



TOWARDS THE CREATION OF NEW OASES ALONG THE WADIS

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ABSTRACT

It is a paradox: why do we fail to take advantage of the prime agricultural land that Mother Nature has placed at our disposal? These are the soils found in the floodplains of the wadis, a vast, dense river network that remains unexploited. Yet, agricultural land is shrinking, sacrificed to urbanization that is accelerating in the wake of rapid population growth. The answer lies in the Sahara, as the oasis dwellers who lived in harmony with flash floods were the first to cultivate the soils of the wadis' floodplains. Between 1990 and 2026, we conducted fieldwork across the oases of the Algerian Sahara. Surveys and interviews were carried out with oasis inhabitants regarding sustainable water management and its impact on oasis agriculture. The study reveals that Algeria possesses a very dense hydrographic network, particularly within the Sahara. It also shows that, despite a climate hostile to life, farmers developed oases along the wadis. They succeeded in integrating the wadi and the oasis into a single unit, creating a unique ecosystem powered by flash floods: the active river channel ensures water security, while the floodplain ensures food security. So why not create new oases along the wadis today, thereby adapting to climate change? Flash floods are an invaluable gift from nature, replenishing the alluvial aquifer to allow for year-round irrigation. Moreover, these floods inundate gardens with nutrient-rich waters a natural fertilizer for agricultural land. Sustainable water management requires the construction of hydraulic structures such as subsurface dams, recharge dams, sand dams, and aquifer recharge stations.

Keywords: Oasis, Wadi, Sahara, Hydro-agricultural development, Water, Floodplain.

INTRODUCTION

The global population has surpassed 9 billion, yet the 90,000 km² of arable land has not kept pace with this growth. Climate change has a significant impact on soil erosion; indeed, following a prolonged drought, torrential rains lash down on parched, crumbling soil, and the runoff carves out small gullies (Remini, 2023; Remini, 2025a). In a second stage, and in the absence of soil conservation methods, these small channels widen to become large gullies. At this stage, it becomes difficult to develop such land, effectively "lost" land. Furthermore, we are currently seeing a resizing of drainage networks to handle flash floods. Wadi channels widen, and new tributaries and gullies form, following every flash flood. These processes occur at the expense of agricultural land (Remini, 2023). It is also worth noting that erosion destroys agricultural land, causing the soil to lose its fertility and productivity. Erosion destroys the topsoil or arable layer of agricultural land, which is rich in organic matter. It also leads to the loss of essential minerals such as nitrogen, phosphorus, and potassium, thereby affecting soil productivity. One consequence of accelerating climate change that threatens agricultural land is the encroachment of the Sahara Desert toward northern Algeria, endangering the fertile soils of the High Plateaus. Another issue stemming from Algeria's rapidly growing population which has now reached 47 million is the rapid urbanization and expansion of cities at the expense of fertile agricultural land. The Mitidja Plain, for instance, is globally renowned as a prime example of highly fertile agricultural land. Located in northern Algeria, the Mitidja Plain covers an area of 1,300 km² (Driouche et al., 2019); residential development there evolved from colonial-era villages and has recently expanded to include private housing estates and high-rise developments (Boustila, 2023). However, in recent years, thousands of hectares of Algeria's most fertile land have been swallowed up by concrete, to the detriment of agriculture. The use of saline irrigation water, combined with high evaporation rates and poor drainage, leads to soil salinization. This phenomenon severely degrades soil quality and reduces fertility. Oasis management relies on the proper handling of both water and agricultural land. While these oases once functioned as well-balanced hydraulic systems, some now suffer from an excess of water. The Ouargla oasis considered one of the most important in the Algerian Sahara is a case in point, suffering from water surpluses. Such conditions give rise to harmful issues, particularly soil salinization, which accelerates the degradation of agricultural land. All these natural and human-induced factors contribute to a reduction in fertile soil, thereby complicating food security. Algeria has recently launched major agricultural projects in the Sahara; vast tracts of new farmland have been developed in the middle of the desert, with the Souf region serving as a notable example. The people of the Souf region have taken a different path today. Every day, the area of new agricultural land expands at the expense of the sands of the Grand Erg Oriental, which recede as bulldozers advance. This article addresses a novel topic regarding the search for new agricultural land. It directly answers a question we have been asking for over a decade: "Why are no new oases being created?" It is worth recalling the importance of these ecosystems; oases play a highly strategic role in arid zones areas that, despite housing only 0.1% of the global population, manage 30% of the Earth's land surface (Clouet, 1995). Furthermore, the oasis plays a vital role in climate regulation, agricultural production, and the preservation of human and animal life

in a hyper-arid environment like the Sahara. Finally, the oasis is the only ecosystem that has managed to maintain a balance however fragile between resource availability and societal needs. Despite the arid environment and extreme climatic conditions, oasis communities have developed production practices that preserve natural resources, making the oasis an atypical example of sustainable development in drylands (FAO, 2019). Moreover, as a wetland, the oasis plays a crucial role in climate change mitigation and adaptation, creating a microclimate while preserving biodiversity and the dryland environment. Consequently, multiplying oases across the Algerian Sahara represents a large-scale adaptation project capable of transforming the desert's character. Developing new oases in the Algerian Sahara is both our dream and our goal; this article specifically discusses the creation of new oases along the wadis.

STUDY AREA AND METHODOLOGY

Presentation of the study area

The Sahara the planet's largest and most beautiful hot desert covers an area of over 8.5 million km² in the north of the African continent. It spans eleven countries: Algeria, Mali, Mauritania, Niger, Tunisia, Morocco, Sudan, Chad, Libya, Egypt, and Western Sahara. The Sahara's landscape comprises ergs, plateaus, regs, hamadas, lakes, wadis, rocky massifs, sebkhas, chotts, and gueltas. Additionally, hundreds of oases are found throughout the region. Sandy areas specifically the dune fields known as ergs account for only 1.7 million km², or 20% of the Sahara's total surface area. Rocky massifs cover 820,000 km², representing 10% of the Sahara's area (Remini, 2021). However, the majority of the Sahara consists of regs flat, stony expanses.

Algeria is located in the north of the African continent, covering an area of 2.34 million km² and sharing borders with seven countries and the Mediterranean Sea. To the north, it is bordered by the Mediterranean Sea along a 1,600 km coastline. To the west, it shares a 1,000 km border with Morocco and an 800 km border with Western Sahara. To the south lie Mauritania (400 km border), Mali (1,000 km border), and Niger (1,000 km border). To the east, it is bordered by Tunisia (600 km) and Libya (1,000 km) (Fig. 1).

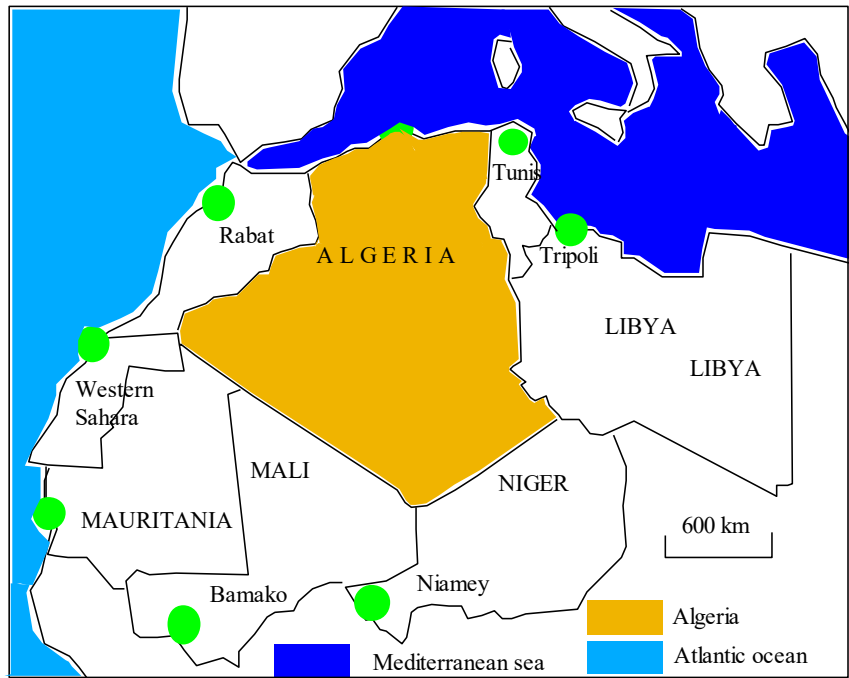


Figure 1: Geographical location of Algeria (Remini, 2025b)

Two distinct parts of Algerian territory can be identified: the north and the south. Northern Algeria encompasses the coastal basin (1.2%), the Tellian basin (3.3%), and the High Plateaus (9%). Southern Algeria consists of the Algerian Sahara, which accounts for 86.5% of the total land area (Fig. 2(a and b)). The territory is subdivided into five hydrographic basins. This hydrographic organization was established by Executive Decree No. 96-100 of March 6, 1996 which mandated the creation of hydrographic basins and defined the standard status for public management agencies defining a hydrographic basin as the topographic area drained by the wadis (intermittent streams) and their tributaries, such that any flow originating within this area follows a path leading to the outlet. In 1996, Algeria's territory was divided into five hydrographic basins (Figs. 2a and 2b):

- Oranie-Chott Chergui ;
- Constantinois-Seybouse-Mellègue.
- Algérois-Hodna-Soummam.
- Cheliff- Zahrez.
- Sahara.

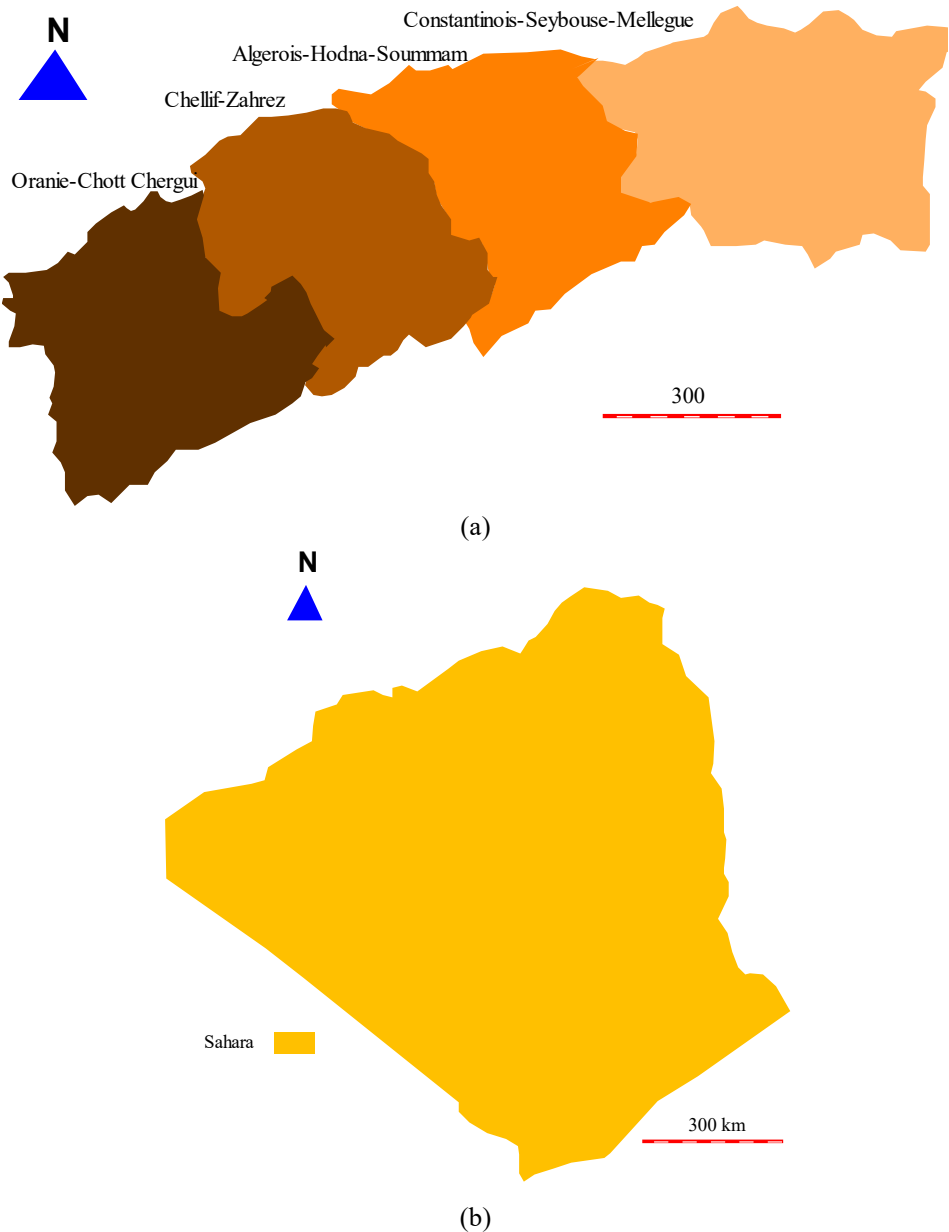


Figure 2: Algeria’s five river basins; (a) The four drainage basins of northern Algeria, (b) Sahara drainage basin; (Source: Basin Agency; diagram by Remini, 2025b)

Each of these two regions (north and south) possesses vast water resources. Across the combined northern and southern regions of Algeria covering a total area of 2.34 million km² the average annual volume of precipitation is 200 billion m³, with each region receiving 100 billion m³ per year (Demmak, 1982). However, the southern region's subsurface is far richer than the north's, containing deep, extensive reservoirs that span more than 50% of the Algerian Sahara's surface area. In addition to the North-Western Sahara Aquifer System, Algeria possesses five other transboundary aquifer systems. These include natural subsurface reservoirs such as the North-Western Sahara Aquifer System, the Murzuq Basin, the Iullemeden-Tanezrouft-Taoudeni Aquifer System, the Er-Rachidia-Bechar Basin, the Tindouf Aquifer System, and the Maghnia Aquifer. Several renewable shallow aquifers have never been inventoried. In northern Algeria, there are 50 shallow aquifers (water tables) with a total capacity of 2 billion m³ (Remini, 2025c). The northern Algerian river network comprises over 50 major wadis capable of draining 12.5 billion m³ (Remini and Amitouche, 2023a; Remini and Amitouche, 2023b). Eighty-one large dams have been constructed within this network to store approximately 9 billion m³ of water. These dams are threatened by annual evaporation rates ranging from 2 to 3 meters (Remini, 2005). Successive silt deposits have reached a volume of 65 m³/year (Remini, 2017a). The Algerian Sahara features a distinctive and unique drainage network comprising over 100 large wadis. Unlike those in northern Algeria, Saharan wadis are characterized by very wide sections exceeding 1 km in places and lengths that can surpass 200 km, while channeling flash floods with flow rates reaching up to 2,400 m³/s (Remini, 2023).

Working methodology

This work stems from extensive fieldwork carried out across the Sahara between 1990 and 2026. We spent a great deal of time in oases and wadis. Two features particularly fascinated us: the first is a human creation that breathed life into the Sahara; the second is the wadi itself a gift of nature that sustains local flora and fauna. Combining the two wadi and oasis adds a new dimension to the vegetation along the wadi's edges, creating a unique form of biodiversity. We were especially impressed by the "wadi oases" found along the M'zab, Metlili, Nsa, Tiout, and Labiod wadis. In this type of oasis, the minor riverbed is dedicated to water security, while the major riverbed (the floodplain) is reserved for food security. The wadi's secret lies in its prime agricultural land soil that is naturally fertilized by the periodic floodwaters coursing through the channel. These wadi-based palm groves feature a unique dual-irrigation system: permanent irrigation using groundwater, and temporary irrigation using surface water that floods the gardens whenever the wadi rises. This process results in the natural fertilization of the palm grove soils situated along the wadi banks. Starting from this premise, we raised several questions regarding this natural treasure: Have we truly harnessed all its potential? Why has the development of new oases along wadi banks stalled, despite the Sahara's dense hydrographic network? Is it possible to revitalize oasis-based agriculture? We will attempt to address these questions in the remainder of this modest paper.

RESULTS

Towards a shrinking agricultural land base

The global population, currently estimated at 8 billion, is growing while agricultural land shrinks and becomes depleted due to urbanization, soil salinization, and soil erosion. The latter phenomenon accelerated in recent years by climate change has contributed to the degradation of vast areas of agricultural land. According to a report by the Food and Agriculture Organization of the United Nations (FAO), soil degradation continues to accelerate at an alarming rate, thereby threatening food security (Azertac, 2026). Algeria has faced this same problem for years; rapid population growth has led to a proliferation of housing developments at the expense of the best agricultural land. Today, ensuring the country's food security necessitates the development of new agricultural lands.

The oases of the algerian sahara

Comprising a dwelling, gardens, and a water source, an oasis is like a beauty mark on the desert a natural paradox, a wetland within an arid zone. Hundreds of oases have developed across the Algerian Sahara, distributed throughout the territory. Numerous field missions have been carried out in these Saharan oases since 1990. Investigations were conducted at the sites of ancestral hydraulic structures, and surveys were carried out among the oasis inhabitants. Meetings were organized with elderly farmers who possess impressive expertise in agriculture, architecture, and water management. Over this long period spanning 35 years (1990-2026), we visited every oasis in the Algerian Sahara (Fig. 3).

These include the oases of the M'zab, Souf, Righ, and Saoura valleys ; the oases of Touat, Gourara, and Tidikelt ; the Ziban and Aurès oases ; the oases of Metlili, El Guerrara, Ahaggar, Tassili n'Ajjer, Berriane, Laghouat (Aïn Madhi and Tadjmout), Bou Saada, and El Bayadh (Stitten, Boualem, Ghassoul, Arbaouat, El Abiodh Sidi Cheikh, Chellala, Assla, Brezina, Boussemghoun) ; the Aïn Sefra oases (Tiout, Sfissifa, Moghrar) ; the Tindouf oases ; and the Tabelbala oasis. These studies reveal that the Algerian Sahara is indeed a region rich in insights regarding ksour architecture, agriculture, and water management systems. It can be said that the Algerian Sahara remains an open-air laboratory for studying issues related to climate change. Regarding sustainable water management in these oases, there are numerous water harvesting and storage techniques well-suited to the arid climate. If a solution exists to further increase freshwater reserves thereby guaranteeing water security and a high level of national food security it can only come from the Algerian Sahara. Based on our fieldwork in these areas, there are three types of oases most common in Algeria: the foggara oasis, the wadi oasis, and the ghout oasis. The foggara oasis is the most widespread type in Algeria; these oases have developed in two regions of the Algerian Sahara. These include the oases of Touat, Gourara, and Tidikelt, as well as the oases of the Saoura, which adopted the foggara as the primary source of irrigation and drinking water (Remini, 2017b; Remini and Achour, 2013) (Fig. 4).

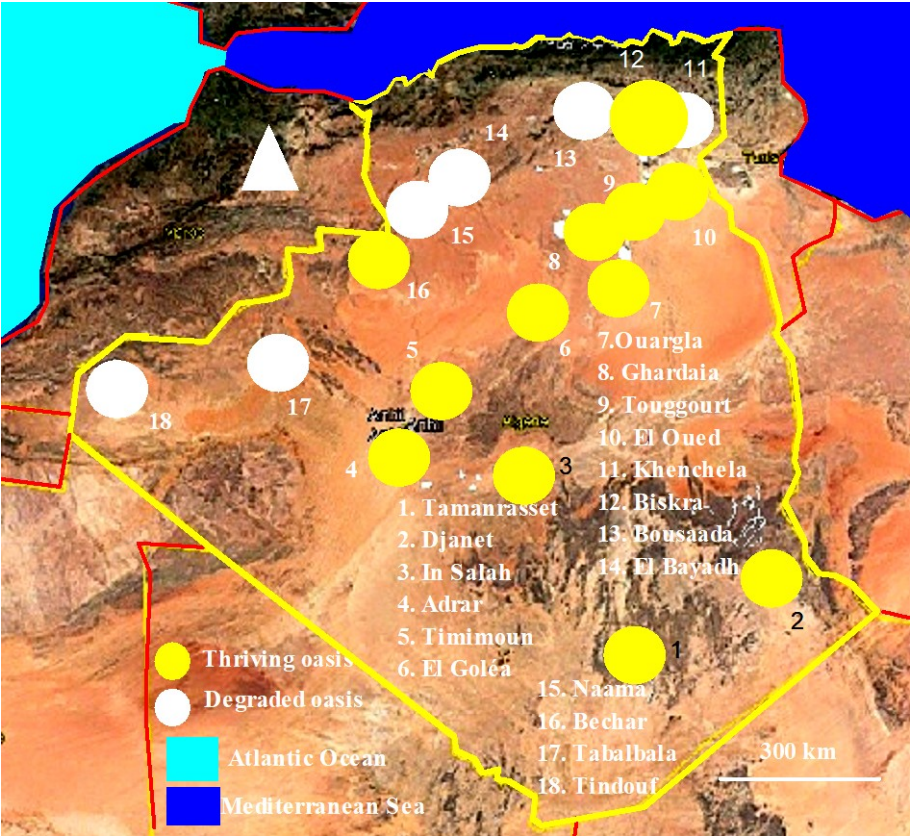


Figure 3: Oases visited and studied (Remini, 2026)

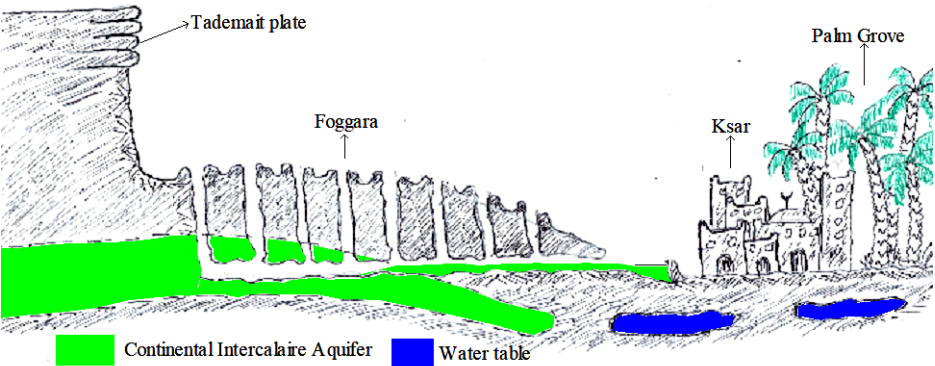


Figure 4: Simplified diagram of an oasis in foggara of Touat (Remini diagram, 2026)

A wadi oasis is one where the watercourse serves as the primary source for irrigating the palm grove (Fig. 5). In this context, two types of irrigation exist: permanent irrigation, supplied by natural springs located within the wadi bed, and in wadis lacking natural springs the exploitation of the alluvial aquifer via animal-drawn wells (Remini, 2020). Temporary irrigation occurs during flood periods; thanks to a water-sharing system, each farmer receives a share of sediment-laden water to flood their plot. The entire palm grove is inundated during each flash flood by water rich in silt, clay, and sand particles, as well as nutrients such as phosphorus and potassium.

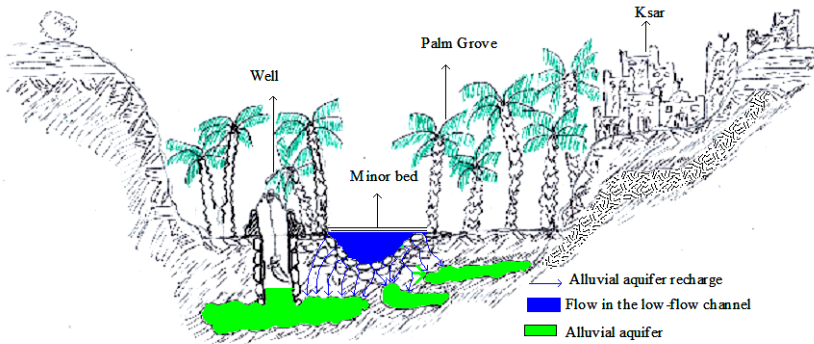


Figure 5: Simplified diagram of a wadi oasis (Remini diagram, 2026)

The ghout oasis a type of foggara oasis widely found in the Souf valley consists of planting around a hundred date palms within a crater approximately 100 meters in diameter (Fig. 6). The water table lies at a depth of between 1 and 3 meters. After six months of irrigation using water from a counterweighted well, the young palm trees' roots reach the groundwater. Unlike other oasis types, this variety consists of a circular, family-owned palm grove situated inside a crater. Furthermore, whereas other foggara systems are associated with settlements where farmers live in a communal village, the ghout oasis is associated with individual homesteads. A defining characteristic of this type of oasis is that the palm grove requires no active irrigation, as the palm roots remain in constant contact with the groundwater (Remini and Kechad, 2011).

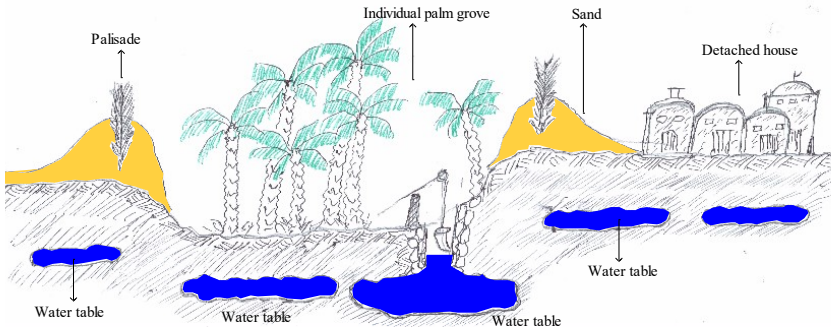


Figure 6: Simplified diagram of a Ghout oasis (Remini diagram, 2026)

Is the wadi an ideal space for developing oasis agriculture?

During our travels along the wadis (ephemeral watercourses) of the Algerian Sahara, we have often raised questions about this ecosystema fascinating yet understudied subject that has not yet revealed all its secrets. What, then, is the true function of this hydrological feature in the heart of the desert? Its role extends beyond merely transporting water from the highest point to the watershed outlet. It is important to distinguish between a wadi a watercourse in a desert environment and a river, which is a watercourse in a humid environment. Saharan wadis are characterized by widths ranging from several meters to over a kilometer, and lengths spanning many kilometers. Flood events in a wadi generally last no more than 24 to 48 hours, yet they are extremely violent and can cause significant material damage and loss of life. In recent years, peak flow rates exceeding 1,000 m³/s have been recorded during certain floods. The flood on the M'zab wadi on october 10, 2008, reached a flow rate of 1,200 m³/s. Similarly, an exceptionally violent flood on the Labiod River surged at 1,600 m³/s during the night of November 30, 2011. A flow rate of 2,400 m³/s was recorded during the flood on the Oued Mzi on October 20, 2014. However, such extreme events are infrequent; long periods of drought often grip the region, leaving the wadi without any flow for years at a time. It is an area that, while otherwise unused, serves as a vehicle track, a football pitch, or even a marketplace for the local ksar population. Consequently, ensuring the wadi fulfills a sustainable function requires sustainable water management. Does this necessitate hydro-agricultural development of the wadi? That is what we proposed in the final section of this article. However, any such approach must be grounded in the wadi's primary function: conveying runoff from torrential rains. A significant portion of this water recharges alluvial aquifers, while the remainder evaporates into the atmosphere. We therefore propose hydraulic structures designed to accelerate artificial aquifer recharge, thereby minimizing water loss through evaporation.

Comprising two channels a minor and a major one a wadi in a desert region like the Sahara undergoes four stages during the interval between flash floods of varying intensities. During the first stage, which accounts for the majority of the time, the wadi is dry, as previously mentioned. It is a state of total dryness: both channels (minor and major) are empty; surface water has evaporated, and even the groundwater in the alluvial aquifer has evaporated over time (Fig. 7a). In the second stage, a flash flood rapidly enters the wadi, filling the minor channel; some of the water infiltrates the alluvium at the bottom of the minor channel, recharging the alluvial aquifer. Thus, the minor channel ensures water security (Fig. 7b). In the third stage, the water level rises and occupies the wadi's major channel, which serves as a deposition area for the successive layers of sediment carried by the flash flood (Fig. 7c). Flash flood water is characterized by high turbidity; it acts as a natural fertilizer, containing not only clay and sand particles but also nutrients such as potassium and phosphorus. Consequently, the major channel ensures the oasis's food security. In the fourth stage, following the passage of a flash flood, the minor channel conveys a thin stream of water. Concurrently, subsurface flow through the voids within the alluvial deposits can persist for one to two years without any new water input (Fig. 7d).

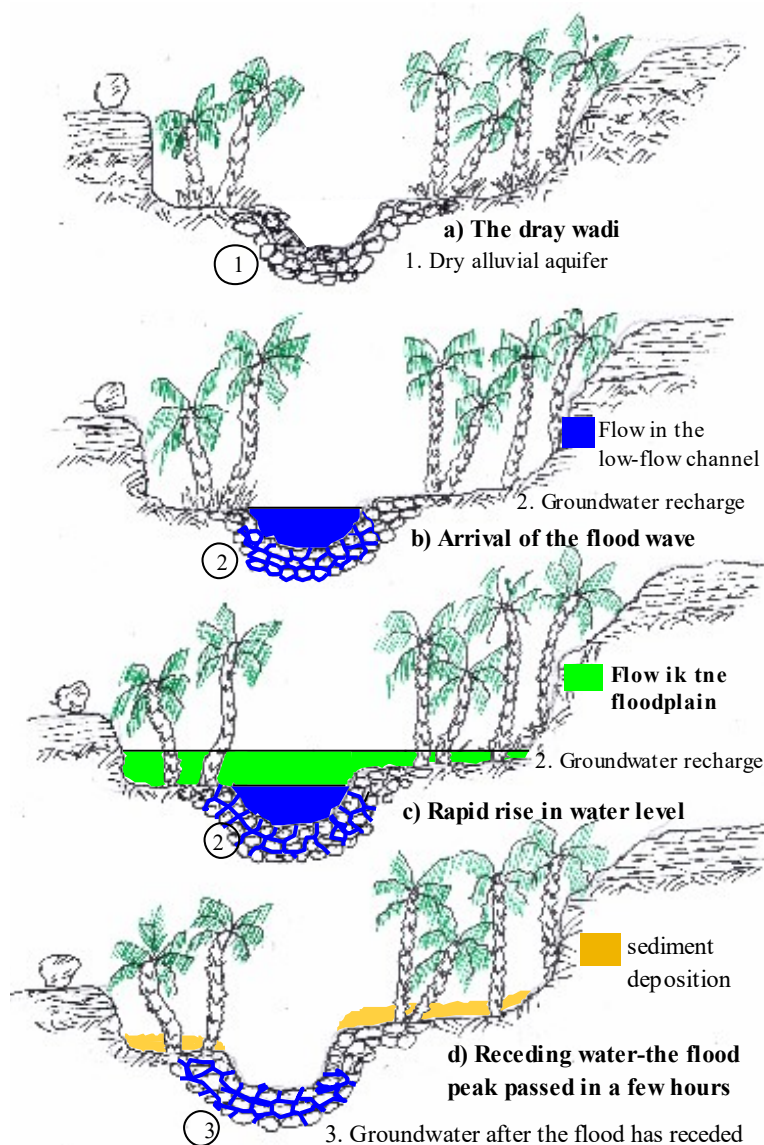


Figure 7: Simplified diagram of a flash flood in a wadi transporting water and mud (Remini Diagram, 2026)

Water for irrigating gardens laid out on the floodplain is available in the alluvial aquifer within the wadi's sandy bed, located at depths ranging from approximately 0.5 to 4 meters (Gast, 1995). These are shallow aquifers specifically interflux or alluvial aquifers that recharge annually following flash floods; they flow through the alluvial deposits beneath

the wadi beds, persisting even when the surface of the wadi is dry (Remini and Achour, 2013). In a desert environment, a wadi is a gift of nature that makes the landscape habitable. It is therefore up to humans to develop the wadi to harness its utility: using the active channel to store flash-flood water in natural underground reservoirs shielded from pollution and evaporation and utilizing the floodplain to ensure food security. Floodplains can be developed into gardens that are periodically fertilized by passing flash floods. Thus, wadis should be developed into oases to foster biodiversity across the Sahara's wadi systems, while housing should be built on higher ground to ensure the safety of the population. What, then, is the relationship between the wadi and the oasis? These two entities one natural (the wadi) and the other artificial (the oasis) combine to form a single hydro-agricultural unit. Fig. 8 illustrates the connection between the wadi and the oasis.

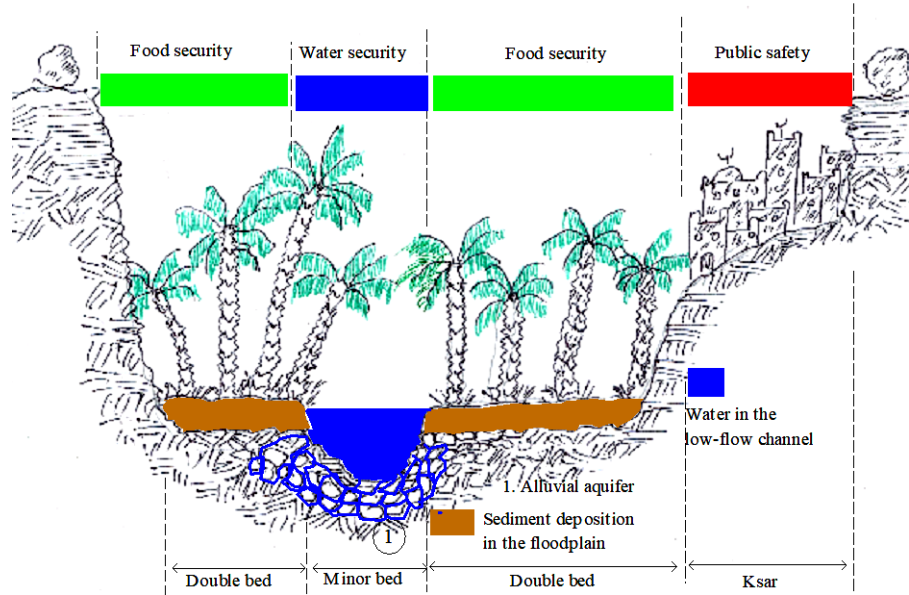


Figure 8: Simplified diagram of the marriage between the wadi and the oasis (Remini Diagram, 2026)

A wadi occupies a stretch of land that has effectively become an unused, wasted area, save for a thin trickle of water flowing through the minor bed throughout the hydrological year. It is only during sporadic flash floods that the major bed is inundated. Nature has thus provided humanity with a ready-made hydro-agricultural system. This is particularly relevant for Algeria, a country boasting over 50 major wadis in the north and more than 100 in the south spanning vast distances (Table 1 and Fig. 9). Yet, the Sahara has not fully revealed the secrets of these watercourses such as the legendary wadis of Igharghar (originating south of the Grand Erg Oriental) and Mya (near Ouargla) (Ballais, 2010).

A wadi consists of a minor bed the channel reserved for water flow and a major bed, an area occupied by high-quality agricultural land. Thanks to the wadi's periodic flash floods, sediment-laden water spills over into the major bed, regularly fertilizing the soil.

Table 1: The wadis of northern Algeria (Remini and Amitouche 2023a ; Remini and Amitouche 2023b; 2026)

No	Name of the wadi	Length (km)	No	Name of the wadi	Length (km)
1	Tleta	12	27	El Harrach	15
2	Tafna	110	28	Hamiz	50
3	Meknassia	27	29	Corso	10
4	Halloufa	25	30	Merdja	5
5	Essenan	37	31	Isser	80
6	Guessiba	12	32	Larba	4
7	Tassmanit	4	33	Sebaou	80
8	El Kerma	6	34	Mleta	24
9	El Hammam	30	35	Youssef	27
10	Chellif	275	36	Ntaida	22
11	Guelta	12	37	Daas	21
12	Tarzoot	15	38	Saket	12
13	Allala	20	39	Soummam	60
14	Bouchehal	8	40	Agrioun	23
15	Goussine	412	41	El Kebir	42
16	Mentrach	12	42	Zhour	15
17	Ouattar	5	45	Tamanarat	9
18	Damous	36	44	Guebli	36
19	Kellal	6	45	Zeramna	15
20	Essebt	12	46	Kebir	36
21	Messelmoun	15	47	Seybouse	35
22	Hachem	22	48	Khelidj	15
23	Nador	8	49	Bounamoussa	20
24	Merzoug	4	50	MessidaZiama	10
25	Mazafran	17	51	Ziama	6
26	Beni Messous	10			

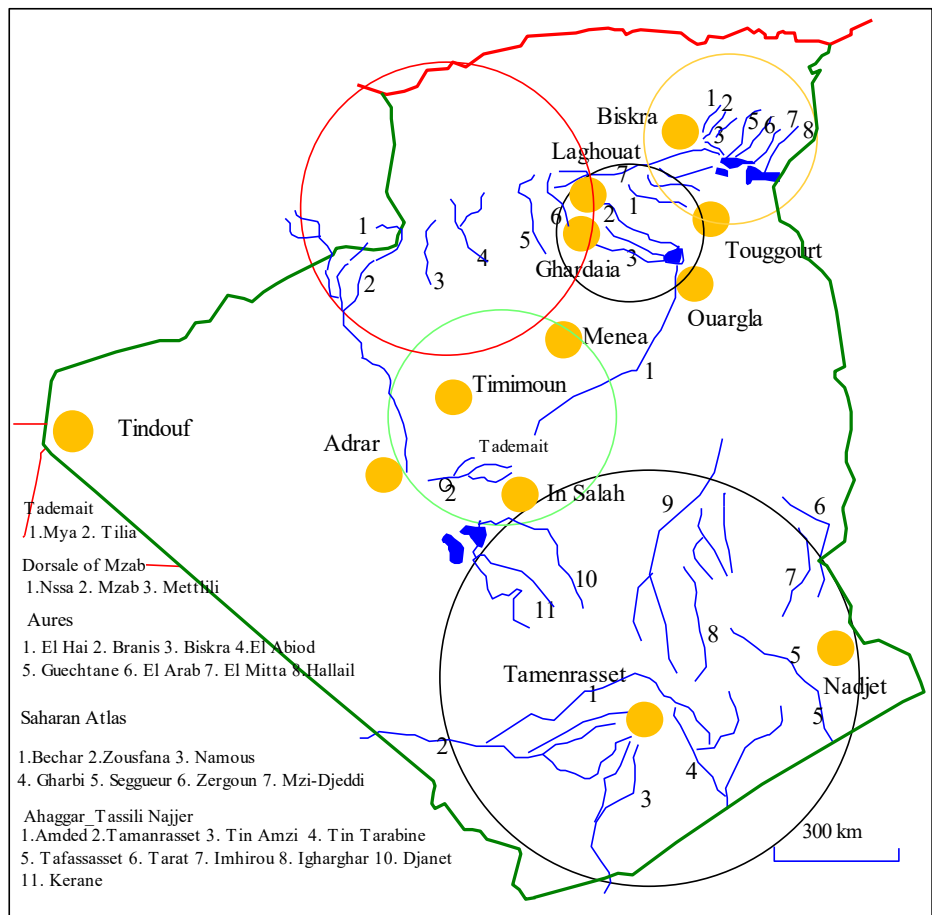


Figure 9: The main wadis of the Algerian Sahara (Dubost, 2002, updated by Remini, 2026)

Indeed, nature has overlooked nothing, even in hyper-arid regions like the Sahara. Wadis in the heart of the desert are conduits for life, as they channel water the very essence of life. Despite the dangers posed by flash floods in these wadis, oasis dwellers have learned to live in symbiosis with them. These floods carry water laden with solid particles, effectively providing two types of water: potable water and water rich in sediments and nutrients. When a flood occurs in a wadi, a portion of the water infiltrates the soil, recharging the alluvial aquifer. Once drawn from wells, this high-quality water is distributed to the local ksar population, whereas the turbid floodwater is shared among farmers. Gardens laid out on the wadi's floodplain are inundated by these turbid waters. Consequently, with every flash flood, sediment is deposited onto the floodplain soil. This deposit acts as a natural fertilizer, being rich in phosphorus, potassium, silt, and clay particles. As noted in previous studies, flash floods transport both water and mud, a characteristic that makes floodplain lands prime agricultural territory. This is why

agricultural produce from wadi oases is ranked among the finest fruits and vegetables. Two notable examples are the pomegranates from the Boussemgoun oasis a wadi oasis which are renowned throughout Algeria for their exceptional quality. In contrast to wadi oases, which are distinguished by the superior quality of their floodplain agricultural land, foggara oases are characterized by the exceptional quality of their irrigation water specifically the spring water supplied by the foggara system. During the 1980s, Adrar was renowned for its high-quality tomatoes. These tomatoes came from foggara fed oases, and Algeria exported several tons of them to France.

The Ghardaïa oasis serves as an example of successfully managing both water and food security. It was established in a rocky region with a hyper-arid clim a) Low flowate; the only available space for creating a palm grove was along the M'zab River. Lacking both water and arable land, the Mozabites adopted a hydro-agricultural layout that utilized the farmland within the wadi of M'zab's floodplain. To address the water issue as the area relies solely on the flash floods that occasionally occur along the M'zab wadi the Mozabites tapped into the region's only water source: groundwater. Using animal-traction wells known as khottaras, they draw potable water from the aquifers to supply the ksar (fortified village) and irrigate the gardens of the Ghardaïa palm grove. Furthermore, the initial waters of the M'zab River flash floods are diverted directly to flood the gardens via an ingenious distribution system. These turbid floodwaters are rich in nutrients, fertilizing the soil with every flood event channeled by the wadi. This highlights the special value the ksar population places on this sediment-laden water; indeed, the turbid floodwater is shared among farmers through a distribution system that is unique in the world.

As for the El Guerrara oasis, the situation differs completely from that of Ghardaïa. Indeed, the El Guerrara palm grove was originally established at a distance from the Zegrir wadi. Irrigation for the grove's gardens relies on tapping into the groundwater table using animal-drawn wells. However, recognizing the value of the sediment-rich waters carried by flash floods, the local ksour population diverted the Zegrir wadi from its original course to flow closer to the El Guerrara palm grove. A 30-meter-wide dam was constructed to recharge the alluvial aquifer and capture the runoff generated by flash floods in the Zegrir River. Furthermore, the palm grove expanded on both sides of the wadi to take advantage of these sudden rainfall events.

For centuries, humans have harnessed this natural wadi, creating an oasis within the wadi itself specifically, on the floodplain. Over time, the two have become inextricably linked, with humans successfully creating a wetland environment amidst arid surroundings. With water hidden underground, gardens laid out along the water's path, and dwellings built on higher ground, people live in harmony with nature. As previously mentioned, humans have enhanced around ten wadis by establishing oases along their courses. Today, however, such projects are no longer being undertaken. Left to their own devices, the wadis...

The complexity of sahara wadis

According to technical literature, a wadi channel consists of two parts: a minor bed and a major bed. However, after conducting fieldwork across various parts of the Sahara, we observed a range of different cross-sectional profiles. In our view, the "minor and major bed" configuration is more applicable to perennial rivers than to wadis; the configuration of a wadi is far more complex. Some wadis consist of a single channel that can exceed 1,000 meters in width. Flow within these wide channels moves in multiple directions. During a flash flood, the water covers the entire width spanning over a kilometer creating a spectacular sight (Fig. 10(a and b)). We find this type of wadi in the Tamanrasset and Djanet provinces. Other wadis exhibit a stepped cross-section: during low-flow floods, the current may shift from one bank to the other (Figs. 11a and 11b).

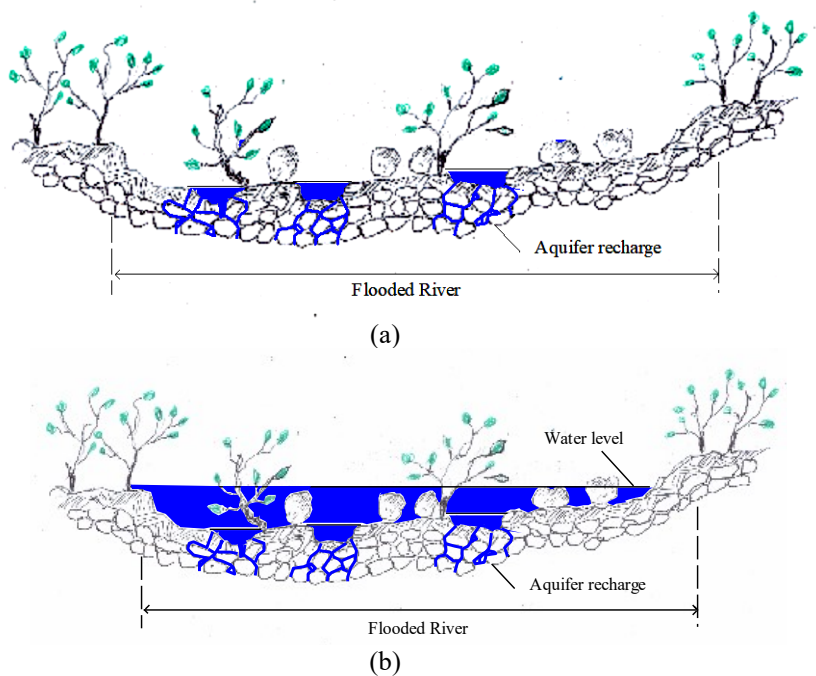


Figure 10: Simplified diagram of a complex channel of a wide wadi; (a) Low flow; (b) Flooded wadi; (Remini diagram, 2026)

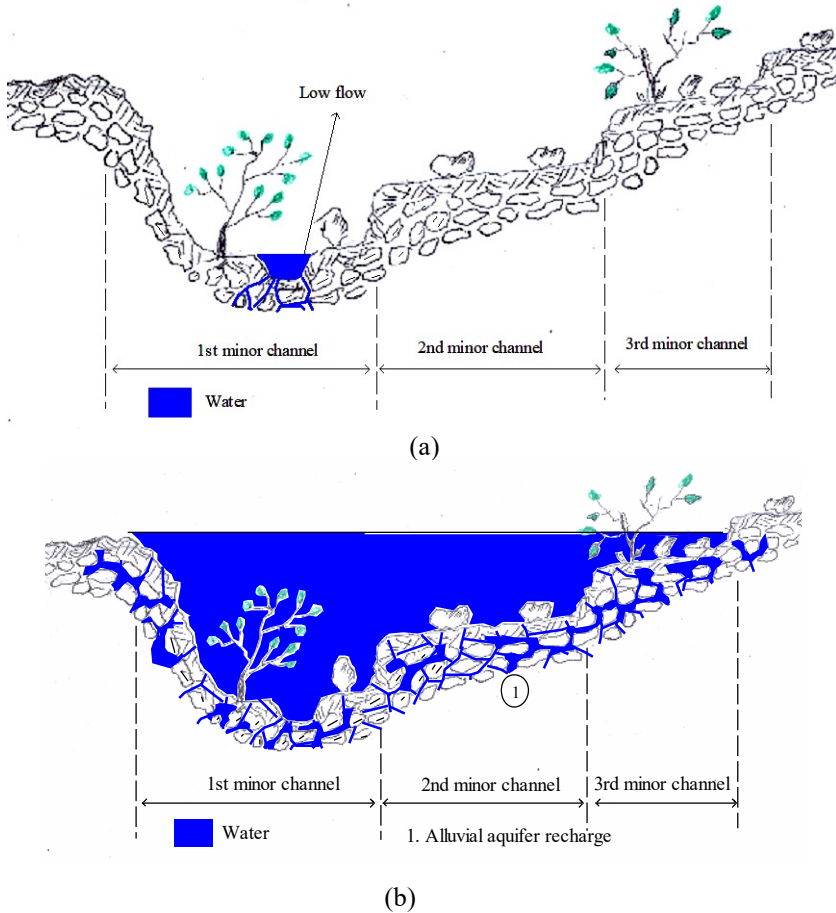


Figure 11: Complex stepped wadi channel; (a) Low flow; (b) Flooded wadi; (Diagram by Remini, 2026)

The role of flash floods in the natural fertilization of soils

Based on information gathered from farmers and palm grove owners during our field missions, we have outlined the stages of a palm grove's evolution following flash flood inundation. As previously noted, despite the destructive force of flash floods as they sweep past an oasis, they transport clay and sand particles, as well as nutrients such as phosphorus and potassium. When a young or even a degraded old palm grove is flooded by the muddy waters of a flash flood, these particles and nutrients settle throughout the grove, effectively providing the soil with a dose of natural fertilizer. Early signs of recovery appear as the palm fronds turn green; gradually, the palm tree returns to its original state (Figs. 12a, 12b, and 12c). If weather conditions are favorable and the grove experiences a second flash flood within the year, it gets a new lease on life, and all the

palms regain their lush green color. The soil is naturally well-fertilized by the flash floods, which bring in both water and silt. This results in the excellent quality of agricultural produce from these oases (Figs. 12d and 12e). It should be noted that date quality depends on both water and soil quality. In the Touat and Gourara oases, palm groves are irrigated using groundwater captured via foggara systems. This water is renowned for its high quality; being groundwater, it flows slowly through the underground galleries, allowing it to become enriched with mineral salts. However, the soil in these oases does not receive natural fertilization due to the absence of wadis (seasonal watercourses). Let us consider the case of a wadi oasis, such as Tiout (Naama). The palm grove is permanently irrigated by spring water. Furthermore, the soil is flooded by flash floods once or twice a year. In this instance, we have high-quality irrigation water (spring water) and high-quality soil, as it is naturally fertilized by the flash floods occurring once or twice annually. You can draw your own conclusions from this.

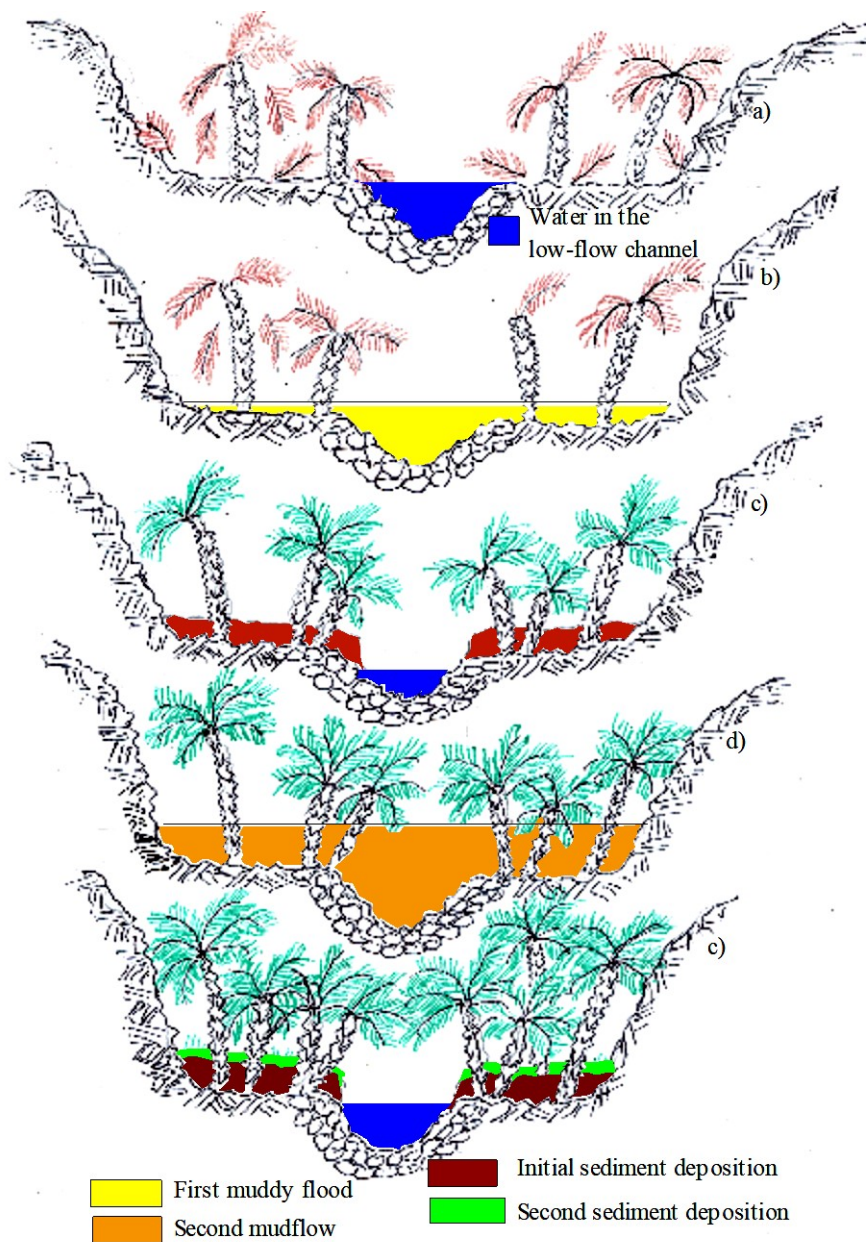


Figure 12: Simplified diagram of the natural fertilization of the soil in wadi floodplains (Diagram: Remini, 2026)"

New management strategy for algeria’s watersheds

In light of the climate change currently affecting Mediterranean countries and Algeria in particular watersheds must adapt to this disrupted climate by adopting new rainwater harvesting techniques. Algeria’s 150 Rivers (seasonal watercourses) need to be equipped with hydraulic structures capable of storing rainwater underground, protected from evaporation. Six hydro-agricultural structures can be built along the main wadi of a watershed. The optimal site for constructing one of these six hydraulic structures is determined based on the area’s hydrogeology and soil geology. All six types of hydraulic structures can be built along a single wadi with some types repeated culminating at the watershed outlet with a large surface dam. This constitutes a comprehensive hydro-agricultural development scheme incorporating various structures for aquifer recharge and water storage beneath the wadi beds and in the subsurface (Figs. 13, 14 and 15). These hydraulic structures are as follows: Ideally, the wadi is made far more productive by maximizing the utilization of water from alluvial and phreatic aquifers. Installing multiple structures such as sand dams, recharge dams, underground dams, mixed-type dams, covered structures, and recharge basins along a single wadi maximizes the artificial replenishment of alluvial aquifers. With such a development scheme, the relationship is reversed: the volume of water lost to evaporation becomes significantly lower than the volume of water infiltrated.

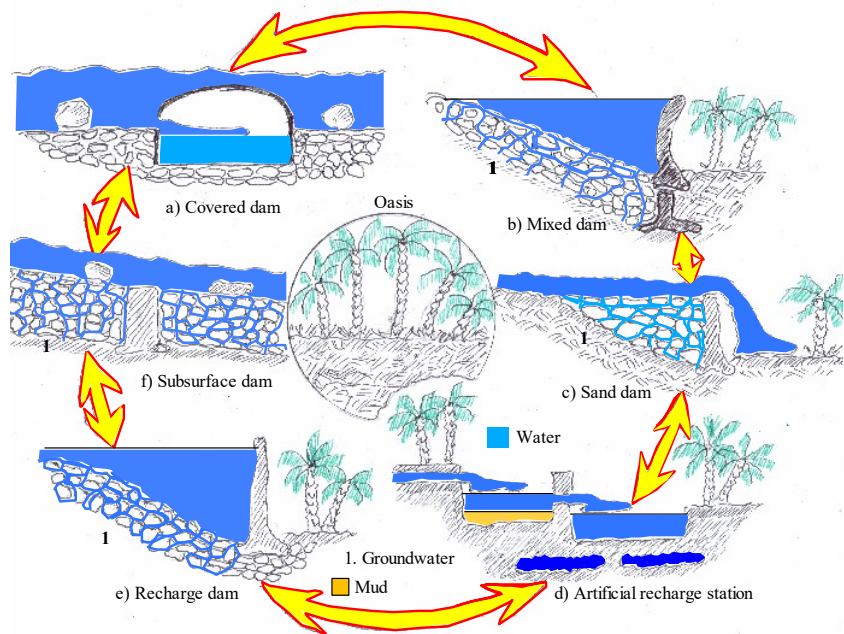


Figure 13: Hydraulic structures adapted to climate change (Remini diagram, Remini, 2026)

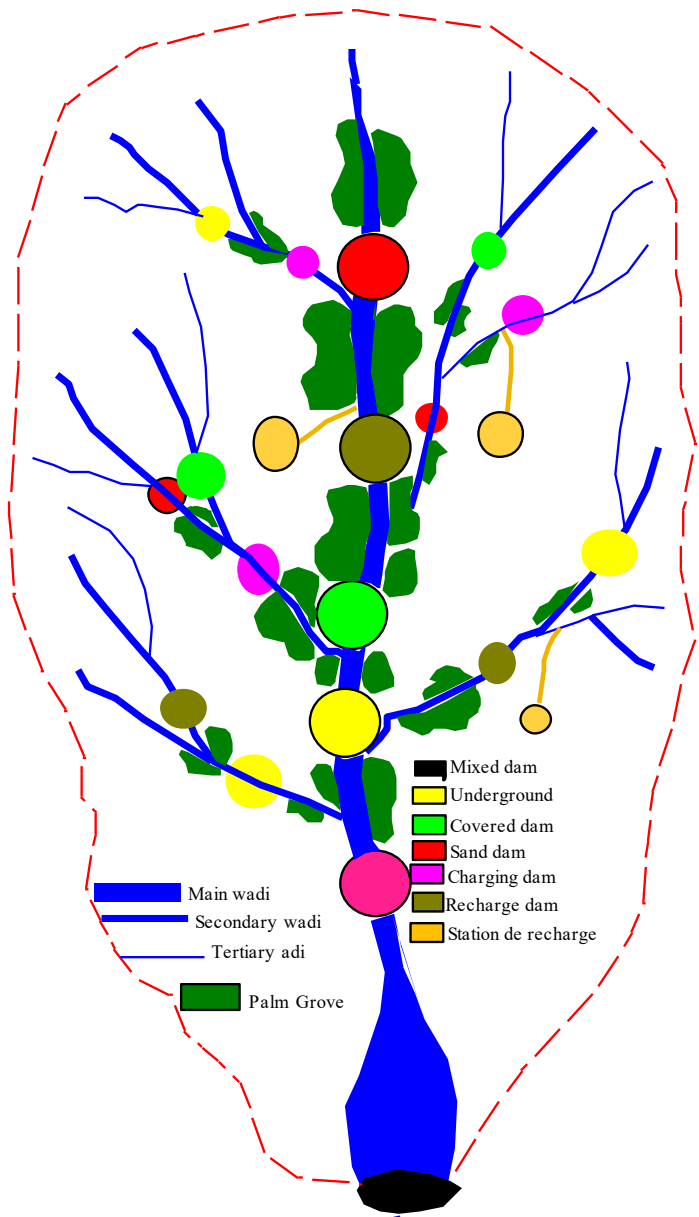


Figure 14: Schematic diagram of watershed management, (Remini diagram, 2026)

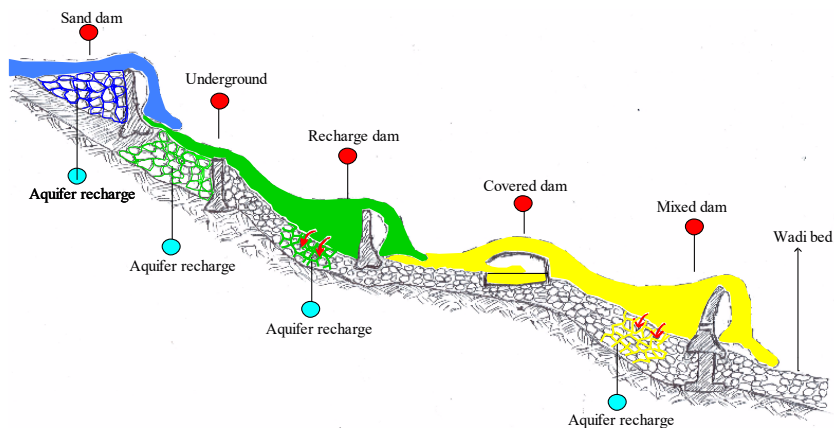


Figure 15: Simplified diagram of a cross-section of a developed wadi, (Remini diagram, 2026).

These new hydro-agricultural developments will be implemented across the entire Algerian territory. The various hydraulic structures to be built throughout the river network, along with the hundreds of boreholes and wells to be installed in these watersheds, require high-level management of all these facilities. To this end, we propose a new division of Algerian territory into eight hydrographic basins (Fig. 16).

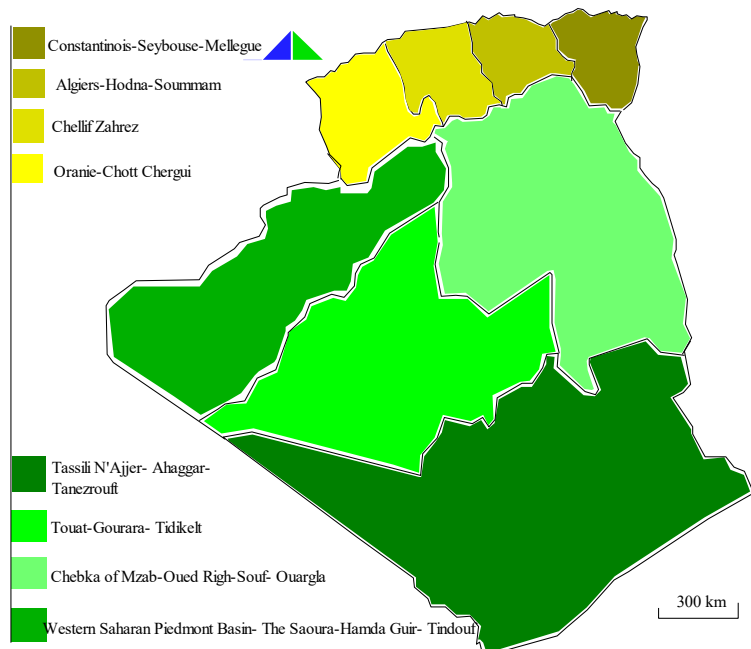


Figure 16: Diagram of the new delineation of Algerian river basins (Remini diagram, 2024)

DISCUSSION

The wadi and the oasis one a gift of nature, the other a human creation are linked by flash floods, creating a wetland environment within an arid landscape. For centuries, flash floods have been a characteristic feature of desert wadis. It is the flood itself that has shaped the dimensions of the wadi's cross-section; the sheer size of this channel reflects the massive volume of water that can fall from the sky in just a few hours a cross-section precisely matched to the flood's discharge capacity. These are best described as "Saharan floods," given their origins in the wadis of the Sahara Desert. The wadi is, in essence, the natural domain of the flash flood. Humans have been warned: one must not encroach upon the flash flood within its own territory. When the flood rages, it rises from the minor bed (the active channel) to the major bed (the floodplain) to convey its waters. Consequently, human urbanization must not intrude upon the wadi's major bed; doing so constitutes an act of aggression. Oasis dwellers have long understood the need to avoid conflict with nature. The flash flood or rather, the Saharan flood is a source of life. In the M'Zab Valley, when a flash flood arrives, families gather along the wadi's edge to express their joy and welcome the waters. Oasis dwellers have learned to live in harmony with these floods. They have implemented hydro-agricultural systems in the minor bed to accelerate the recharging of alluvial aquifers with the flood's clear water, while the major bed has been developed into gardens (Fig. 17). Farmers have adopted two irrigation methods, one of which is permanent irrigation utilizing the clear Saharan floodwater stored within the alluvial aquifers. This involves a form of temporary irrigation where gardens are flooded with muddy water during flash floods a process that revitalizes the soil. The muddy water acts as a natural fertilizer rich in potassium and phosphorus, while clay particles enrich the soil with every flash flood. Thus, the water provides hydration for the plants and nutrient-laden water for the soil. Moving away from this specific area, the oasis dweller lives on the higher ground (Fig. 17).

Thus, the wadi and the oasis are indeed linked by flash floods. It is worth noting that, due to climate change, the Saharan flood pattern has shifted toward Mediterranean basin countries. Unlike a wadi, which is fed temporarily by flash floods, a river is fed by precipitation and snowmelt. Despite this difference, the river has adopted the Saharan flood regime. Consequently, flash floods occurring in these rivers carry muddy water as the drainage network adjusts its dimensions. Channel sections are widening to accommodate these massive volumes equivalent to 6 to 12 months of rainfall falling within just 24 to 48 hours.

Establishing new oases along wadis is a topical issue. The changing climate fosters flash floods, particularly during June, September, and October. The active river channel is managed through hydraulic structures such as sand dams, subsurface dams, recharge dams, covered dams, and aquifer recharge stations. These structures accelerate the infiltration of clear water from Saharan floods to replenish alluvial aquifers, which then provide permanent irrigation for palm groves water that is accessed via wells and boreholes. The nutrient-rich, muddy water is shared among farmers. Gardens laid out in the river's floodplain are inundated by this sediment-laden water, which deposits solid particles and nutrients.

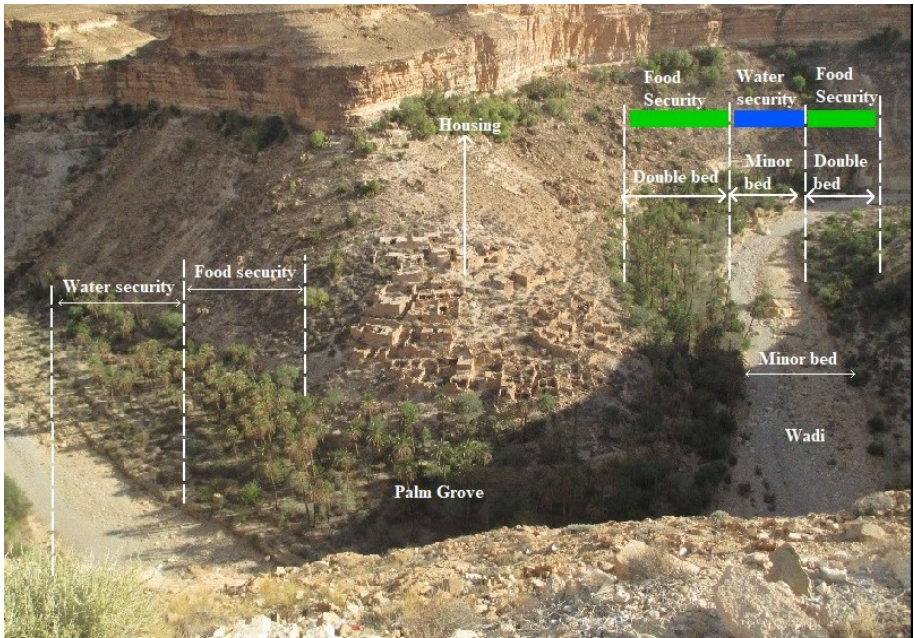


Figure 17: Labiod River. A wadi oasis, life in harmony between humans and nature (Photo Remini, 2013)

This process occurs with every flash flood. These floodplain soils can be ranked among the best agricultural lands. Why, then, have we allowed all this land to be abandoned? We believe that now is the ideal time to rehabilitate these old lands and create new oases along the wadis. It is worth remembering that, for centuries, magnificent oases have flourished along wadis such as the Mزاب, El Hai, Labiod, and Nsa. Our goal is to transform our Saharan wadis into green corridors filled with palm groves, as illustrated in Fig. 18. However, some wadis remain untouched including major ones that have never been developed.

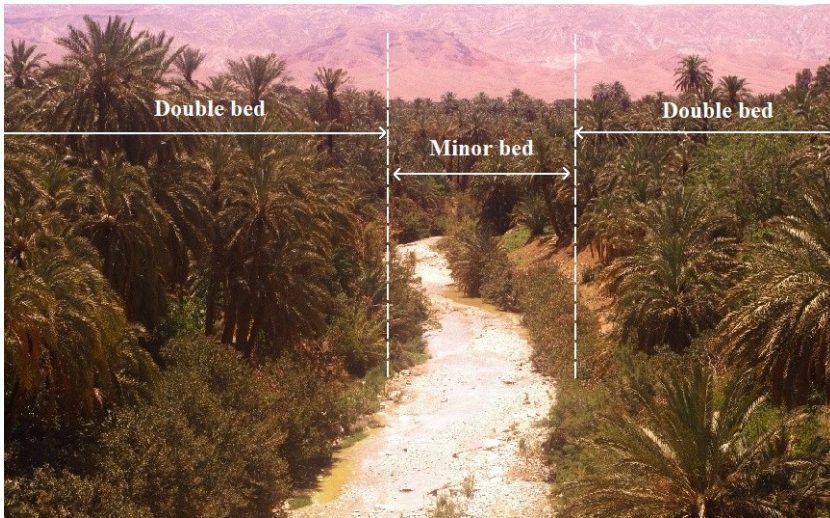


Figure 18: El Hamra Oasis (El Guentra) on the El Hai wadi. This is the result of flash floods: a very dense palm grove on either side of the El Hai wadi's low-flow channel (Photo Remini, 2014)

CONCLUSION

As mentioned at the beginning of this article, agricultural land is shrinking due to urbanization driven by rapid population growth. Other issues, such as soil salinization and erosion, have further contributed to the degradation of agricultural land, thereby threatening food security. On the other hand, Algeria possesses a dense river network a vital resource that is currently underutilized, serving merely to channel rainwater runoff. Climate change affecting Mediterranean basin countries has led to an increase in flash floods. Adapting to this new climate while reclaiming prime agricultural land is essential for ensuring food security. The oasis and the river must be integrated into a single unit a strategy for climate change adaptation. Both the low-flow channel (minor bed) and the floodplain (major bed) of the wadi require coordinated development. The low-flow channel, crucial for water security, should be equipped with hydraulic structures to capture and store flash floodwaters. These flash floods are a gift from the heavens an invaluable natural treasure. They provide two types of water: clear water to recharge alluvial aquifers suitable for drinking water supplies and permanent garden irrigation and sediment-laden water. The floodplain should be managed to allow this silt-rich water to inundate gardens during flash flood events, providing a form of temporary irrigation. In the Sahara region, palm groves should be developed in these floodplains, whereas in northern Algeria, fruit trees should occupy the prime agricultural land found within the wadi floodplains. Furthermore, we can rehabilitate traditional oases; revitalizing oasis-based agriculture offers the potential to produce high-quality crops.

Acknowledgements

This modest study is the result of a monumental effort undertaken over many years. It was fieldwork that required years of travel to locations far from home arduous work, yet deeply rewarding, allowing me to discover the most beautiful country on the planet. It involved trekking for miles along wadis to uncover secrets hidden within the oases. The success of this study is due to the local communities, who made the task easier for me; they provided every possible resource to ensure the work's success. Thank you, thank you, and thank you.

Declaration of competing interest

The authors declare that they have no known competing financial interest or personal relationship that could have appeared to influence the work reported in this paper.

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