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Hydromorphodynamic Sites in The Downstream Part of the Watershed of Assif Ghazzaf, Oum Er Rabia Basin in 2022: Natural Heritage Facing Conservation and Enhancement Constraints

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Abstract

This work focuses on the hydromorphodynamic heritage of the downstream area of the Oued Assif Ghazzaf watershed in Morocco, which is characterized by distinctive topographical, climatic, and hydrological features. This region experiences repetitive floods due to its steep slopes and colder, wetter climate. This dynamic activity gives rise to a multitude of morphogenetic conditions as well as a variety of hydromorphodynamic forms and processes, among which the most remarkable ones are worthy of being integrated into the tourist offering due to their picturesque value.

The study area covers the downstream part of the Oued Assif Ghazzaf watershed, where the river's flow is influenced by the surrounding environment, leading to a range of morphogenetic conditions and hydromorphodynamic forms. The geological context of the watershed is characterized by limestone formations, impacting water flow rates and storage capacity and landscapes.

The methodology involves evaluating hydromorphodynamic sites based on site identification, location, photographic presentation, site presentation, qualitative assessment, and more. The assessment considers dynamic, scientific, socio-economic, and sustainability values. The results show varying values for different sites, with a focus on understanding the dynamics, scientific significance, and socio-economic importance of each site.

Key sites include the Ifri-N-Nihmamn cave, Tizratin and Tissiliwin agricultural terraces, and Taghrot Spring, each contributing to the region's natural heritage and potentially offering tourist and educational opportunities. The study suggests integrating these sites into tourism circuits, creating informative signage, and adapting local dwellings for community-based tourism. Overall, the study emphasizes the importance of valuing and preserving the hydromorphodynamic heritage for both scientific exploration and tourism.

Keywords

Hydromorphodynamic sites, downstream part of the watershed Assif Ghazzaf, Cartography, Hydromorphodynamic method.

Introduction

Mountainous watersheds are among the watershed areas in Morocco that are not protected against floods. They possess distinctive topographical, climatic, and hydrological characteristics, including steep slopes and a colder, wetter climate compared to the plains. These factors result in repetitive floods over time and space, leading to a highly active dynamic.¹

This active dynamic gives rise to numerous morphogenetic conditions and a wealth of hydromorphodynamic forms and processes, with the most spectacular one's worthy of integration into tourist offerings due to their scenic value. These elements are part of our natural and cultural heritage, dynamic yet fragile. Therefore, they deserve recognition and protective measures.

Undertaking an inventory of hydromorphodynamic heritage is of great utility, as it forms the basis for protection and development policies by structuring space according to local constraints and synthesizing geomorphological and socio-economic data. This work contributes to defining the landscape identity of the studied area and constitutes a crucial tool for future territorial management.²

This project aims to inventory, evaluate, and map the Hydromorphodynamic sites in the downstream area of the Oued Assif Ghazzaf watershed, from various perspectives: scientific, dynamic, and touristic. Its primary objective is to contribute to an in-depth reflection on natural heritage and to enhance the overall recognition of the "fluvial geomorphology" discipline. The project also involves experimenting with a new method tailored to the specific characteristics of river hydrodynamic functioning, inspired by the method developed by E. Reynard et al. at IGUL (Institute of Geography, University of Lausanne).

1. Study Area Description

1.1. Location of the downstream part of the Oued Assif Ghazzaf watershed

The watershed of Wadi Assif Ghassaf is one of the mountainous sub-basins within the Oued Oum Er Abia watershed, situated in the Central High Atlas. It is located 15 km east of Demnate and is bordered to the west by the watershed of Wadi Mhasser. Wadi Assif Ghassaf serves as the main tributary of Wadi Lakhdar and covers an area of 577 km², with the river Assif Ghazzaf spanning a length of 35 km. The watershed of Wadi Assif Ghassaf is characterized by its elongated shape,

¹ الغاشي محمد، إدالي محسن & لولو نادية (2014). الخصائص المورفومترية للأحواض الجبلية ودورها في السلوك الهيدرولوجي لحوض أسيف غزاف بالأطلس الكبير الأوسط (جبهة تادلة ازبال، المغرب) *International Journal of Environment & Water* ISSN 2052- 3408, Vol 3, Issue 6, 2014. "حالة الإمتطاح الفيضي لسنة 2009

² Boukhallad M., El Khalki Y. & Mostapha A. (2022). Les Géomorphosites des Communes Rurales Aglmam Azegza et Oum Rbiaa: Potentialités Naturelles et Culturelles Face aux Contraintes de la Sauvegarde et de l'Intégration Touristique. *Européen Scientific Journal, ESJ*, 18 (35), 124. <https://doi.org/10.19044/esj.2022.v18n35p124>

stretching through the central region of the Central High Atlas. It flows from south to north and is bounded to the west by the Wadi Mhasser watershed, which is the primary tributary of Wadi Lakhdar. The flow of Wadi Assif Ghassaf is significantly influenced by the surrounding environment, allowing it to faithfully reflect the characteristics of its watershed, which covers an area of 577 km².³

The studied area encompasses the downstream part of the watershed, extending from the north to the village of Ait Segmine. Here, the slopes increase in intensity, and elevation rises further, accelerating the flow of water. The main course of Wadi Assif Ghazzaf converges with Wadi Ait Zyad, resulting in an increased water flow, thus introducing another form of fluvial dynamics. This region concludes near the confluence with Wadi Lakhdar to the south and falls under the territorial authority of the rural commune of Sidi Boukhalif and Ait Majden.

³ Lagni A. Elouiazzani A. Yazini A. et Elghachi M. (2023): Caractérisation de la morphologie fluviale dans la partie médiane du bassin versant d'Oued Assif Ghazzaf: Cartographie et identification des lits fluviaux. Revue International de la recherche scientifique Vol. 1, No. 4, Août 2023. (DOI): <https://doi.org/10.5281/zenodo>.

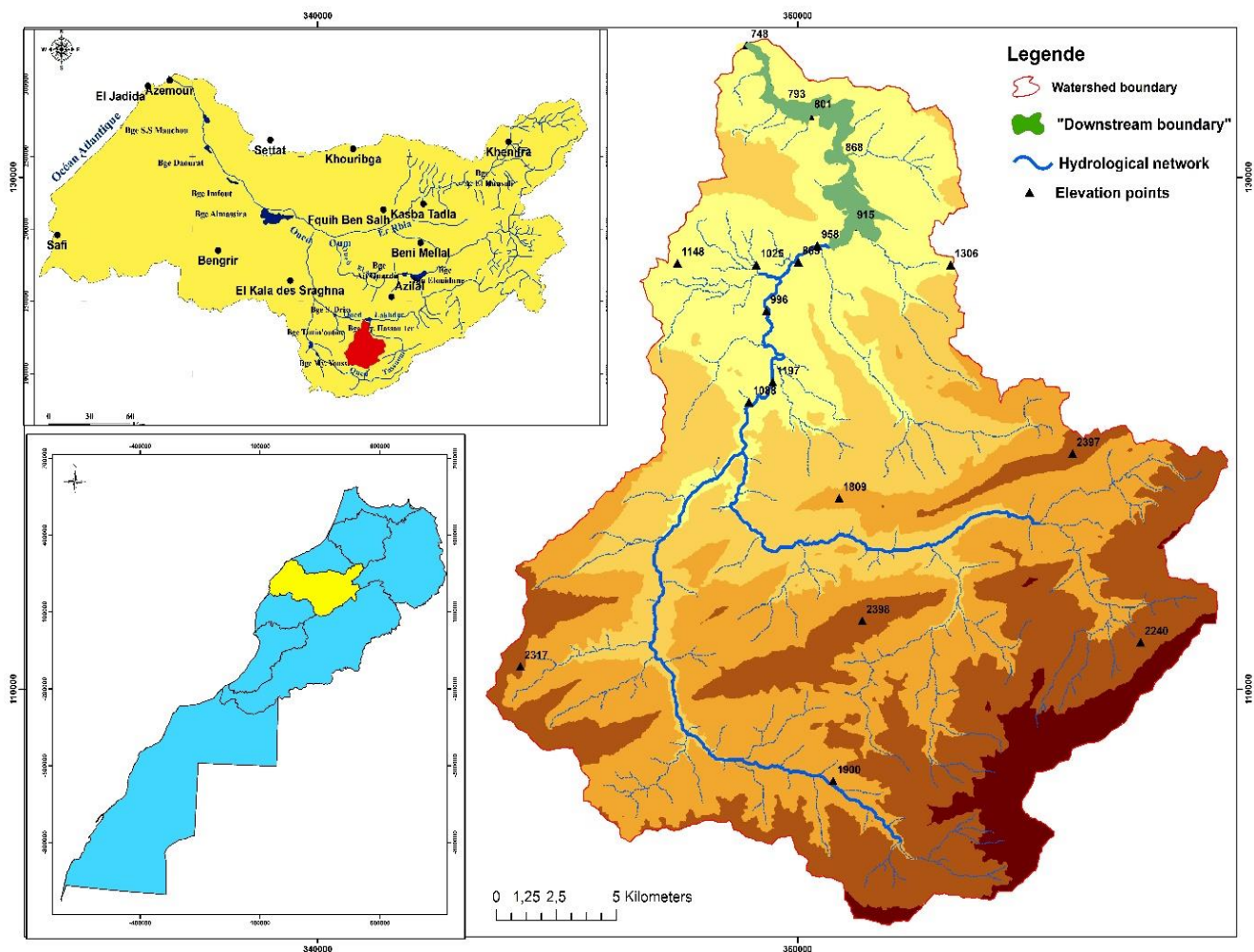


Figure 1: Location of the Wadi Assif Ghazzaf Watershed and Position of the Downstream Areal.

1.2. Hydroclimatic Situation of the Study Area:

1.3. The data concerning variations in annual total precipitation for the period studied in this research reveal irregularities in rainfall from one year to another. The year with high rainfall recorded more than 800 mm at the Ait Segmine station in 2004.

The years of low rainfall, marked by the following values: 1983, 1990, 1992, 1998, 2001, and 2017, experienced annual rainfall below 300 mm.

This variability has highlighted dry or wet trends in the period from 1971 to 2017.

According to Figure n, we observe:

- A difference of 700 mm between the wettest year (880 mm in 2004) and the driest year (180 mm in 2017).

- A difference of 370 mm between the wettest year and the average.
- A difference of 530 mm between the driest year and the average.

In conclusion, the variability in precipitation reveals dry or wet trends in the period from 1971 to 2017.

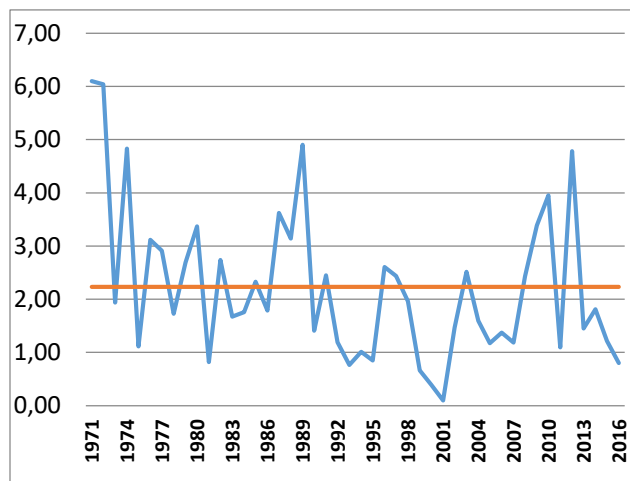


Figure 2: Average annual discharge at the Ait Segmine station (1971-2015)

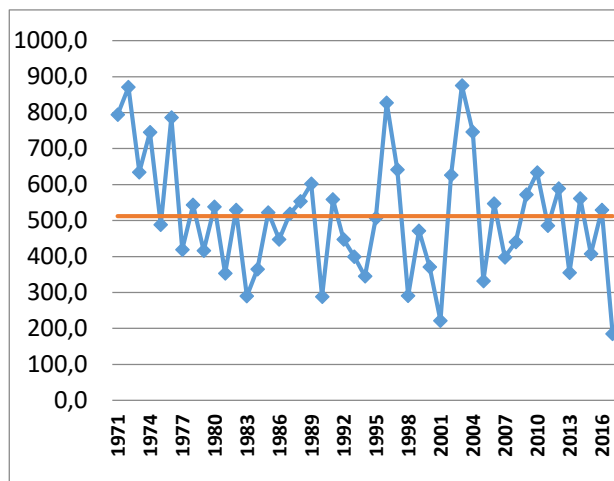


Figure 3: Annual precipitation at the Ait Segmine station compared to the average (1971-2017)

Figure N° 3 illustrates an irregular annual variation observed at the Ait Segmine station, located at the heart of the study area. The data covers a 44-year period from 1971 to 2015, with an average discharge of 2.2 m³/s over this period. Significant variability in the average discharge also characterizes year-to-year variations.

During the periods of 1971-1972 and from 1989 to 2013, elevated discharges are noticeable, reaching a maximum of 6.10 m³/s in 1971. A peak is also observed in 1989, with a discharge of approximately 4.90 m³/s, which contributes to the occurrence of flood events.

1.4. Geological Context of the Watershed

From a geological perspective, the watershed of Wadi Assif Ghazzaf is part of the limestone Central High Atlas, characterized by a topography marked by a series of anticlines and synclines, interspersed with narrow and deep valleys (Missenard, 2006). Furthermore, the underlying lithological diversity plays a crucial role in determining water flow rates.⁴

⁴ Legates D. et Willmott J. (1990) : Mean seasonal and spatial variability in global surface air temperature, Theor. Appl. Climatol., 41:11-21.

The hydrogeological characteristics of the subsurface are closely related to the thickness and lithological nature, which determine water storage capacity.⁵ The watershed of Wadi Assif Ghassaf is primarily composed of sedimentary sequences ranging from the Paleozoic to the Quaternary, starting with the Ordovician of the Praguian OI stage, with gaps in the Silurian series of the primary era and the entire Tertiary period. The main Quaternary deposits have accumulated at the valley bottom, including various stages of the Moroccan Continental Quaternary, such as the Rharbien and Soltanian, present in the middle part of the watershed along Wadi Assif Ghassaf.

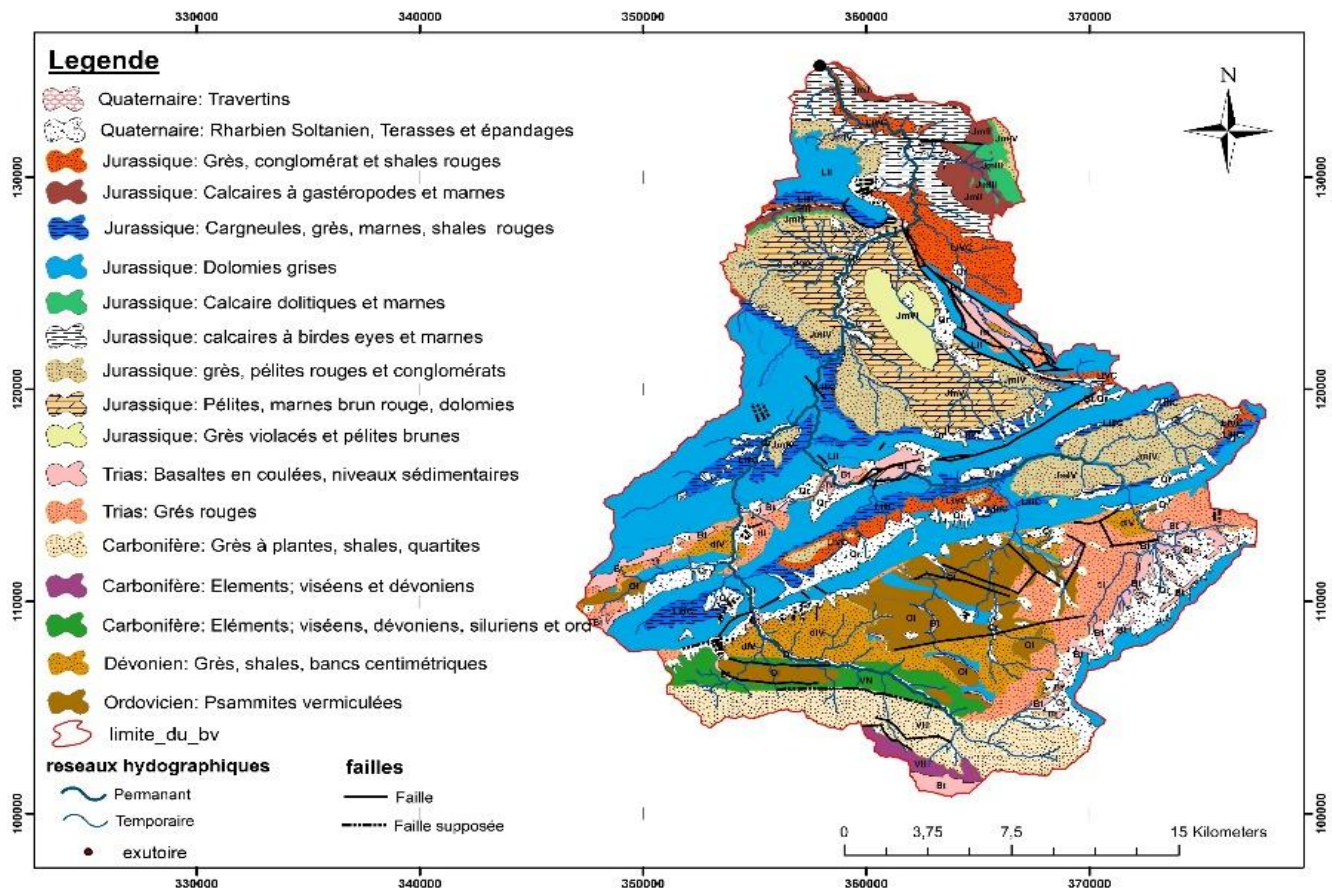


Figure 4: Geological Map of the Watershed of Wadi Assif Ghazzaf

2. Problematic:

The Assif Ghassaf watershed is considered one of the unmanaged mountainous sub-basins, characterized by high altitudes and steep slopes, as well as irregular and spatially variable

⁵ Souhel .A. (2001) : Haut Atlas Central, partie nord-ouest North-western Central High Atlas, éditions du service géologique du Maroc, Rabat,106 p.

precipitation intensity over time. This irregularity exacerbates hydrological events that accelerate the dynamics of watercourses, along with climate changes that amplify the occurrence of extreme phenomena such as floods and inundations.

As a result of these factors, the fluvial dynamics in the Assif Ghassaf River become highly active, leading to various spectacular fluvial forms involving erosion, transportation, and deposition. Among these forms, there are sites referred to as "hydromorphodynamic sites" that hold scientific, ecological, economic, and other types of significance. Our focus is on identifying, mapping, and valorizing these hydromorphodynamic sites.⁶

3. Objectives:

The general objective of this work aims at enhancing the value of hydrogeomorphological heritage and its sustainable scientific and touristic integration. To achieve this goal, it is necessary to address the following specific objectives:

- Create an inventory of hydromorphodynamic sites in the downstream area of the Assif Ghazzaf watershed and establish a list of these sites.
- Evaluate the hydromorphodynamic sites using a specific method.
- Identify existing and potential threats to the hydromorphodynamic sites.
- **Theoretical and Methodological Framework:**

3.1. Hydromorphosites:

Or sites Hydromorphodynamic are landforms found either within the riverbed or in the floodplain, which have acquired scientific, cultural, historical, aesthetic, and/or socio-economic and/or ecological value. These features belong to our natural and cultural heritage, often being insufficiently understood, dynamic, and fragile. For these reasons, they warrant recognition, awareness of their significance (both by the public and authorities), and protective measures.

3.2. Hydromorphodynamic Approach:

Based on the discussion of the two methods (OFEV, IGUL), we have proposed a new method for its use in our subsequent evaluation. This choice was not arbitrary; we have several reasons rooted in the specific objectives of our study, which can be summarized as follows:

As the ultimate goal of our study, we aim to integrate sites that result from fluvial dynamics, which necessitates considering all aspects of dynamics (morphogenesis, form, hydrology, location, topography, vegetation, etc.).

⁶ Reynard E. (2005). Paysage et géomorphologie: quelques réflexions sur leurs relations réciproques », In: Droz Y., Miévilleott V., La polyphonie du paysage, presses polytechniques et universitaires vomandes, Lausanne, 101-124.

In our inventory, we work at the valley and river scale where we aim to promote geotourism of the region through educational and/or tourist circuits, as well as suggesting agricultural utilization. Therefore, the obtained sites will be evaluated separately, which is not available in the OFEV and IGUL methods.

3.3. Cartography:

In the geographical domain, cartography is the essential tool for presenting information. In the basin of the Assif Ghazzaf River, information was collected during field trips conducted during the low-water period of the year 2022 when the phenomena in the minor channel are visible, which is not the case during the high-water period (when the channel is filled).⁷

3.4. Methodology:

The methodology for evaluating Hydromorphosites is based on the use of an inventory form divided into 5 sections, each containing several sub-criteria (Table N1):

Table 1: Inventory Form for Hydromorphodynamic Sites

Sections and Criteria	Sub-criteria
1. Site Identification	Code, Site Name, Location, Altitude, Site Ownership, Coordinates, Site Shape
2. Site Location	Hydrological Location, Topographical Location, Geological Location, Administrative Location
3. Photographic Presentation	A panoramic view of the site using Google Earth images, on-site photographs of the site.
4. Site Presentation	<ol style="list-style-type: none"> 1. Topographical Presentation 2. Lithology, Geology, and Structural Presentation 3. Topography Presentation 4. Hydrological Presentation 5. Hydromorphodynamic Functioning 6. Site usage

⁷ Lagni A. Elouiazani A. Yazini A. et Elghachi M. (2023) : Caractérisation de la morphologie fluviale dans la partie médiane du bassin versant d'Oued Assif Ghazzaf : Cartographie et identification des lits fluviaux. Revue-IRS, ISSN: 2958-8413 Vol. 1, No. 4, Août 2023.

5. Qualitative Assessment	Dynamic Values
	1. Location Value
	2. Morphology Value
	3. Vegetation Value
	Scientific Values
	1. Representativeness Value
	2. Rarity Value
	Socio-economic Values
	1. Aesthetic Value
	2. Economic Value
	3. Social Value
	Sustainability Values
	Vulnerability Assessment
	Management

4. Results and Interprétations:

We considered several values for the selected hydromorphosites, but our primary focus was on dynamic, scientific, socio-economic, and sustainability values, as our objective is the integration of this heritage for both tourism and scientific purposes.

The inventory of hydromorphodynamic sites in the Wadi Assif Ghazzaf has enabled us to establish a database of the region's natural heritage and to pinpoint these sites using cartographic techniques. Furthermore, the evaluation of these hydromorphodynamic sites was conducted using the Hydromorphodynamic method, thereby paving the way for the appreciation and integration of the area's natural heritage for tourism and educational purposes.

Table 2: Presentation of Hydromorphodynamic Sites in the Downstream Area

N°	code	Site name	Coordinates		Location
			X	Y	
1	Ifr-Gro-1	Cave d'Ifri-Nihmamen	362279	127930	Downstream Part of the Watershed
2	Tis-Ter-2	Tissiliwin Agricultural Terrace	361839	129621	
3	Tag-Sou-3	Taghrout spring	361771	13184	
4	Tiz-Ter-4	Tizratin Agricultural Terrace	358718	13438	

4.1. Inventory and Mapping of Hydromorphodynamic Sites in the Downstream Part of the Assif Ghazzaf Watershed

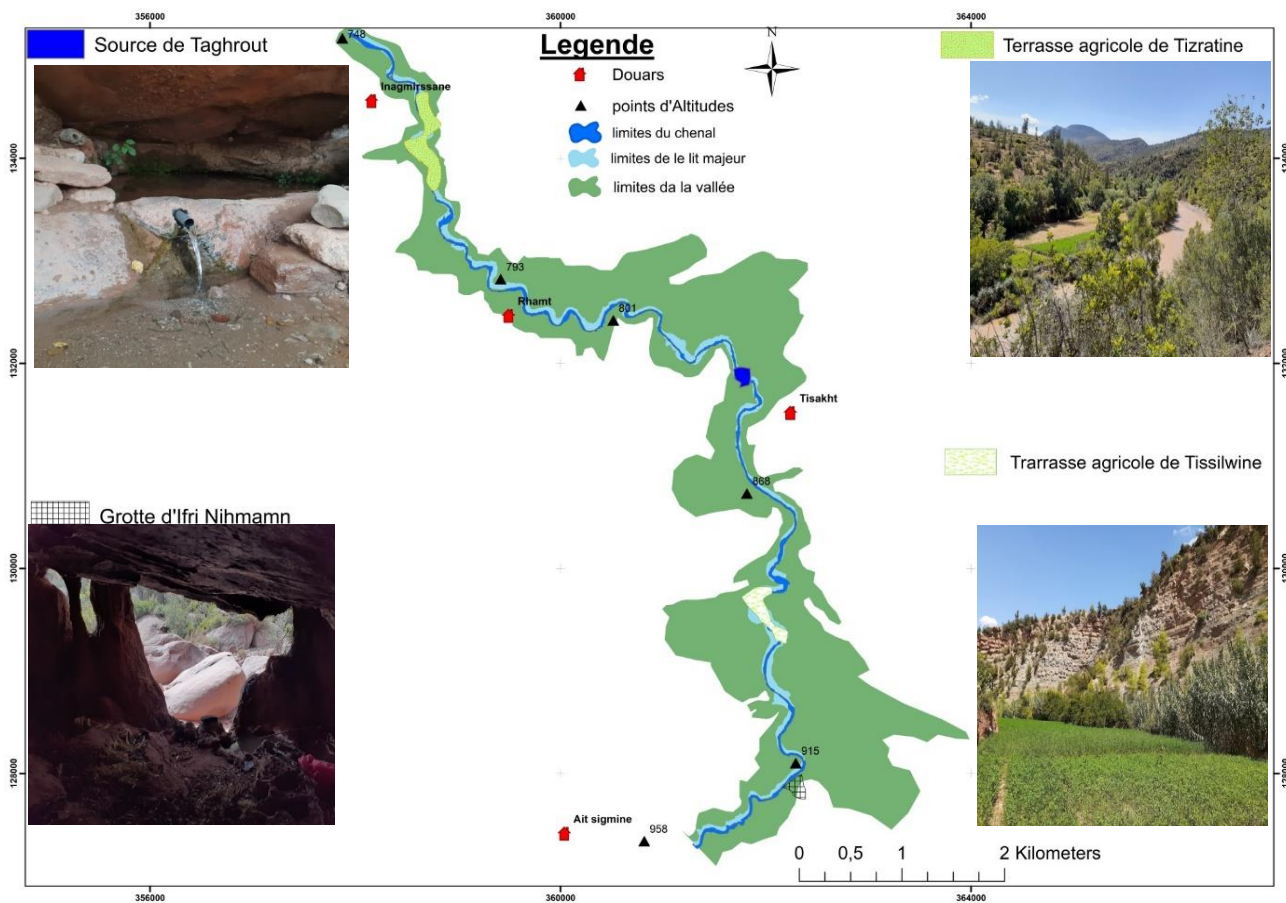


Figure 5: Hydromorphosites of the Middle Part of the Watershed

4.1.1. Cave d'Ifri-Nihmamen:

The site consists of a spectacular cave on the bank of Wadi Assif Ghassaf on the left side, at an altitude of 910 meters. This irregularly shaped cave covers an area of 30 m². The Ifri-N-Ihmamn cave is the result of karstic dissolution that enlarges the discontinuities present in limestone and other karstifiable rocks, such as dolomitic limestone and dolomite.

These discontinuities can be stratification joints. The excavation process of this cave is primarily influenced by the flow regime that prevailed during its formation, where phreatic conduits were carved in a zone below the water table pressure. This characteristic results in a specific morphology, characterized by more or less horizontal galleries. In this case, the water's work is not guided by gravity.



Photos 1. Cave of Ifri Nihmann

➤ Site Usage :

This site holds significant landscape and tourist appeal for the local population. The cave attracts around a hundred visitors annually, especially during the warmer seasons.

4.1.2. Tizratin Agricultural Terrace :

The Tizratin agricultural terrace covers an area of 2000 m² and is traversed by the Assif Ghazzaf stream with a gentle slope. The site is located in the proximal zone of the confluence between the Assif Ghazzaf and Oued Lakhdar, at an altitude of 773 meters.

The studied site represents a fluvial system with meander-form networks. Sedimentation occurs on the convex bank, creating a meander bar. This bar extends laterally as the meander migrates; a process known as lateral accretion. It is primarily composed of sand arranged in large-scale, oblique bedding, while the channel bottom is covered with pebbles.

Water generally flows through a single channel, but due to the dynamic nature of the system, this channel undergoes significant shifts, following a undulating trajectory. Sedimentation presents fine deposits and well-developed sequences, providing good agricultural opportunities for the local population.



Photos 2: Tizratin Agricultural Terrace

➤ **Site Usage:**

The geomorphological dynamics of this alluvial area are crucial for the development of vegetation, fruit orchards, market gardening, and pastures, which bestow upon this zone a highly valuable economic significance.

4.1.3. Tissliwine Agricultural Terrace :

Located in the downstream part of the watershed within the municipality of Ait Majdene, this site covers an area of 600 m² and is traversed by the Assif Ghazzaf stream with a gentle slope at an altitude of 889 meters. The site in question represents a fluvial system composed of meander-form networks. Sedimentation occurs on the convex bank in the form of a meander bar. This bar grows laterally as the meander migrates; a phenomenon known as lateral accretion. The bar is composed of sand arranged in large-scale oblique bedding, while the channel bottom is covered with pebbles.

Water generally flows through a single channel, but the dynamic nature of the system leads to significant shifts in the channel's position along a undulating trajectory. Sedimentation is characterized by fine deposits and better-developed sequences, thus offering favorable agricultural opportunities for the local population.



Photos 2: Tissiliwin Agricultural Terrace

➤ **Site usage :**

The geomorphological dynamics of this alluvial area are significant for the development of vegetation, fruit orchards, market gardening, and pastures, which bestow upon this zone a highly valuable economic significance.

4.1.4. Taghrout Spring:

The site consists of a spectacular cave on the bank of the Wadi Assif Ghazzaf on the left side. The site is located in the downstream part of the watershed. This irregularly shaped cave covers an area of 30 m². The Tisgui Spring is located on the left bank of the Wadi Assif Ghazzaf. The source's underground water supply originates from a single main source, which is the underground aquifer, resulting in a constant flow of water from the spring.



Photos 3. Taghrout Spring

➤ **Site usage:**

In the past, the water from the Taghrot Spring was fresh and had long served as a source of drinking water and irrigation during the dry seasons for most of the surrounding villages (Douars). However, recently, all the Douars have been connected to potable water supply networks managed either by potable water associations or rural municipalities. As a result, the use of this spring has diminished, except in exceptional cases such as potable water supply issues or for agricultural purposes.

4.2. Evaluation of Hydromorphodynamic Sites in the Downstream Part of the Oued Assif Ghazzaf Watershed:

Following the inventory of hydromorphodynamic sites in the Oued Assif Ghazzaf watershed, we will proceed with the synthesis of the obtained results. This synthesis will involve an in-depth discussion covering various perspectives, considering multiple criteria such as dynamic, scientific, socio-economic, and sustainability values. Additionally, we will include proposals aimed at enhancing the natural heritage of the area.

4.2.1. Dynamic value:

Dynamic values play a minor role in the assessment of hydromorphodynamic heritage. However, they provide valuable opportunities for understanding the characteristics of each site and their behavior in relation to watershed functioning.

The dynamic value is obtained by calculating the average scores of six sub-criteria: location, morphology, hydrology, vegetation, lithology, and topography.

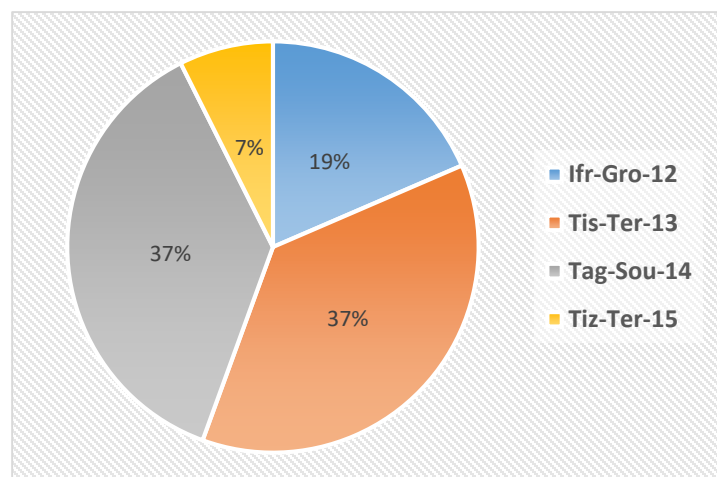


Figure 6. The dynamic value of the studied sites

Based on the above figure, we can conclude that the dynamic value of hydromorphodynamic sites in the study area is generally moderate, as two sites have exceeded the average (Tissiliwin and Taghrot, both at 37%). However, two sites exhibit relatively low values. The significance of the dynamic value for most selected sites is associated with a highly active current dynamic in the downstream part of the Oued Assif Ghazzaf watershed.

4.2.2. Scientific Value:

Scientific value is based on two main criteria: representativeness and rarity. These criteria are used to assess hydromorphodynamic features and appreciate their significance from a hydrodynamic perspective.

As mentioned earlier, the hydromorphodynamic sites were selected considering four criteria: scientific value, dynamic value, socio-economic value, and sustainability. Therefore, it is quite natural for the scientific value of the sites to be generally high.

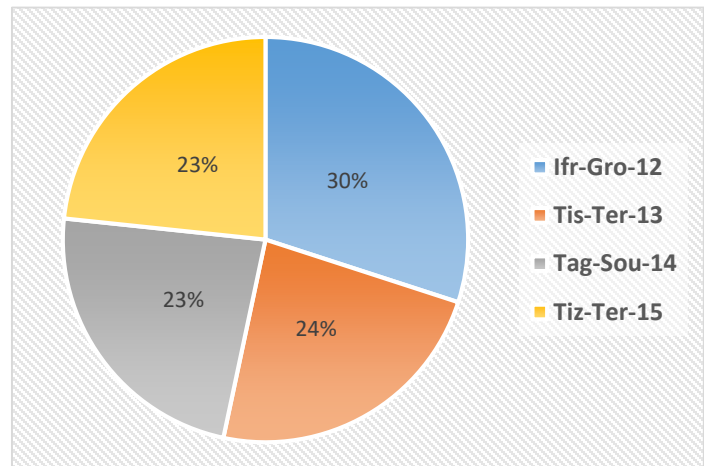


Figure 7. The scientific value of the studied sites

4.2.3. Socio-Economic Value :

The inventory and assessment of hydromorphodynamic sites have diverse objectives. However, socio-economic values play a minor role in the evaluation of hydromorphodynamic heritage.

Nevertheless, they allow for the integration of other interests that may be associated with each landscape. These additional values can be grouped into three categories: aesthetic, economic, and social.

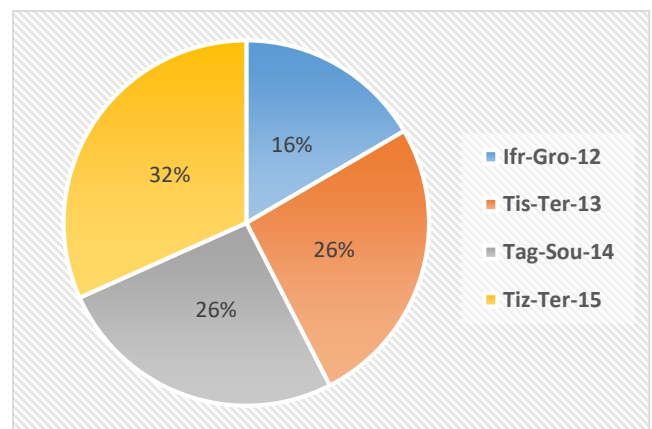


Figure 8. The socio-economic value of the studied sites

In the following passage, we will present the three socio-economic values for all the selected sites. According to the above figure, it can be observed that the socio-economic value is on average.

4.2.4. The value of sustainability :

This section aims to synthesize the key characteristics of the studied site, highlighting the risks that could alter the site. Furthermore, it assesses the sustainability of the site using site-specific measures of vulnerability and planning.

According to the above figure, it can be concluded that the value of sustainability of the hydromorphodynamic sites in the study area is moderate. The Tizratine site accounts for 42% of the socio-economic values.

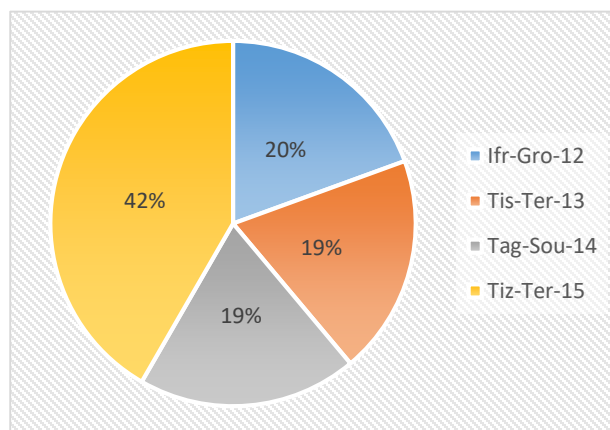


Figure 9. The value of sustainability of the studied sites.

4.2.5. Global Synthesis :

After evaluating the listed Hydromorphodynamic sites and analyzing the results of this assessment, several overall conclusions can be drawn:

- ✚ The dynamic value is generally high for all sites in the study area, particularly concerning the criteria of representativeness and rarity.
- ✚ Regarding sustainability values, the average remains low for each site compared to the scientific and dynamic value. This phenomenon can be attributed to a lack of planning and the absence of protection for this natural heritage.
- ✚ Some sites, such as the areas around Ifri Nihmann cave, hold significant ecological and geomorphological importance. They will serve as a foundation for any future development within the framework of the Khénifra National Park in terms of ecology.
- ✚ Lastly, the most remarkable Hydromorphosites in terms of scientific, aesthetic, and ecological significance will form a database for proposing tourist and scientific circuits.

4.3. Valorization of the Hydromorphodynamic Sites of Wadi Assif Ghazzaf:

Creation of forest campsites around the most characteristic and spectacular sites in the lower part of the Assif Ghazzaf watershed. In this regard, we propose the Agricultural Terrace of Tissliwine. For hikers, we suggest establishing a network of pedestrian trails and campsites, connecting all the sites in the lower part of the watershed.

In the educational realm, we propose integrating a school subject into the region's schools, focusing on the local heritage. The hydromorphodynamic sites will be the central theme of this subject, aiming to instill a sense of ownership of this heritage among the new students, who represent the generations of the future.

From the sites identified in this inventory and assessment, we recommend creating informational signage using written content and visual aids to educate visitors about the sites and draw attention to factors that could contribute to their degradation.

Adaptation of a few local dwellings along the proposed circuits for use as guesthouses in the realm of community-based tourism, coupled with training for their owners in this area.

Conclusion:

The inventory of hydromorphodynamic sites within the watershed of Wadi Assif Ghazzaf has enabled us to establish a database of the natural heritage within the study area. Simultaneously, the assessment of all hydromorphodynamic sites using a novel method proposed in this study has paved the way towards the valorization and integration of the hydro-morphodynamic heritage for tourism and education purposes within the area. The identified hydromorphosites possess various values: dynamic, scientific, and socio-economic. The scientific and aesthetic values particularly encourage the integration of this heritage into tourism and scientific exploration, fostering its appreciation and utilization.

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