in flows between the 7 gauging campaigns, and on a spatial scale there is heterogeneity of flows between upstream and downstream.

There is a great variation between the hydrological profiles, for example between January, April and May, the hydrological profiles have taken the same form in terms of distribution, with different flows from one profile to another and within the same profile from upstream to downstream. On the scale of the three profiles, the month April recorded the highest values, followed by the month of May, and the high flow of these months is caused by the melting of the snow, and on the scale of the 7 measurement points, point (7) recorded a high flow due to the fact that the inhabitants living in this area discharge wastewater into the River (Photo panel 2).

Photo panel. 2. Waste water in point (7)

A comparison of the hydrological profiles for November and December 2021 shows a large difference in flow. This is due to the transition from low water (November) to high water (December) according to the monthly flow coefficient.

The two hydrological profiles for February and March, which correspond to the period of high water, record low flows of between 20m^3/s and 85m^3/s due to high abstraction (Photo panel .3).

Photo panel. 3. Withdrawal of water from the Ouaoumana River for irrigation purposes

Conclusion

Hydrological profiles are an important tool for determining flow variations at different points along the river, and for quantifying and assessing the water resources currently available from 7 gauging stations.

The flows in the Ouaoumana River are highly variable both spatially and temporally. During our fieldwork, we noticed the presence of a group of springs which should help to feed and increase the valley's flow, but the inhabitants use this water for agricultural irrigation through a group of techniques such as motor pump, This also leads indirectly to the depletion of the water table and thus to a reduction in the flow of water into the river, and a high flow rate appears in the downstream part of the basin (station 7), due to wastewater expelled by local residents, resulting in surface water pollution, which will create major environmental problems in the future.

It can be concluded that the Ouaoumana River basin flow is characterized by a wide variation under the effect of several natural, hydrogeological and anthropic indicators.

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