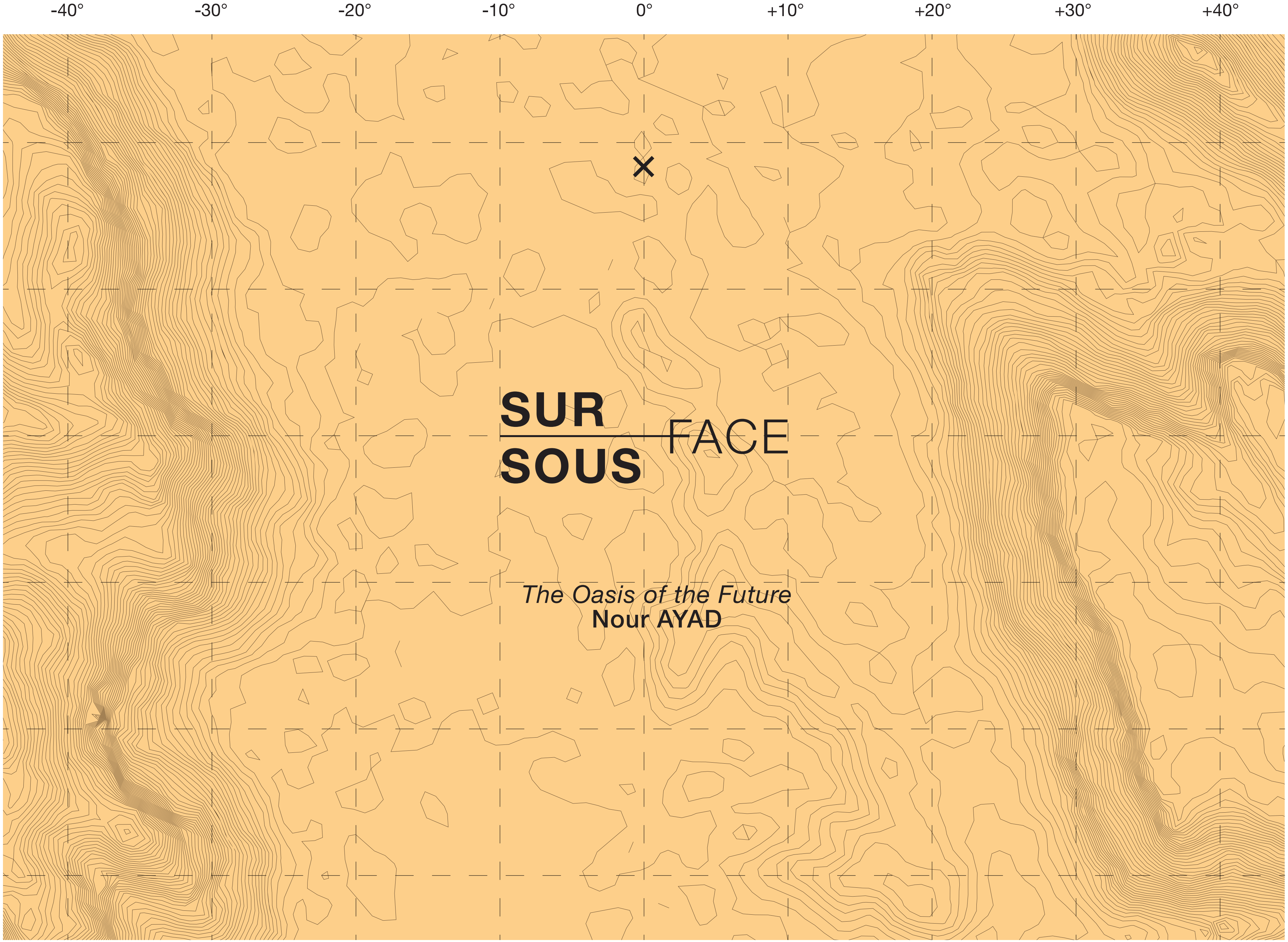

SUR SOUS FACE

The Oasis of the Future

Nour AYAD

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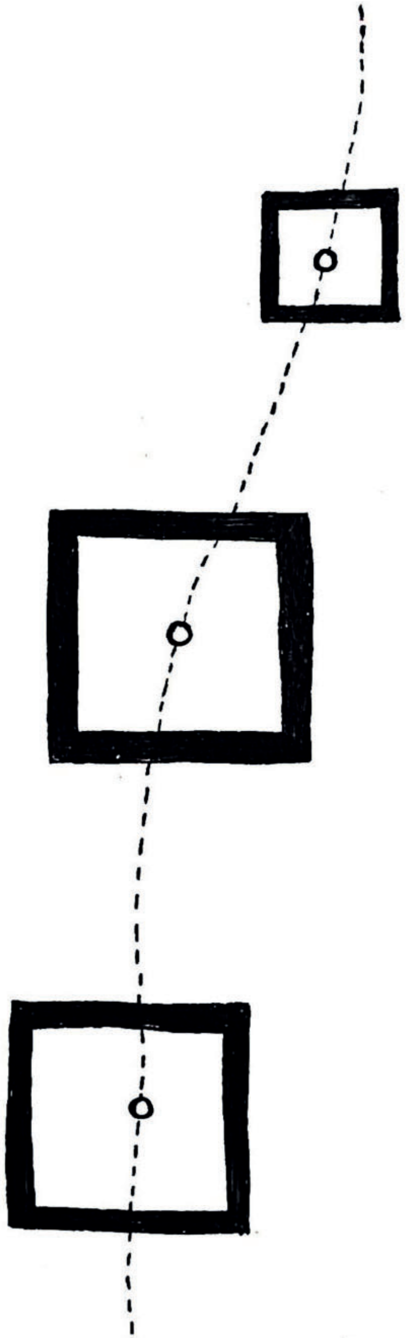
Timimoun

تيميمون



SUR SOUS FACE

The Oasis of the Future

Inhabiting Timimoun : the new Agham
Master’s Thesis – Design Project

Nour Imene AYAD - 10982336
Academic year 2024-2025
Architecture and Urban Design
Supervised by Maria Chiara Pastore - Politecnico di Milano
Co-supervised by Mathieu Mercuriali - Ecole Nationale Supérieure d’Architecture Paris Val-de-Seine

ABSTRACT

This thesis examines contemporary living in the Timimoun oasis, a Saharan territory undergoing deep climatic, social, and urban transformations. Using a research-through-design approach, it explores the ground as a living archive, a medium of memory, and a matrix for architectural renewal. Field surveys, resident interviews, archival analysis, and observation of traditional irrigation systems reveal how the physical and symbolic layers of the soil reflect the oasis's history and fragile balance.

Three concepts structure the project : memory, inhabiting the palm grove, and building community. Memory appears as a palimpsest inscribed in the earth, in built remnants, and irrigation networks. Inhabiting the palm grove emphasizes the link between dwelling, agriculture, and microclimate, where agham and djnen embody traditional ways of life balancing protection and production. Community is expressed through collective water management, the organization of ksour, and the transmission of knowledge.

Based on this research, the “New Agham,” a model of collective housing, results from a gradual analytical process in which each hypothesis was confronted with the site. The architectural form does not preexist the research: it emerges from it. Spatial, constructive, and programmatic choices arise from local resources, climatic constraints, existing structures, and demographic projections. Architecture thus develops over time, as a synthesis of observations, experiments, and scenarios of evolution, rather than as a predefined formal object.

Centered on a productive garden, the New Agham combines domestic spaces, shared areas, and climate regulation devices, with water management inspired by the foggara system.

By situating architecture at the intersection of memory, resources, and use, this work positions Timimoun as a laboratory for Saharan cities, advocating an adaptive approach that strengthens the oasis's resilience in the face of urban transformations.

ACKNOWLEDGEMENTS

I would first like to express my deepest gratitude to Mr. Mathieu Mercuriali and Ms. Maria Chiara Pastore, who supervised this final year project with care and kindness. Their guidance and support throughout this work were invaluable.

I would also like to thank the faculty members of the « Situations » field of ENSAPVS, who introduced me to the architecture of oases. Their guidance during the early stages of reflection proved to be a valuable project tool.

I wish to express my particular thanks to Mr. Paolo Tarabusi for his commitment and passion, which he successfully conveyed to me in relation to the demanding conditions of the desert context.

I would also like to thank Ms. Nadya Rouizem, who supervised the first phase of this work dedicated to the writing of the research thesis, and who kindly agreed to ensure its continuity during this second phase devoted to the final year design project.

My thanks also go to the inhabitants of Timimoun, who welcomed me with generosity and understanding during my site analysis, and who turned my site visits into genuine human adventures.

I am also grateful for the opportunity to have studied Timimoun with the Union for the Mediterranean, as well as with the teachers and all the students who participated in the Timimoun workshop, whose commitment and exchanges greatly enriched my reflection.

Finally, I would like to thank all those who took the time to engage in discussion with me, to contribute to the reflection, and to support this work through their encouragement.

AI Usage Statement

Artificial intelligence tools were used to assist with the translation of this thesis from French to English. All research, analysis, design development, and conclusions are entirely the author's original work.

FOREWORD

This final year project is part of a trajectory marked by a particular attention to fragile territories. My double degree in architecture and urban design, enriched by a year-long exchange at the Politecnico di Milano, enabled me to broaden my approach to design: to consider architecture not as an isolated object, but as a living system shaped by social, ecological, and cultural issues.

During my first semester of the master's programme in Milan, I had the opportunity to work on the theme of agriculture in fragile territories under the supervision of Ms. Pastore. This experience, conducted in Maputo, Mozambique, proved to be formative. Working in an environment confronted with rapid urbanisation, soil degradation, rising water levels, and a colonial legacy led me to consider architectural design as a tool for territorial regeneration. This relationship between soil, habitat, and resources has since become central to my design approach. Subsequently, my work on Al-Ula, in Saudi Arabia, further developed this reflection around the oasis landscape and the memory of place.

Last year, this line of inquiry was extended through an in-depth research project entitled "Sur-face | Sous-face: Soil as a Witness of Memory. The Oasis of Timimoun." This thesis constituted the methodological and conceptual foundation of the present final year project. It allowed me to approach the oasis not only as an ecosystem, but as a social organism, in which each element contributes to the overall balance.

The research methodology adopted, based on research by design, proved to be decisive. I chose to develop the written thesis and the design project in parallel, in order to establish a constant back-and-forth between analysis and conception. This approach made it possible to build a solid analytical framework directly placed at the service of the project. In my view, it reflects the very essence of the architect's profession today: to design through research, and to research through construction. In a territory as sensitive as the oasis, understanding the context requires a genuine research process, while the project itself becomes a field of experimentation through which knowledge can be advanced.

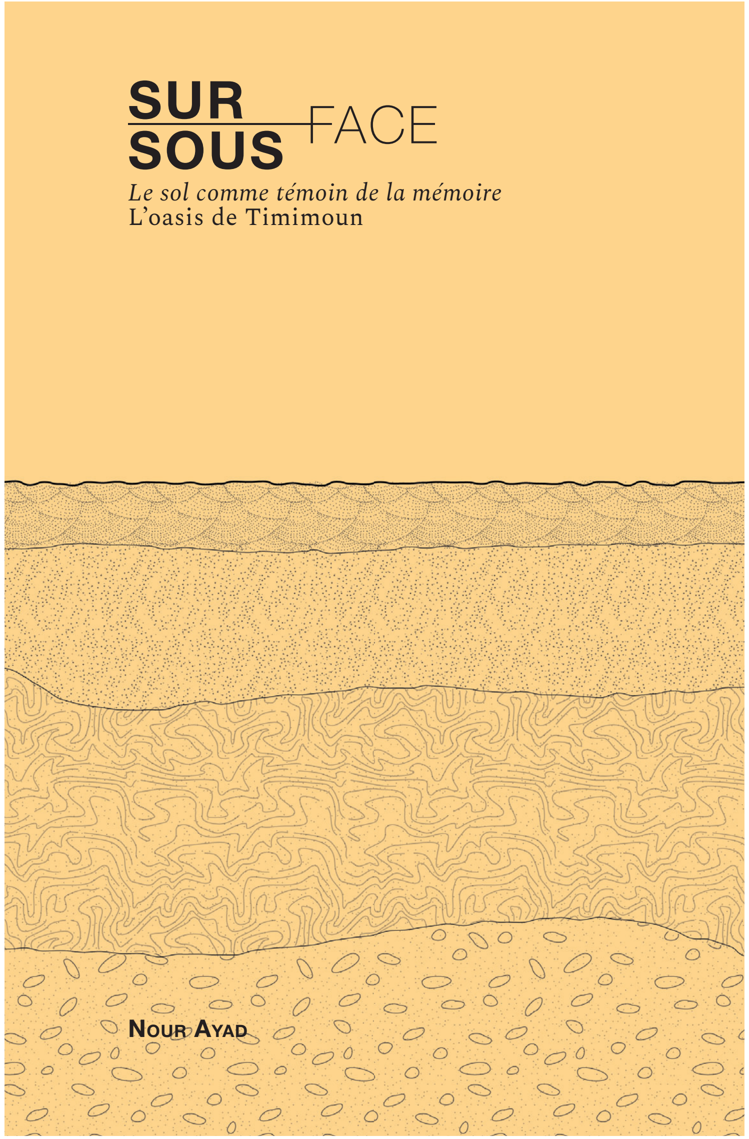
It is within this continuity that this final year project takes place, focusing on Timimoun, an emblematic oasis in southern Algeria. It concentrates the tensions inherent to Saharan territories: the progressive loss of its palm grove, water scarcity, urban growth, and the transformation of ways of life. These changes raise a fundamental question: **How can the oasis be inhabited anew without breaking the bond that connects the community to its resources?**

To explore this relationship, the project is structured around three scales of interpretation: the surface, the soil, and the subsurface. It proposes the reconstruction of a collective housing model inspired by the ksar and the palm grove, in which the community gathers around a productive garden: the new Agham. Conceived as a micro-urban oasis, this central space combines agricultural production, social life, and climatic regulation.

At the scale of the dwelling, the project explores degrees of intimacy and the emerging needs of a young population, while preserving local values and the spatial hierarchy inherent to Saharan culture. Water plays a structuring role: captured, stored, and redistributed through a new blue network extending from the palm grove to the reg, it becomes the driving force of a regenerative urbanism.

The entire system is based on a logic of autonomy and sharing. Each Agham is equipped with a shared borehole supplying the garden, domestic spaces, and collective facilities. Beneath the surface, a system for water recovery and storage regulates flows and prevents flooding. The project explores several possible scenarios of evolution, enabling the city to grow through extensions, appropriations, and hybridisations.

Thus, this final year project is addressed to architects and public authorities of oasis territories, but above all to their inhabitants. It is a project conceived with and for the local population, present and future. Through both form and materiality, as well as through programme, the project is conceived as a kind of toolbox inviting a reconsideration of oasis development. By proposing a contemporary way of inhabiting the oasis—where soil, water, and community once again become the foundations of architectural design—Timimoun is envisioned as a laboratory for the Saharan future, in which the memory of place guides us in restoring meaning to the act of dwelling.



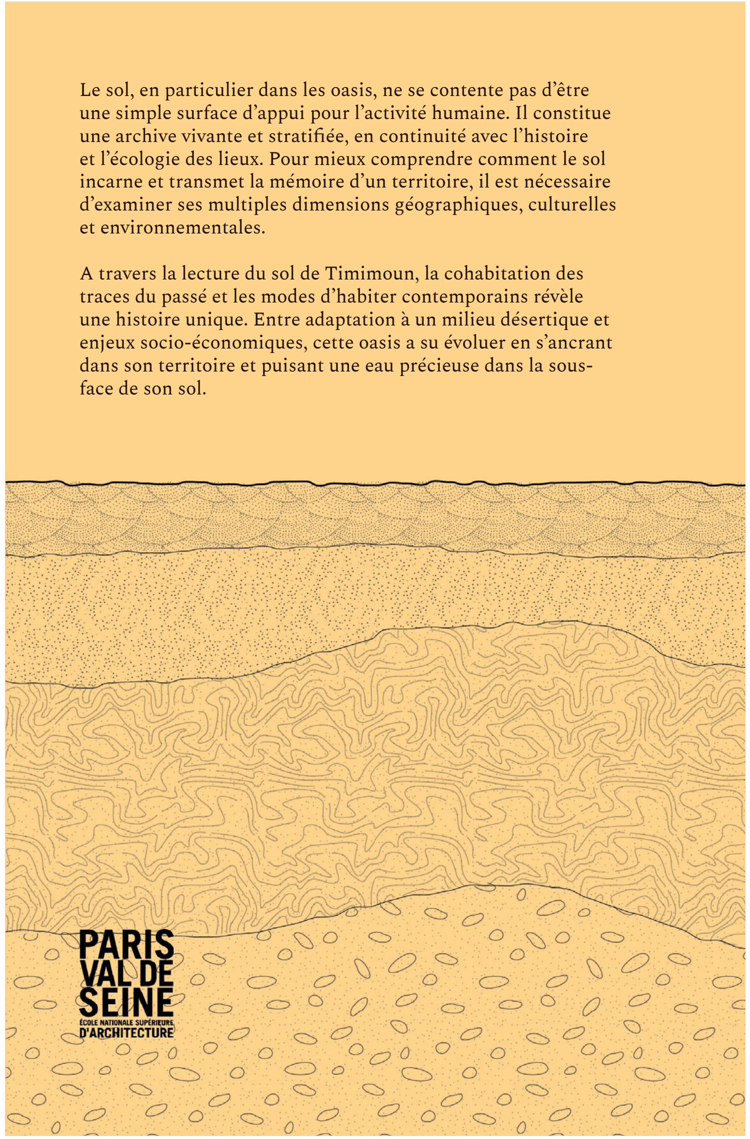


Figure 1 : Première et quatrième de couverture du mémoire de recherche de master. Document de l'auteur

RESEARCH, THE SUBSURFACE OF THE PROJECT

During the writing of the master's thesis (Figure 1), the methodology was primarily based on research by design, combining contextual and historical analysis, field observations and surveys, and the cross-referencing of collected data.

My research by design translated into theoretical reflections concretized during the design exercises. Practical applications and design solutions allowed me to test hypotheses and generate new questions. This process demanded constant flexibility and adaptation. Such an approach is essential for architects, as design both nourishes research and depends on it. The full potential of a project rests on the quality of knowledge and questions applied throughout the process.

This research by design was particularly enabled by participation in an international workshop on the agricultural systems of Timimoun, in collaboration with partner schools and institutions. This collective experience allowed for an in-depth study of the foggaras and the simulation of different scenarios for the territory's evolution.

Field surveys included both spontaneous observation (sketches, photographs, visual notes) and structured observation (comparative plans between the palm grove, the colonial town, and the new urban extensions). This work made it possible to monitor the development of the territory along a stretch of more than three kilometers and to assess its impact on collective memory. The methodology was embedded in a critical reflection, inspired by the work of Alessandro Sartor[1] and Donna Haraway[2].

Interviews with local inhabitants complemented these surveys, providing access to a sensitive understanding of urban and social transformations. In parallel, a comparative study with the oasis of Al-Ula, in Saudi Arabia, broadened the reflection by highlighting convergences and divergences in adaptation strategies for fragile territories in response to environmental and social changes.

Finally, documentary research—particularly at the Archives Nationales d'Outre-Mer and the Algerian Centre for Built Cultural Heritage—enabled the collection of historical maps, images, and surveys of the traditional foggaras hydraulic system. These sources were cross-referenced with contemporary surveys and interviews to reveal the dynamics of territorial transformation and the memory inscribed in the soil of Timimoun.

The core of the research focuses on the soil as a witness of memory. In the oasis of Timimoun, the earth is not merely a support for the city. Sediment layers, irrigation traces, and the palm trees themselves bear the imprint of successive generations. This materiality preserves the memory of agricultural practices, uses, and forms of habitat over time. Studying the soil thus allows us to understand how a community builds itself through time, inscribing its history into the landscape.

This relationship with the soil goes beyond materiality, encompassing a symbolic and cultural dimension. The soil carries stories, legends, and shared memories that make the oasis an emblematic place. From this perspective, the research revolves around a dual objective: to analyse the layers of the soil and to understand how it becomes a vector of memory.

The research centers on a key question: how do the different layers of soil express the memory of a fragile territory? In the oasis of Timimoun, each layer—whether agricultural soils, ruins within the palm grove, or the hydraulic remnants of the foggaras—reflects a historical period and reveals the ecological, social, and political transformations of the territory. The fragility of the oasis, linked to water scarcity, environmental pressures, and urban change, accentuates this stratified reading. This fragility shows that memory is never fixed, but constantly in tension between preservation and erasure. The soil thus becomes a site of negotiation, where the community's capacity to preserve its identity while adapting to change is enacted.

1
2

Memory of Place

The first concept highlighted is that of memory of place. It refers to the way in which a space retains traces of the past and contributes to identity formation. The oasis bears the marks of the generations who have inhabited and traversed it. These marks are not solely material; they are also immaterial, composed of stories, memories, and ritual practices.

Memory of place can be defined as a spatialized memory. While history records chronologies, space offers a palimpsest, a superposition of layers that can still be read, even if partially erased. The oasis of Timimoun functions both as a material archive and as a medium for symbolic transmission.

This concept also highlights the role of the soil as a mediator between past and present. Inhabitants refer to it to legitimize their belonging, to remember their ancestors, and to project future uses. Memory of place is therefore not fixed; it is dynamic, constantly reactivated through practices and narratives. Memory and place are inseparable, for to remember is always to remember a place.

Inhabiting the Palm Grove

The second essential concept is inhabiting the palm grove. To inhabit is not merely to occupy a space; it is a way of living, practicing, and experiencing a place. In the oasis, the palm grove is far more than an agricultural area: it is the framework of daily life, an environment where sensitive, social, and spiritual relationships are woven.

Inhabiting the palm grove involves attuning to natural rhythms, the alternation of light and shadow, water scarcity, and soil fertility. Every act of cultivation, every walk along the paths, every encounter in the shade of the palms inscribes the inhabitants in a relationship of coexistence with their environment. The palm grove illustrates that space is not passive; it engages in dialogue with those who occupy it.

Furthermore, inhabiting the palm grove means maintaining a continuity between nature and culture. It is a social and cultural construct, shaped by humans who have organized and symbolically invested in it. To inhabit this space is to position oneself within a long history, shaped by memory but also by continuous evolution and adaptation to the environment.

Building Community

The third concept is building community. In the oasis, space is not only experienced individually; it is a place of collective life that structures social relations. Agricultural practices, religious festivals, and the shared management of water and land are occasions where the collective comes together and is reinforced.

Building community emphasizes that space enables social cohesion. The community is constructed through shared practices, such as the collective management of the foggaras. In addition, daily practices embedded in space : walking, cultivating, trading, produce the commons. In this sense, the palm grove functions as a social stage.

Finally, building community entails a dimension of transmission. In the oasis, agricultural gestures, stories from elders, and collective rituals ensure the continuity of the group over time. To build community is, therefore, to maintain a living shared memory.

At the conclusion of this research, several questions arise. First and foremost, the issue of the articulation between memory and adaptation:

How can architecture support the transformation of Saharan oases by reconciling memory of place, new modes of inhabitation, and resilience?

This central question opens multiple lines of inquiry that guide the project. It invites a critical examination of the relationship between memory and adaptation, questioning how one can engage with the history and traces of a place without freezing the oasis into a nostalgic image. The challenge lies in responding to climatic, social, and economic changes while preserving the balances that underpin the community. Transformations linked to climate, production practices, and migration compel a reconsideration of what it means to inhabit and to build community in a context of change.

Furthermore, the question explores the role of architecture in the evolution of social practices and consumption patterns, as well as the position of the architect in planning urban and domestic uses. Water management, land use, and social connections thus emerge as central concerns within the design process, alongside the development of tools capable of supporting transformations while preserving the ecological, social, and cultural balances of the palm grove.

Finally, this reflection situates itself within the broader challenge of resilience in Saharan cities. Confronted with extreme climatic conditions and rapid transformations, the project investigates how architecture—from urban strategy to micro-scale interventions—can propose solutions that maintain viable spaces and foster a responsible mode of inhabitation, one that is chosen rather than imposed.

The study of the Timimoun oasis highlights the central role of soil as a witness of memory. Through the research process, it became possible to understand how a place can carry memory, how it is inhabited in an intimate relationship with nature, and how it serves as a support for collective life.

It is also essential to understand how domestic and urban practices influence the built form, and conversely, how architecture can guide, support, or transform these practices. This underscores the architect's role in planning activities, not only at the urban scale but also within domestic spaces, while integrating social, cultural, and economic dimensions of the territory.

Within this framework, the management of water, land, and social relations emerges as a fundamental concern in the design process. Intervening in a sensitive space such as the palm grove requires negotiating a fragile balance between memory, modes of inhabitation, and community life. The project thus seeks to explore architectural, urban, and programmatic tools capable of supporting ongoing transformations while preserving the traces, uses, and relationships that give meaning to the lives of the inhabitants, in order to avoid rupturing existing social dynamics.

The three structuring concepts—memory of place, inhabiting the palm grove, and building community—serve both as analytical lenses for understanding the oasis and as guiding principles for proposing solutions.

The role of the project, therefore, is to accompany these transformations while respecting the material and immaterial traces that structure the place.

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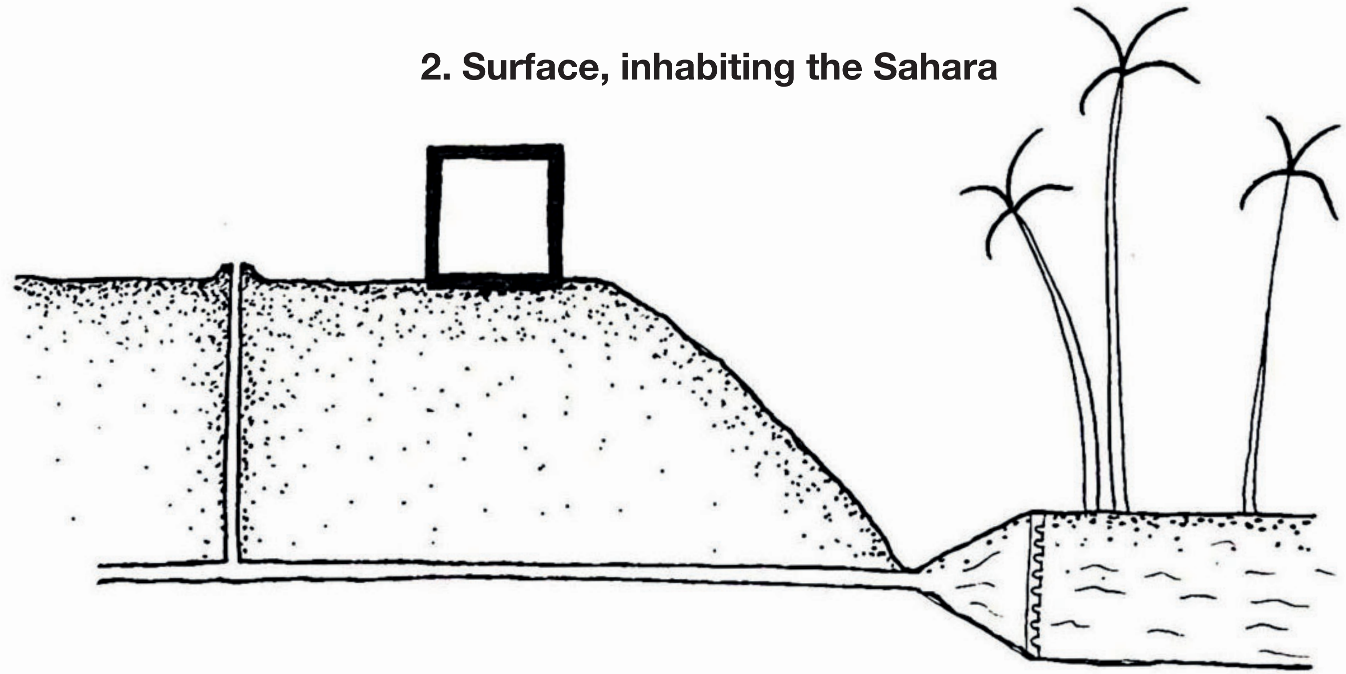
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INTRODUCTION

This project is primarily intended for the inhabitants of Timimoun, a Saharan city of approximately 40,000 residents, whose way of life, environment, and territorial balance are currently undergoing profound transformations. Every aspect of the project has been designed to respond to their daily needs, while also supporting long-term development in a fragile territory exposed to multiple pressures. The palm grove, a historic pillar of the oasis, is gradually degrading; climate warming increases water scarcity; population growth and the rise of tourism alter local uses and priorities; finally, the memory of the place is fading in favor of imported models, often unsuitable for the Saharan context.

In response to these challenges, the project proposes an approach rooted in local knowledge and the resources offered by the soil of Timimoun. Water, earth, stone, vegetation, and topography become the very foundations of architectural and urban reflection. The aim is not to freeze the past, but to draw inspiration from it to address current needs and anticipate future developments. Within this framework, the concepts of Agham and Djnen emerge as essential references. This original typology underpinned the formation of the oasis: dwellings made from local earth, protective against external threats, combined with a fertile interior garden ensuring both subsistence and coolness. The system was made possible by an ingenious hydraulic infrastructure, the foggara, which ensured equitable and sustainable water distribution.

The project is structured around three main themes:
Saharan soils;
Surface, inhabiting the Sahara;
Subsurface, the blue gold.

The first section analyzes how the relationship with the soil has shaped spatial organization, flows, and settlements, as well as the very structure of architecture, from wall composition to construction systems.

The second section focuses on inhabitation, showing how the Agham and Djnen can be reintegrated into the contemporary city, revitalizing the palm grove and generating new social and economic dynamics within the selected neighborhood.

Finally, the third section develops a new water management system, conceived as a contemporary continuation of the foggara, which has now become obsolete but still carries relevant principles.

Through these three axes, the project seeks to address the following central question:
How can the foundational elements of the Timimoun oasis be reinterpreted to strengthen the resilience of the territory in the face of climatic, social, and cultural transformations?

Each major section is composed of two analytical subsections, enabling an understanding of the context, mechanisms, and challenges, followed by a project-oriented subsection. In this way, the "New Agham" offers a comprehensive and coherent response to current challenges, reaffirming the link between architecture, soil, and water as the basis for sustainable development firmly rooted in the identity of Timimoun.

1. SAHARAN SOILS

1.1. Territorial Specificities

Sahara

The Sahara, the largest desert on the planet, is an expanse of sand covering approximately 9 million km². It stretches from the Atlantic Ocean to the Red Sea over more than 6,000 km, and from north to south, between the Mediterranean Sea and the Sahel, over more than 2,000 km. Between plains and mountain ranges, the landscape is primarily composed of rock and gravel; contrary to popular belief, sand dunes occupy only a small portion of the desert (light grey areas on maps). Eleven North African states share the Sahara Desert.

The Saharan climate is classified as arid and desertic, with hot and dry conditions. Daytime temperatures vary greatly from nighttime temperatures. Humidity remains very low, resulting in rare rainfall and limiting vegetation cover.

Rainfall is irregular and varies across the region: in the northern Sahara, it generally falls in winter, while in the south, it occurs as tropical summer showers. The Nile is the only river in the region that flows continuously. In contrast, oueds (riverbeds that are usually dry) fill only after rare rainfall events.

Within this harsh landscape, oases stand out as exceptions. Palm groves generally develop where groundwater or natural springs are present, creating a striking contrast with the surrounding desert environment.

Traditionally, the Sahara has been an open and traversed territory. Throughout history, it has served as a refuge for numerous ethnic and religious minorities. In the medieval period, trade routes crossed the entire desert, from north to south between the Mediterranean and the Sahel, as well as from east to west, following paths used by merchants and pilgrims on the Hajj route (see map). Major oases such as Timimoun, Nefta, and Siwa functioned as convergence points where traders sold goods, forged social ties, and rested during arduous desert journeys.

Until the colonization of the Sahara by Western powers, the desert was perceived as a vast space of exchange, where people and goods moved freely, without the borders known today. The major caravan trade routes active in the Middle Ages continued to operate into the 19th century (see map).

Following the penetration of the Sahara by Western armies, the traditional trans-Saharan network was drastically altered. Its organization became militarized: borders were drawn with precision, ignoring the irregularities of the terrain. The primary objective was to control populations and trade. This restructuring of the Saharan network profoundly impacted local connections and weakened nomadic practices. Even after the withdrawal of Western troops, the military organization left lasting marks on Saharan societies. Until the mid-20th century, intercity connections remained fragile.

Between 1945 and 1965, population growth in the Sahara remained moderate, increasing by 1.5 to 2 million people. From this period onward, more sustained demographic growth emerged, gradually accelerating to reach approximately 5 million by the end of the 20th century. This expansion resulted from both a high birth rate and internal migratory movements within the continent, facilitated by large-scale development projects and urbanization initiatives implemented by newly independent states. In the Maghreb portion of the Sahara, settlements exceeding 100,000 inhabitants became increasingly common. In contrast, the Sahel, less economically developed, experienced slower urbanization.

Two forms of urban settlements coexisted. Ancient cities, often marginalized, gradually declined unless revived by governmental initiatives. At the same time, modern urban centers emerged, designed by architects and urban planners often external to the region. These urban projects, frequently conceived without fully considering local climatic conditions or inhabitants' lifestyles, often struggled initially to adapt to Saharan realities.

3 et 4 PLIEZ. O. (2011). Les cités du désert : Des villes sahariennes aux saharatowns.

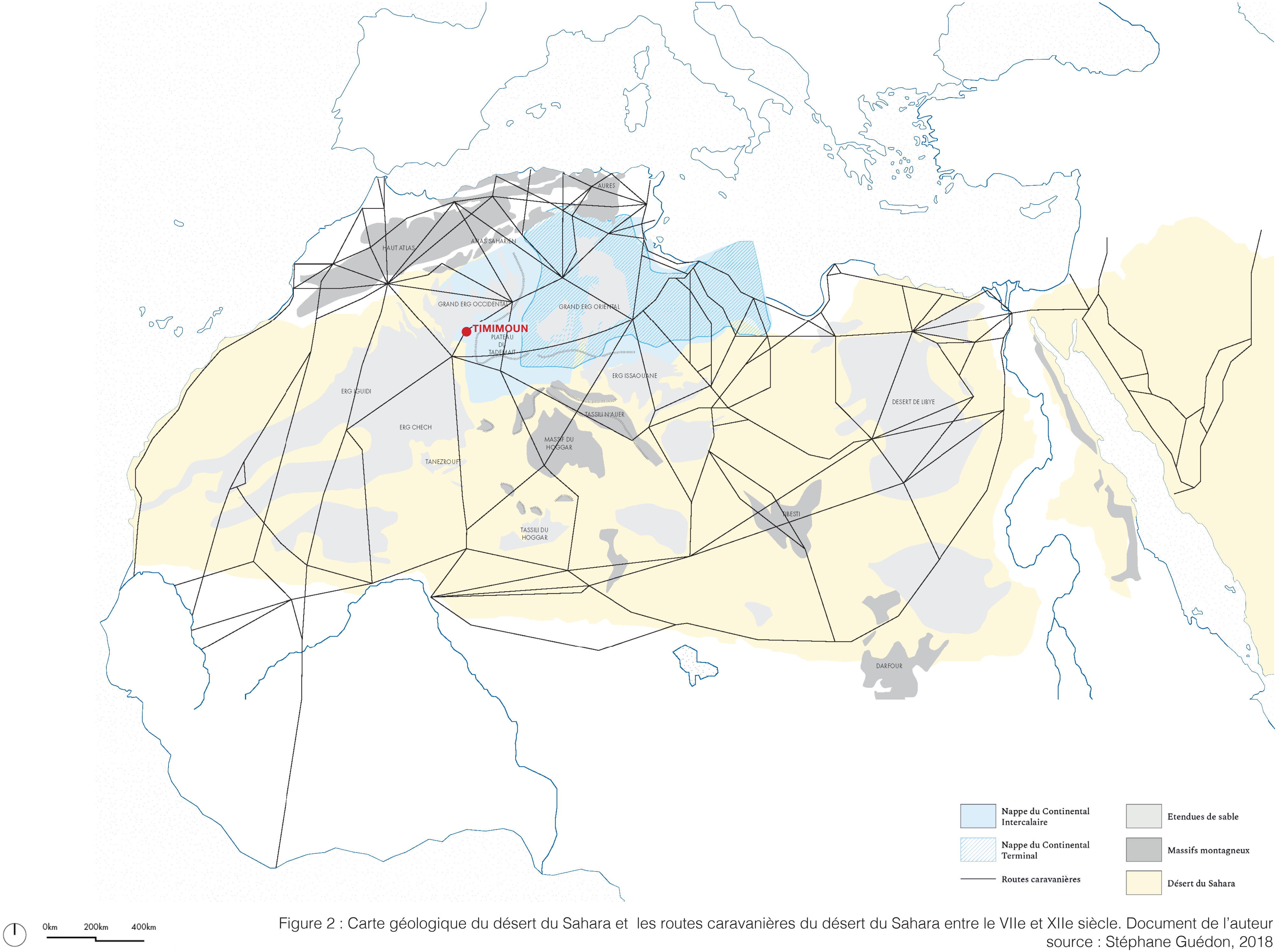


Figure 2 : Carte géologique du désert du Sahara et les routes caravanières du désert du Sahara entre le VIIe et XIIe siècle. Document de l'auteur
source : Stéphane Guédon, 2018

Gourara

Within the complexity and diversity of the Sahara, the Gourara region occupies a singular position. Nestled between the Grand Erg Occidental, a vast sea of dunes, and the Reg of Mguiden, an arid stony plateau (see map), Gourara lies at the intersection of multiple geological formations as well as sebkhas—salt flats—whose mineral-rich soils reflect a long process of evaporation.

The soils of this region belong to the sodic soil family, classified as non-degraded saline soils depending on depth and salt concentration. Three main types can be distinguished: lightly or moderately saline soils, highly saline soils, and soils covered with gypsum or gypsosaline crusts, which are harder and more restrictive for agriculture. Paradoxically, these pedological constraints have contributed to the development of an agricultural and social system adapted to extreme conditions.

Like much of the Algerian Sahara, Gourara relies on the Continental Intercalaire aquifer (see SASS cross-section), a gigantic underground reservoir formed millions of years ago during a period when the climate alternated between wet phases and prolonged droughts.

During rare rainfall events, the beds of temporary rivers, known as oueds, fill briefly, transforming the valleys into unpredictable torrents. These floods, often intense, flow over the surface without significant infiltration, as the soils, too dry and compacted, struggle to absorb water. For this reason, although oueds are omnipresent in the landscape, they do not constitute a reliable source of water supply.

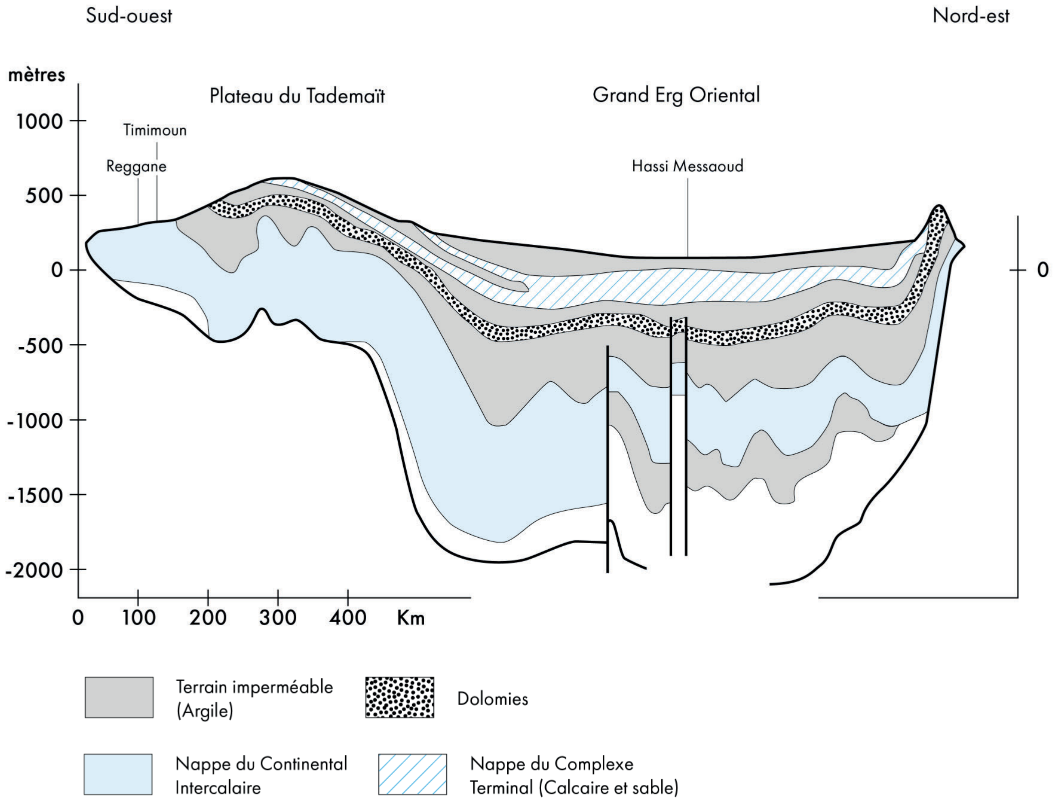


Figure 3 : Coupe hydrogéologique du SASS. Document de l'auteur
source : Vanessa Rousseaux (2004) et UNESCO (1972)

Figure 4 : Carte de la région du Gourara. Document de l'auteur
source :Bisson (1999) et Schrader (1894)

Timimoun

Timimoun s’étend à environ 260 mètres d’altitude au cœur du Sahara, sous les coordonnées 29,26° nord et 0,24° est. Son climat désertique, est rythmé par une chaleur intense, une sécheresse quasi permanente et des amplitudes thermiques importantes entre le jour et la nuit.

Les températures suivent un cycle annuel particulièrement contrasté. En hiver, les matinées peuvent être fraîches, proches de 5 °C, tandis que les après-midis tournent autour de 20 °C. À partir du printemps, la chaleur s’installe rapidement : en avril, la moyenne dépasse déjà les 30 °C. L’été atteint ensuite des valeurs extrêmes, souvent comprises entre 40 et 45 °C, avec un pic en juillet et août. À cette période, le soleil domine sans partage et les nuits, bien que plus supportables, restent chaudes, rarement en dessous de 27 à 30 °C. En automne, la température retombe progressivement, revenant autour de 25 °C en octobre avant de retrouver la douceur hivernale vers la fin de l’année.

Les précipitations sont extrêmement rares. Les mois de l’année peuvent s’écouler sans qu’une seule goutte de pluie ne tombe. La moyenne mensuelle de jours de pluie significative (plus de 2 mm) est proche de zéro, ce qui confirme la sécheresse permanente du climat saharien. Les rares épisodes pluvieux se produisent de façon isolée, souvent entre novembre et mars, mais ils restent trop faibles pour influencer réellement l’aridité du sol.

En général, un vent faible oscille entre 2 et 20 km/h. Toutefois, certaines périodes peuvent voir souffler des vents plus forts, notamment lors des épisodes de sirocco, ce vent chaud et sec venu du sud-est qui transporte le sable. Accentuant l’ensablement des jardins et maisons et réduisant considérablement la visibilité.

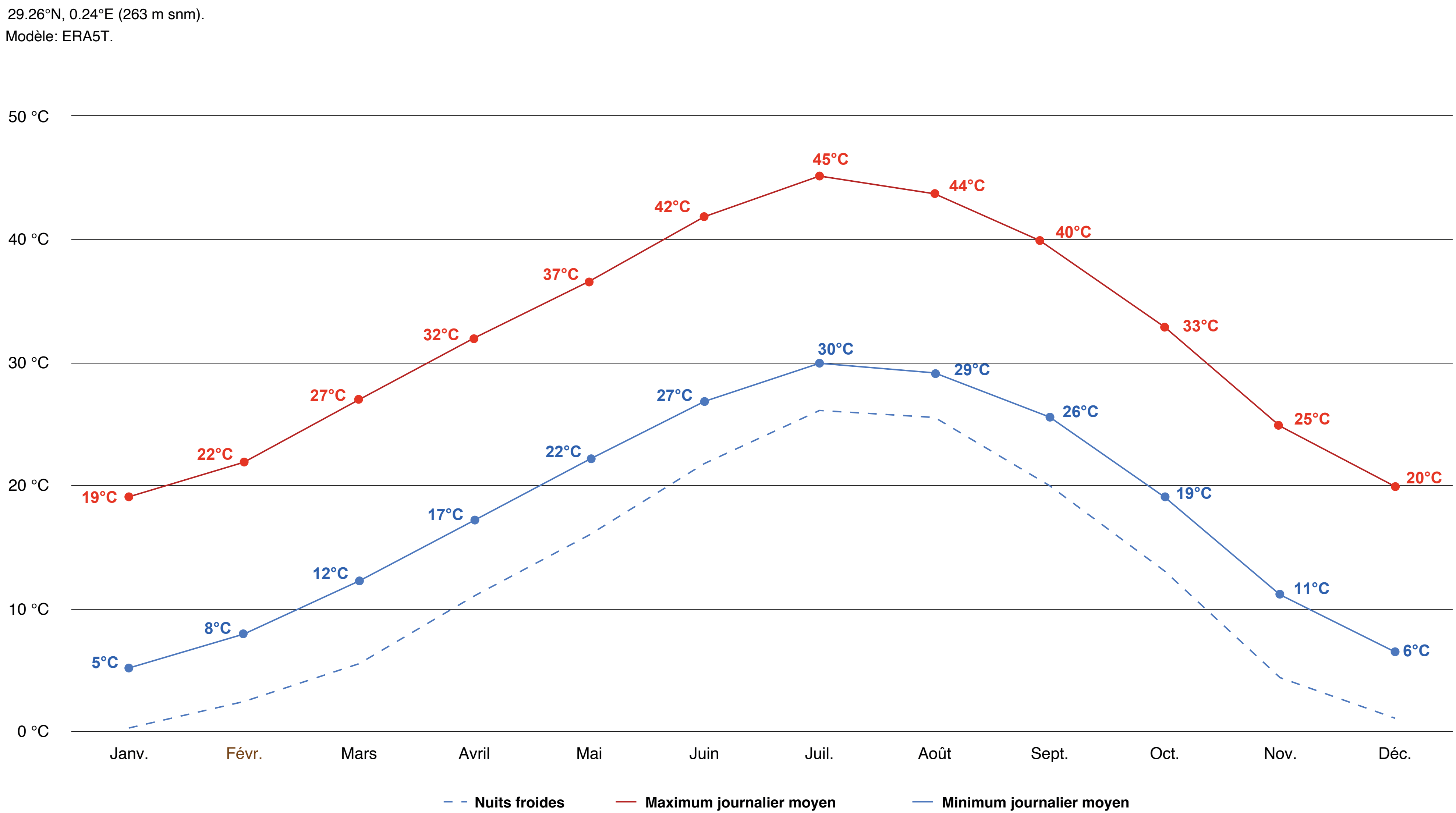


Figure 5 : Données de température de la ville de Timimoun. Illustration de l'auteur
source : *météoblue*

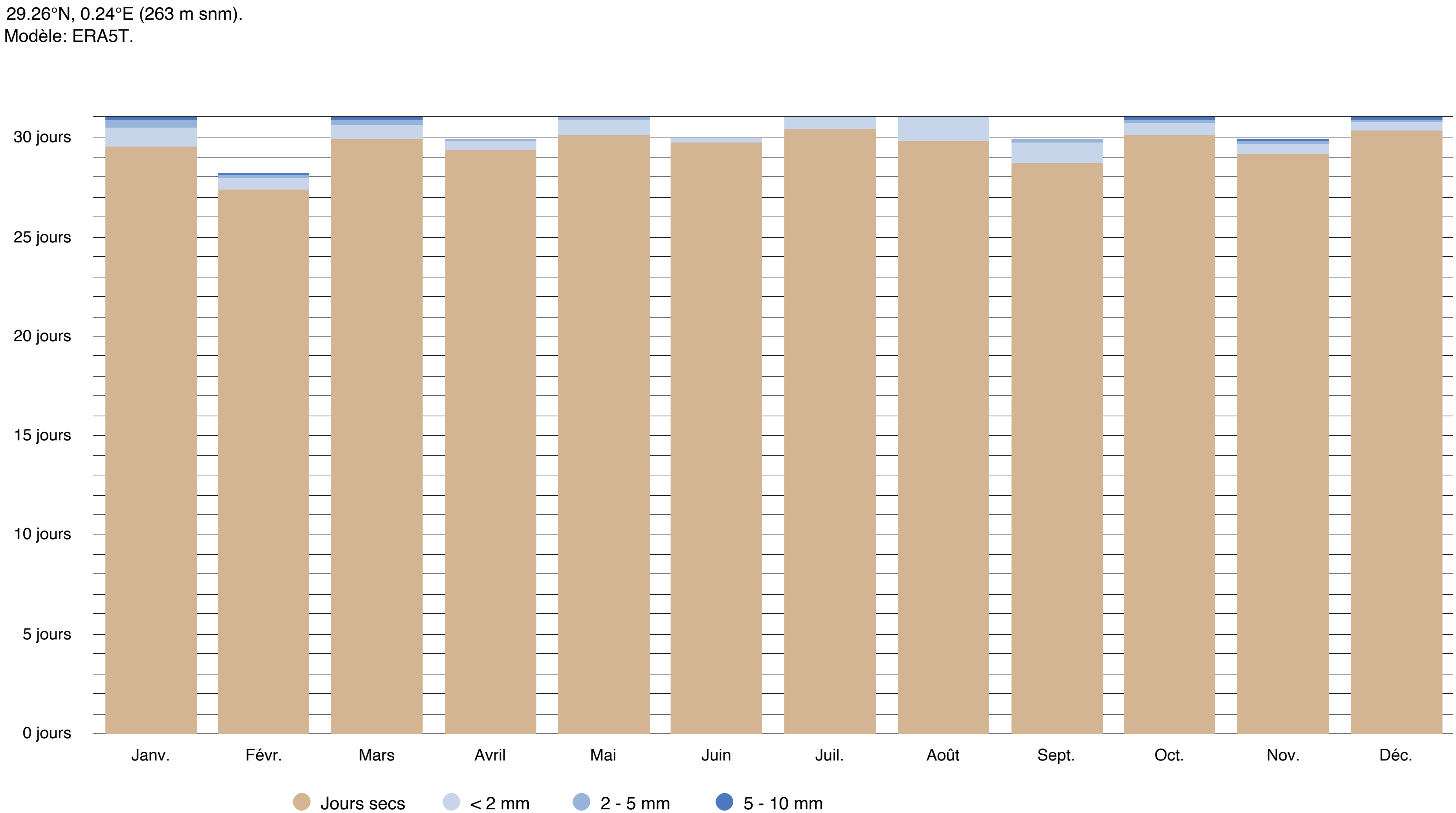


Figure 6 : Données des précipitations de la ville de Timimoun. Illustration de l’auteur
source : *météoblue*

29.26°N, 0.24°E (263 m snm).
Modèle: ERA5T.

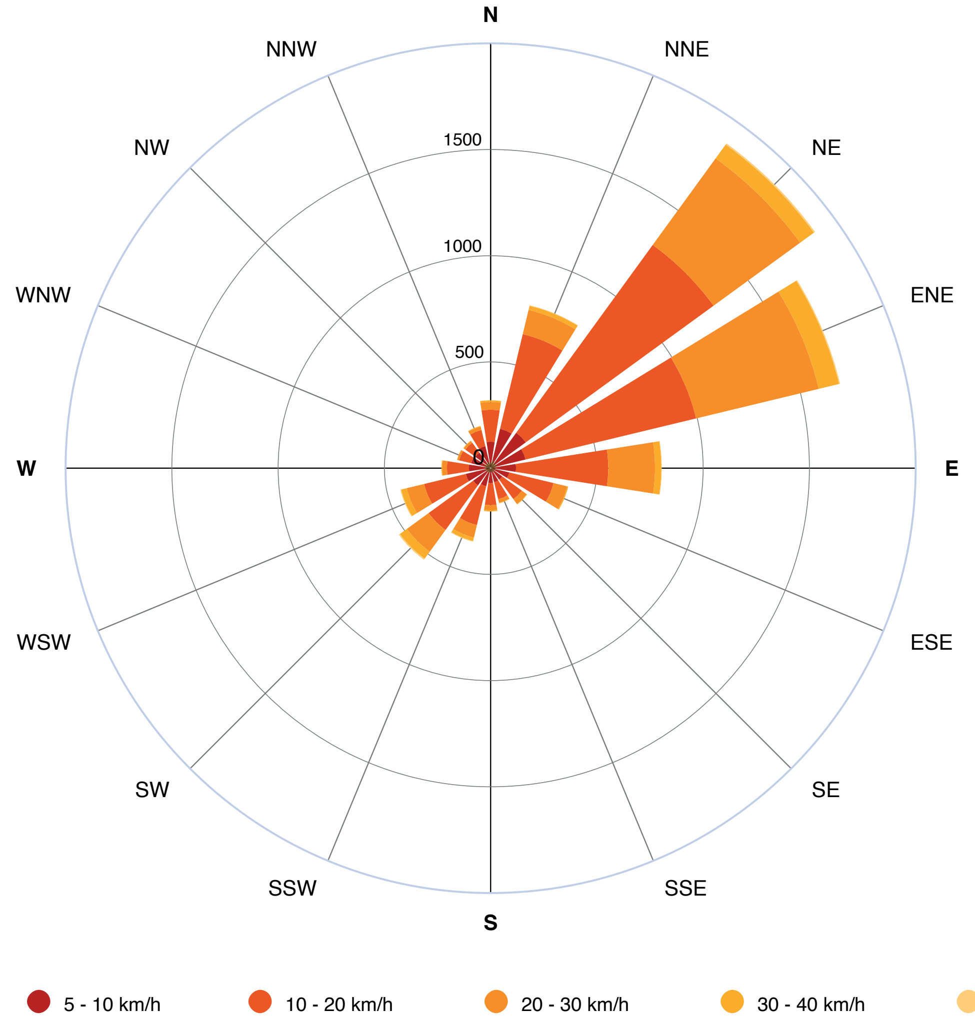


Figure 7 : Données des vents de la ville de Timimoun. Illustration de l'auteur
source : *météoblue*

1.2. Supports and Ressources

To better understand how past populations adapted to such a harsh climatic context, it is necessary to examine their modes of inhabitation.

Construction techniques in the Gourara are based on the methodical use of local resources, each mobilized for its specific properties. Foundations, a crucial element for building stability, are systematically made of stone. Tafza, a porous sedimentary sandstone considered the bedrock, constitutes the main material, providing a solid base for construction. Foundations generally reach a depth of around 50 cm, sufficient to anchor structures on dry, stable soils.

Other types of stone complement this framework. Flat stones, locally called Hajar Al-Safah, are sourced from limited rocky areas. They were historically used to construct Ighamawen, as well as Muslim funerary structures. Their use has gradually decreased, now focusing primarily on decorative applications. Harder, non-porous quartzite stones, Hajar Al-Sami, are distinguished by their durability. They were also employed in Ighamawen construction and remain in use today, primarily found on plateau surfaces such as the Tademaït.

Walls, for their part, are built in adobe, following a traditional technique based on the production of sun-dried clay bricks. Two types of soil are used: Trab El-Miyet, the arable topsoil layer (20–30 cm), containing minerals, humus, air, and water; and Trab El-Hay, a richer clay extracted from the T'gazza. (Figure 8)

Trab el-miyet
Terre morte

Tqaza
ou Trab el-hay
Terre vivante

Tafza

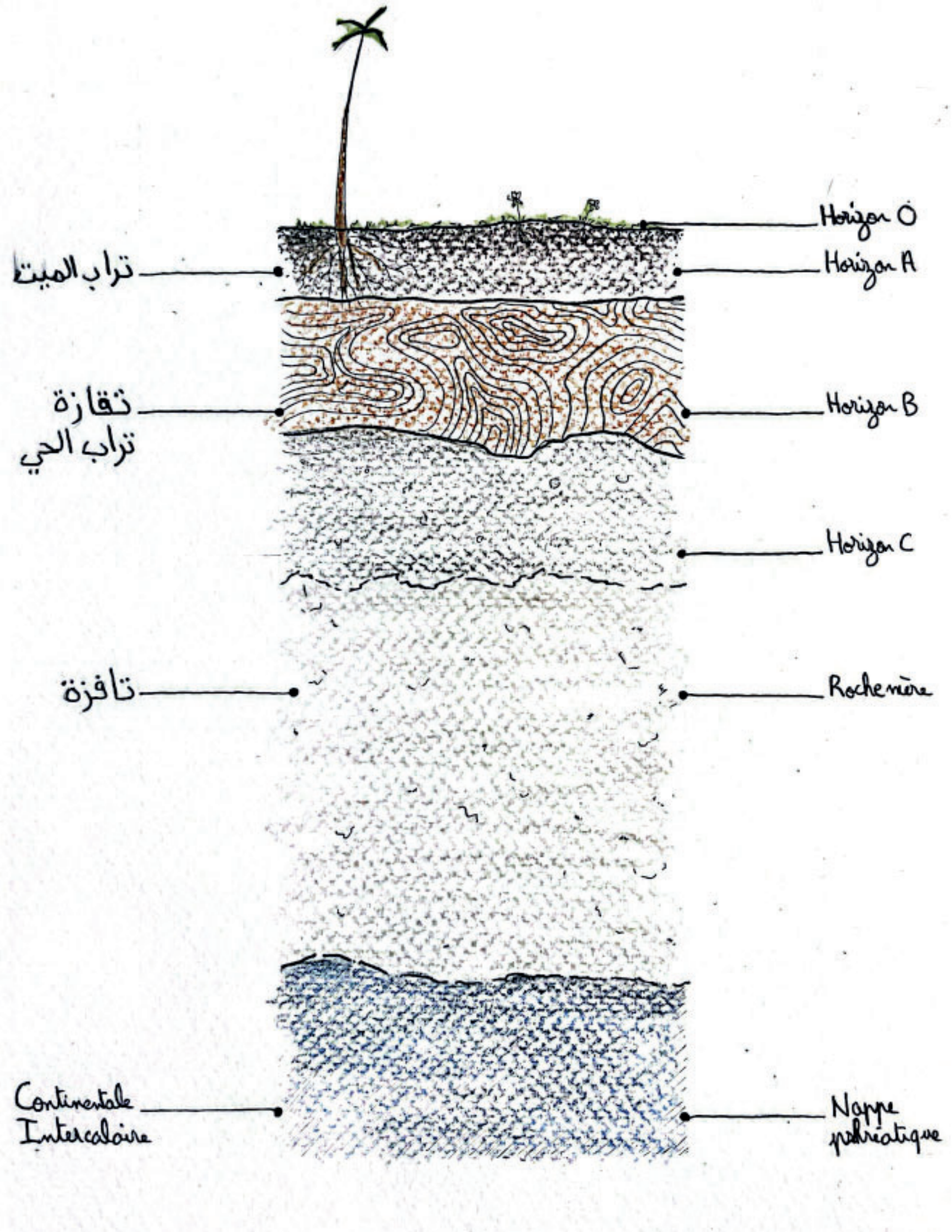


Figure 8 : Coupe des différentes strates de sol. Illustration de l'auteur
Source : Otmane et Kouzmine (2009)

Mixed with water and natural fibers in proportions adapted to their intended use (bricks, mortar, plaster), the soils are worked in a 2 m × 2 m pit, where the material rests for several days. Molding is then carried out in frames placed on a sanded surface to prevent adhesion. Standard brick dimensions are 30 × 15 × 15 cm or 35 × 15 × 15 cm. The mixture is pressed into the mold to prevent air bubbles, then dried for two to three days on each side. Once formed, bricks are stored under shelter to preserve their structural properties.

Wall thickness varies according to requirements: toba corresponds to the thickness of a single brick, while toba o noss equals one and a half bricks. These adjustments allow the strength and performance of walls to be adapted to the specific constraints of the building.

Field observations revealed the inhabitants' attachment to the ancestral "lougma" technique, a facade finishing method using clay balls projected onto walls. Its implementation reflects a sensitive relationship between the craftsman's hand and the material. According to the maalem, this direct contact influences the thermal performance and durability of the wall, making each gesture part of the memory of the place.

Regarding horizontal structural elements, the date palm is used in its entirety, with each component serving a specific function. Four main parts are generally distinguished. The trunk can be used as a load-bearing beam or converted into joists. Trunks are stored for a minimum of three months, elevated to promote air circulation and reduce termite risks.

The second, third, and fourth components correspond to the petiolar, spiny, and foliated parts of the leaves. Each of these elements has a specific role within the construction system, notably in floor construction. Palm leaves are also used to form windbreaks along roads and around agricultural plots. Leaves are typically stored in a cool environment until use.

Today, palm trunks are often replaced by steel beams to achieve longer spans. However, arching techniques already existed and allowed for greater structural capacity, particularly in sacred spaces.

This construction system, based exclusively on local resources, demonstrates a precise mastery of materials and a genuine adaptation to local conditions.

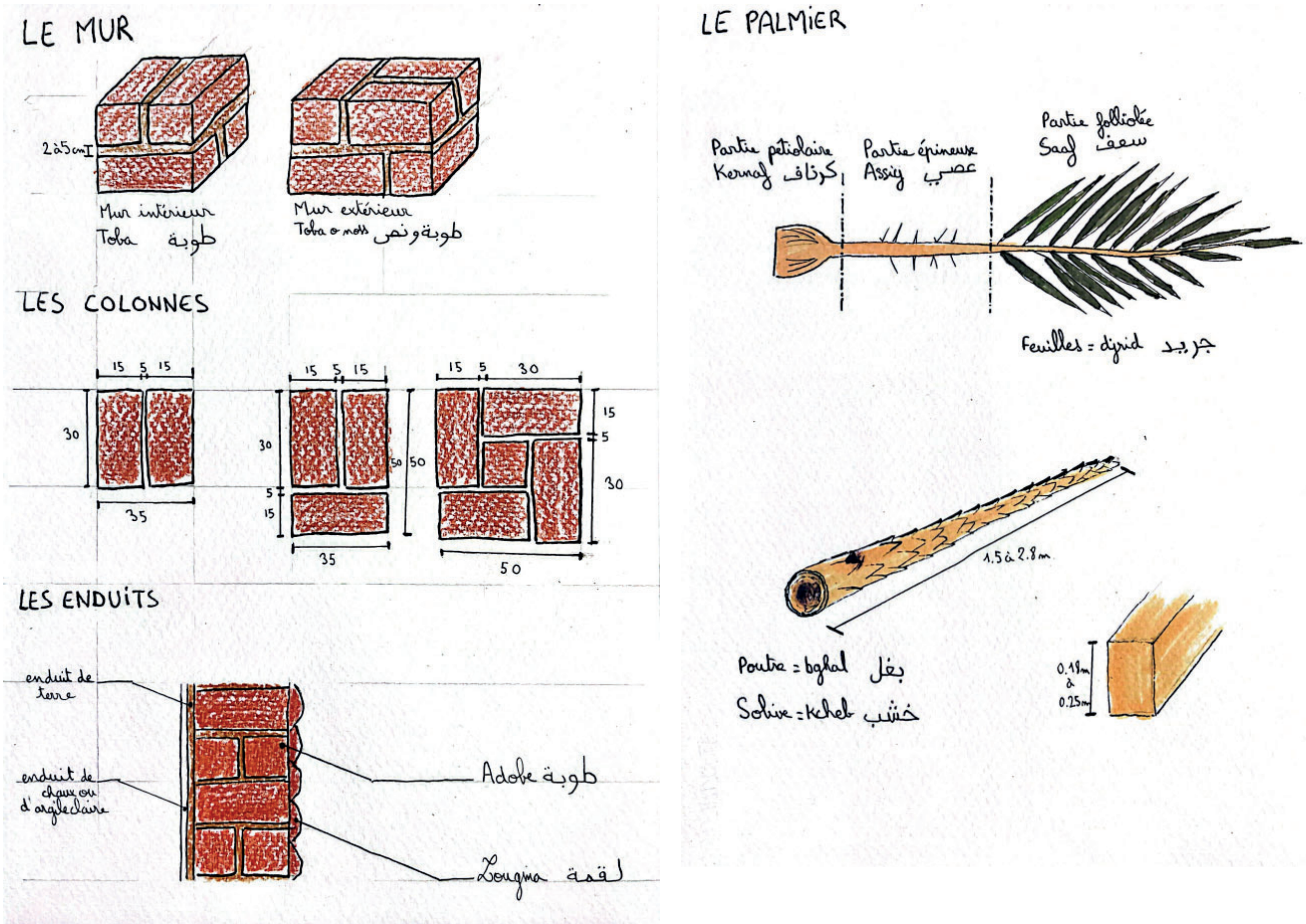


Figure 9 : Les assemblages en terrue crue et en bois. Illustrations de l'auteur
Source : Otmane et Kouzmine (2009)

1.3. Materials

Within the city, the main flows, whether commercial or tourist, continue to structure the territory. The project builds upon these dynamics to propose an urban reinterpretation based on improved accessibility. A new street network is envisioned to facilitate pedestrian circulation throughout the city. This route connects different neighborhoods and revolves around new housing, whose ground floors host local facilities and services, thus promoting an active and balanced neighborhood life.

The relationship to the soil, central to the preceding research, remains a key element. The project is part of a broader reflection on adapting architecture to the Saharan climate of Timimoun, prioritizing passive, low-energy solutions and relying on local materials. In a context characterized by high temperatures, strong solar exposure, and significant diurnal temperature swings, the main challenge is to design an envelope capable of limiting heat gains during the day while maintaining stable thermal comfort indoors, without relying systematically on air-conditioning systems.

From interior to exterior, the wall is composed of a 2 cm lime plaster, a 35 cm load-bearing adobe wall, a 15 cm insulating layer made of densely palm-fiber reinforced sun-dried clay bricks, and finally, a 1 cm external clay-lime wash.

The load-bearing adobe wall constitutes the main structural element of the project. Raw earth, an abundant locally available resource, possesses high thermal capacity and excellent inertia. It allows the storage of nocturnal coolness and delays the transmission of external heat to the interior.
The 35 cm thickness was chosen as a compromise between thermal performance, structural stability, and constructibility. This mass provides a thermal lag of approximately sixteen hours, particularly suited to desert climates: heat absorbed during the day is released when outdoor temperatures are lower, facilitating nocturnal ventilation.

The interior face of the wall is protected by a 2 cm lime plaster. This layer plays a crucial role in regulating indoor hygrothermal conditions. Lime, permeable to water vapor, is compatible with raw earth and prevents moisture accumulation within the wall. The mixture consists of air lime, fine sand, and water.

On the exterior of the adobe wall, a 15 cm insulating layer is installed, composed of lightweight sun-dried clay bricks with a high proportion of palm fibers. These bricks are non-structural; their function is exclusively thermal. The addition of plant fibers reduces material density and increases porosity, significantly lowering thermal conductivity. The mixture consists of sieved local soil, chopped palm fibers, and a small percentage of lime. This mild stabilization improves material cohesion, limits shrinkage during drying, and enhances durability on the facade.

The stability of this exterior insulating layer is ensured by its direct connection to the adobe wall. The insulating bricks are laid with a clay-lime mortar, providing material and hygroscopic continuity between the different wall layers. Integrated binding devices ensure the stability of the finish and prevent detachment over time. The wall thus functions as a homogeneous system, without synthetic membranes or vapor barriers, in accordance with the natural behavior of earthen materials.

Protection of the earthen facade is reinforced by the regular integration of flat stones acting as drip edges. These stones are laid horizontally between each row of vertically mounted insulating bricks. Their function is to interrupt water runoff along the facade and direct flows away from the wall surface, reducing erosion and progressive material degradation.

The stones used are local flat stones, embedded at a minimum depth of 8–10 cm in the masonry, ensuring stability and proper load transfer. Each stone projects 3–5 cm beyond the outer wall surface, providing sufficient overhang to deflect water away from the wall. A slight outward inclination of 5–10% is applied during installation to facilitate water runoff and prevent stagnation. The stones rest on a clay-lime mortar bed, ensuring good adhesion while remaining compatible with raw earth. Repeating these drip edges along the height of the facade provides long-lasting protection and contributes to the architectural expression of the project, highlighting the constructive stratification of the wall.

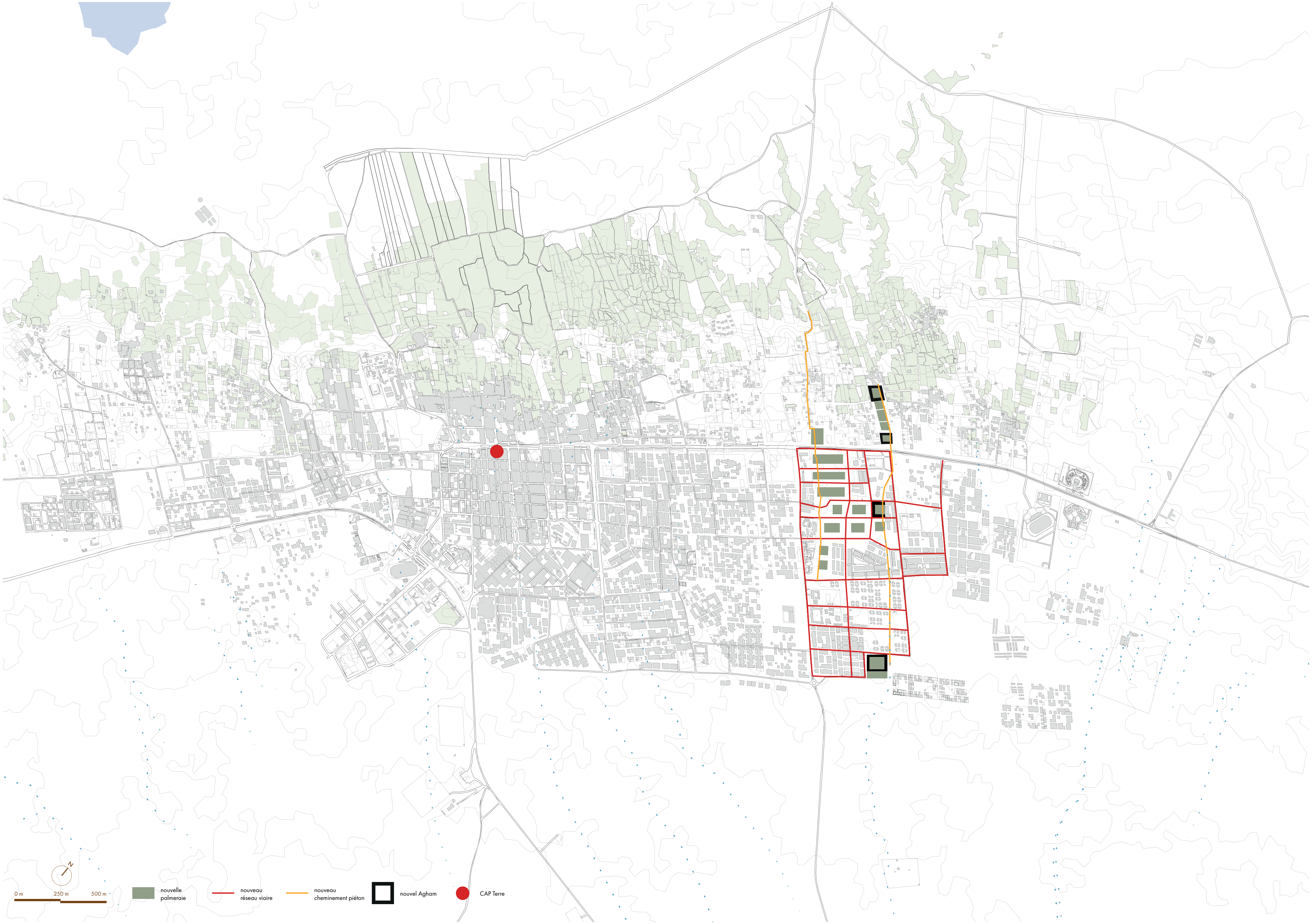


Figure 10 : Carte du nouveau réseau viaire à Timimoun. Document de l'auteur.

The final protection of the wall is achieved through an exterior clay-lime wash applied in a thin brush-on layer. This finish consolidates the surface and reduces water absorption without masking the materiality of the earth. The binder dosage remains deliberately low to preserve wall breathability and allow for simple maintenance over time.

To protect the earthen walls from ground contact and capillary rise, the project integrates a stone plinth along the entire height of the basement level (R-1) and the ground floor. The basement is fully constructed in lime-bound stone masonry, providing excellent resistance to moisture and mechanical stresses. Basement walls are finished with a lime plaster, ensuring hygrometric regulation and structural durability.

On the ground floor, the stone plinth is left exposed. It provides mechanical protection against impacts, splashes, and wear from daily use. This mineral base clearly marks the transition between the ground and the earthen elevations, visually anchoring the building in its context and reinforcing its architectural expression. A continuous stone band at the top of the plinth prevents capillary moisture from rising into the adobe walls.

Thermally, this wall composition achieves an overall resistance of approximately 3.3 $m^2 \cdot K/W$, significantly reducing heat flux through the wall. Heat transmission to the interior remains low, while the thermal inertia of the adobe wall ensures a time lag consistent with the desert day-night cycle. This passive system contributes to long-lasting thermal comfort and minimizes reliance on air-conditioning.

The project's execution relies on the support of CAP Terre in Timimoun, a key organization promoting earthen architecture in the region. CAP Terre plays a central role in transmitting local know-how, experimental construction, and adapting traditional techniques to contemporary challenges. Their expertise ensures material selection, mix ratios, brick production, and construction methods are technically controlled and contextually appropriate. This collaboration also presents an opportunity for local youth, providing training and temporary employment in the building sector.

Through this project, architecture becomes an extension of the territory. The use of earth, palm fibers, and stone, combined with proven and reinterpreted techniques, offers a climatic, ecological, and cultural response suited to Timimoun. The project demonstrates that construction with local, bio-based materials is not a regression, but a contemporary, relevant, and sustainable approach, addressing current challenges while valorizing local resources and know-how.

By prioritizing short supply chains and locally sourced materials, the project embodies an ecological and context-sensitive approach, providing living conditions adapted to the Saharan climate. Cooler spaces, more accessible infrastructure, and a materiality in harmony with the landscape support a lifestyle coherent with the oasis. In this way, the city regains its role as a place of anchoring, where inhabiting the Sahara regains its full meaning.

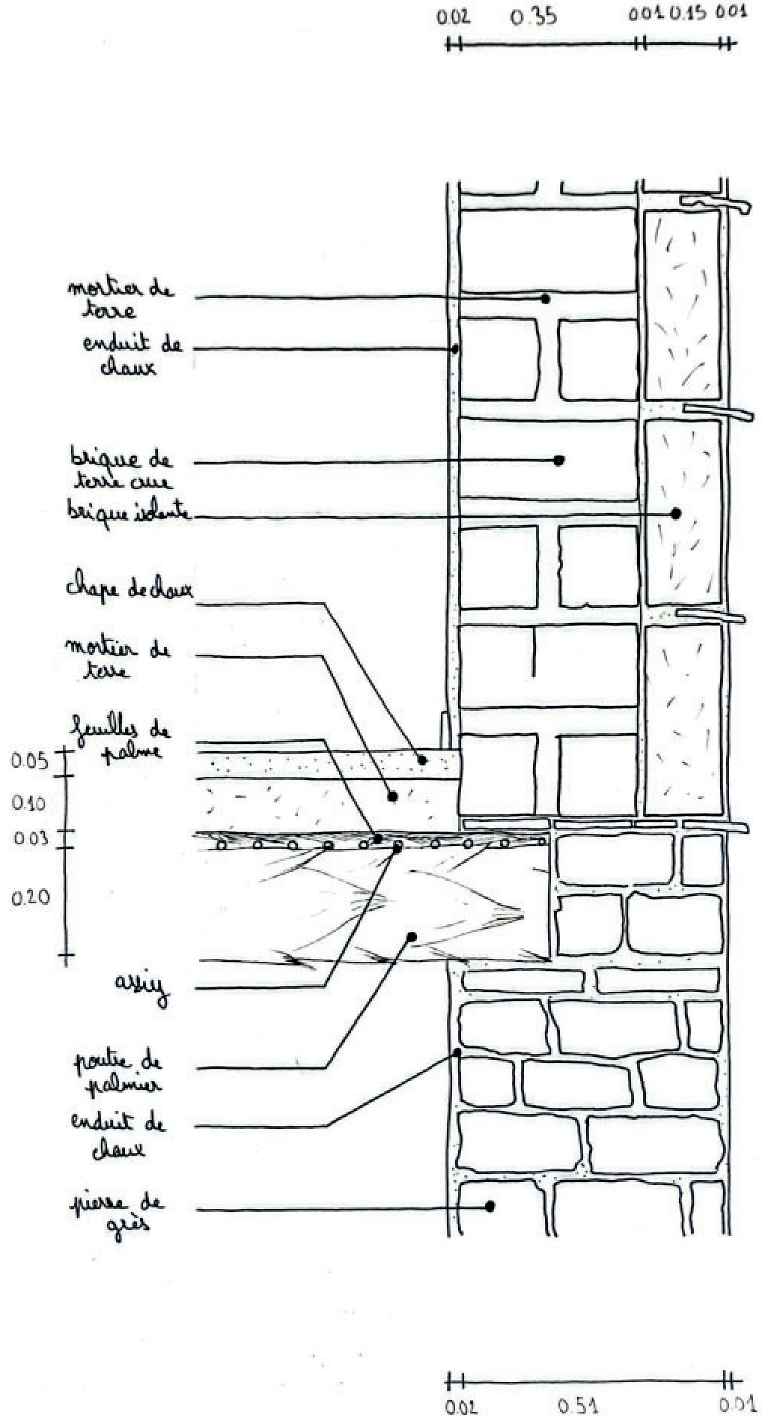


Figure 11 : Coupe de détail d'assemblage. Document de l'auteur.

2. SURFACE, INHABITING THE SAHARA

2.1. The *Agham* and the *Djnen*, birth of the oasis

At the origin of human settlement in Timimoun, only two spaces were truly essential: the dwelling, which provides protection, and the garden, which provides sustenance. The former shielded inhabitants from heat, wind, sand, and external threats, while the latter ensured survival in an arid environment. These two fundamental spaces reflected a modest and respectful way of living, aligned with the ecological and spiritual values of the Sahara and Islam: living with the essentials, producing what is vital, without excess or waste.

Despite extreme conditions, humans were able to settle in Timimoun, between the sebkha and the reg, by establishing a fortified village, the ksar. This comprised a group of ighamawen (plural of agham) built near the emergence point of a foggara, the ingenious subterranean irrigation system that regulated all life in the region.

The agham, an initial defensive dwelling, was designed as an enclosure protected by walls, towers, and occasionally a moat. Access was generally via a bridge, which symbolized both entry and separation.

Inside, the dwellings were organized around a central square, the Rahba, the true communal heart. With population growth, this organization evolved. Successive extensions gave rise to a network of alleys, the zkak, which now structure circulation.

However, to maintain their protective function, the ighamawen could not expand indefinitely. New fortified clusters were then built nearby, often across a ditch, replicating the original model.

Over time, Timimoun evolved into a less introverted urban model. The focus was no longer solely on defense, but also on social and spiritual cohesion. The walis salih, religious and educational figures, established zaouïas, mosques where knowledge was taught and transmitted. Upon their passing, kobbas were erected in their memory, becoming places of reflection and pilgrimage. These spiritual structures, built outside the enclosures, helped expand the ksar's layout and define its symbolic limits.

The evolution of the ksar remained closely linked to the foggara. The location of the ighamawen depended on water availability, and successive settlements followed the path of underground channels. This is how the urban fabric gradually expanded towards the sebkha to the west, in accordance with water resources and management. As the population grew, new ighamawen were built further away, forming small satellite oases. Their placement always responded to topography, soil quality, and the possibility of opening a new foggara channel.

The palmeraie then emerges as the founding element of this organization. It is not merely an agricultural space; it embodies a way of living, a response to climate, and a complete framework for daily life. Across many cultures, gardens represent an image of paradise, a place of harmony between humans and nature. The Arabic word djnen, referring to the garden or palm grove, derives from djenna, the Qur'anic term for "Paradise." Thus, in the heart of the desert, humans sought to recreate a space reminiscent of Paradise, a terrestrial form of this ideal garden. It served as a refuge for body and spirit, where the coolness of shade, the presence of water, dates, pomegranates, and birdsong created a microclimate conducive to work, leisure, and contemplation.

The soil of the palmeraie functions both as a reservoir and as a filter. Water irrigates the clay-loam substrate to provide an ideal texture for agriculture: sufficiently permeable to prevent stagnation, yet dense enough to retain moisture. Palm trees root in these soil layers to access nutrients, while simultaneously reinforcing the ground structure. Over time, a new layer forms, composed of organic matter, fallen leaves, and date debris, enriching the soil and creating a thin fertile layer suitable for a variety of crops, including aromatic herbs and fruit trees.

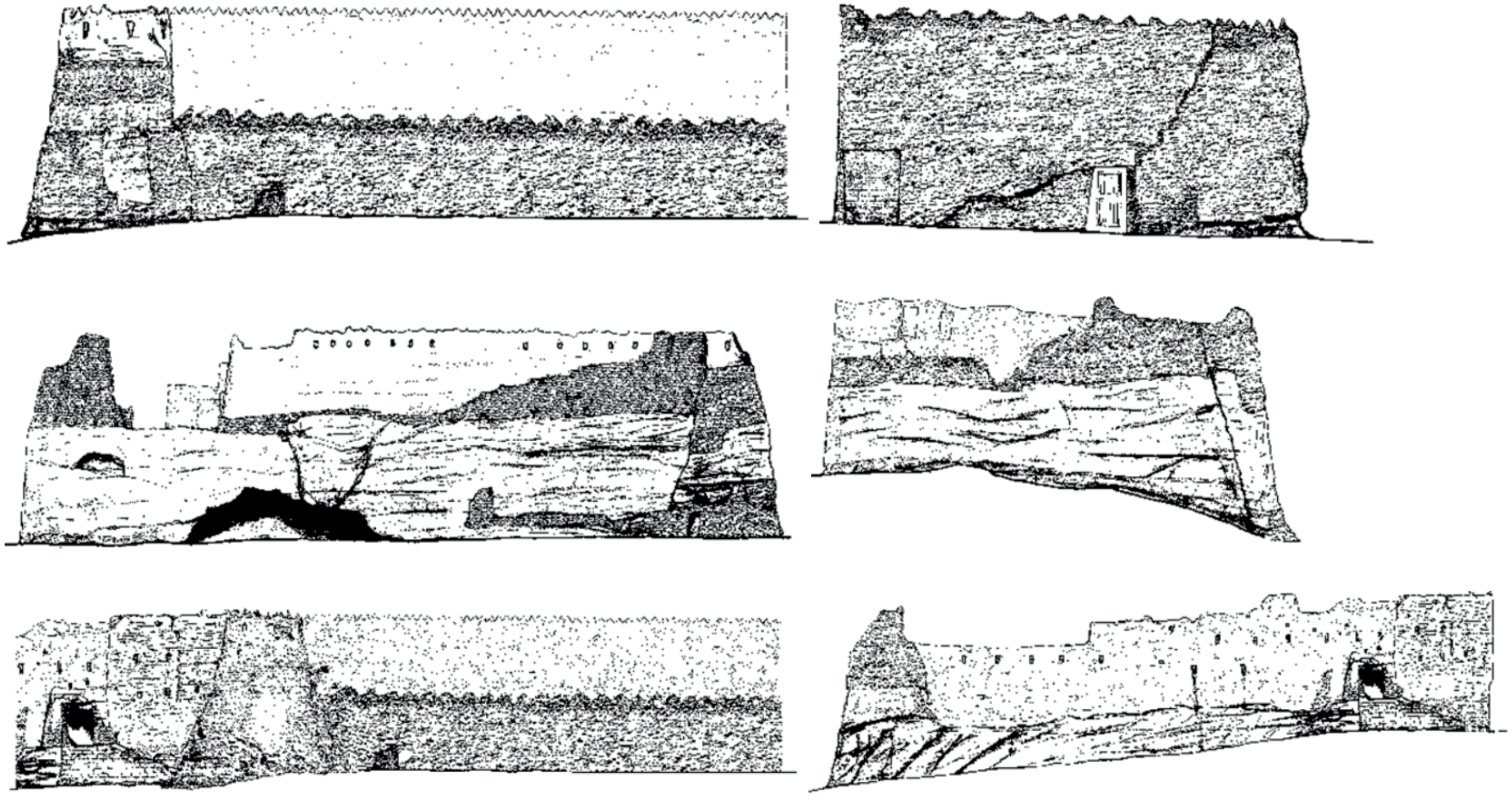


Figure 12 : Dessins des façades de l'*Agham* Sidi Brahim
Source : CAPterre

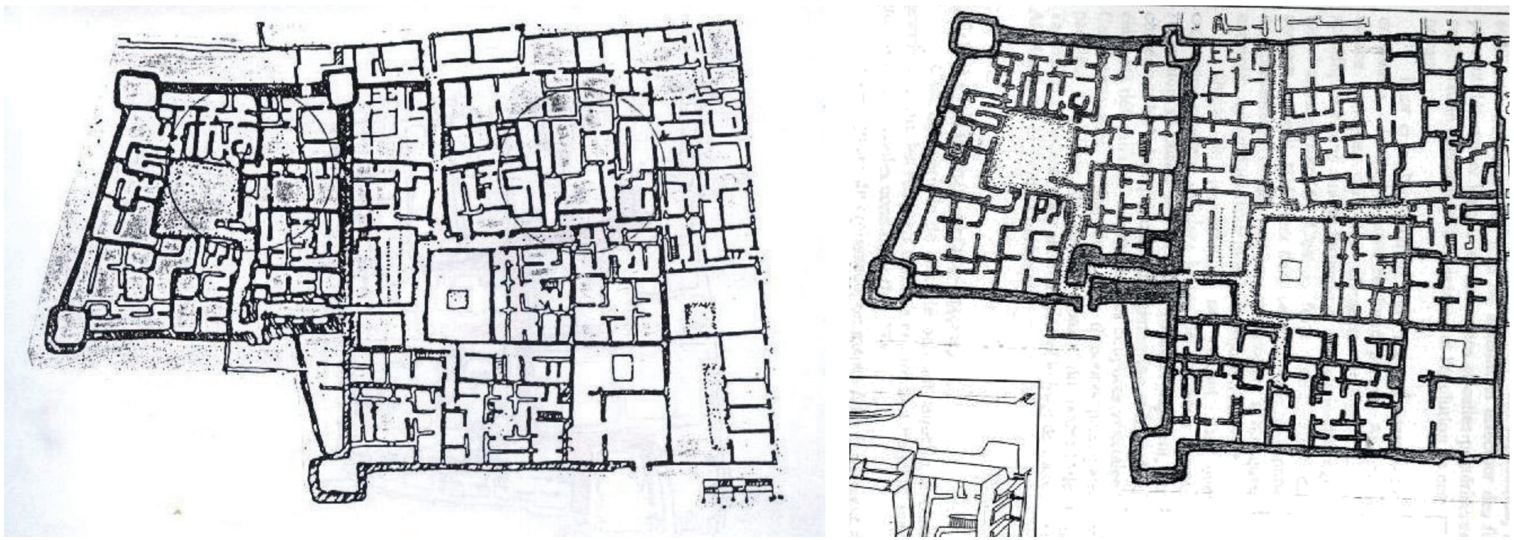


Figure 13 : Plans de l'*Agham* Sidi Brahim
Source : CAPterre

Figure 14 : Carte des *Ighamawen* entre le IVe et XIVe siècle. Document de Samia Moukhenachi, d'après Blida 1995

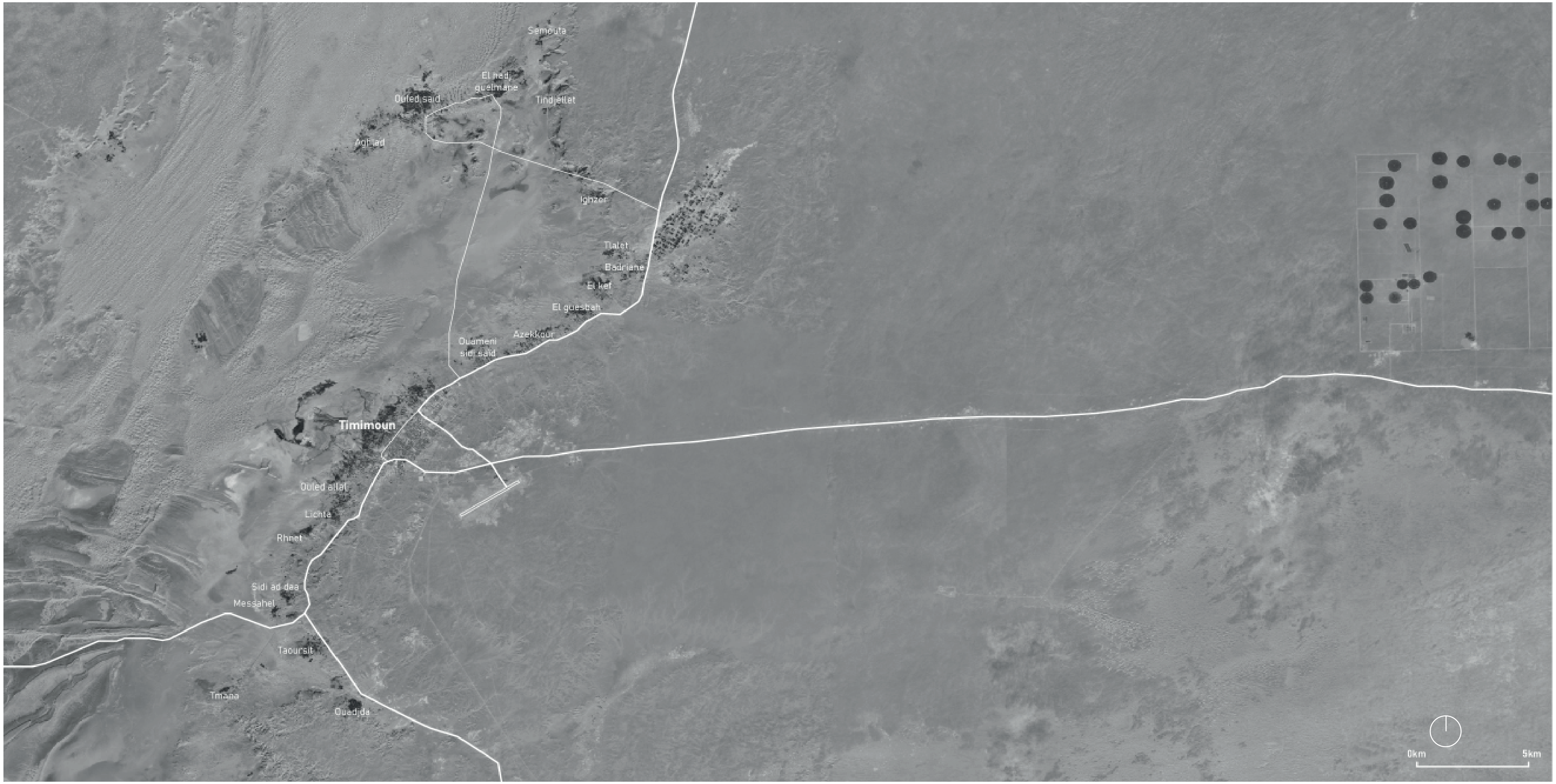


Figure 15 : Alignement des ksours autour du kasr principal de Timimoun. Document de l'auteur d'après QGIS

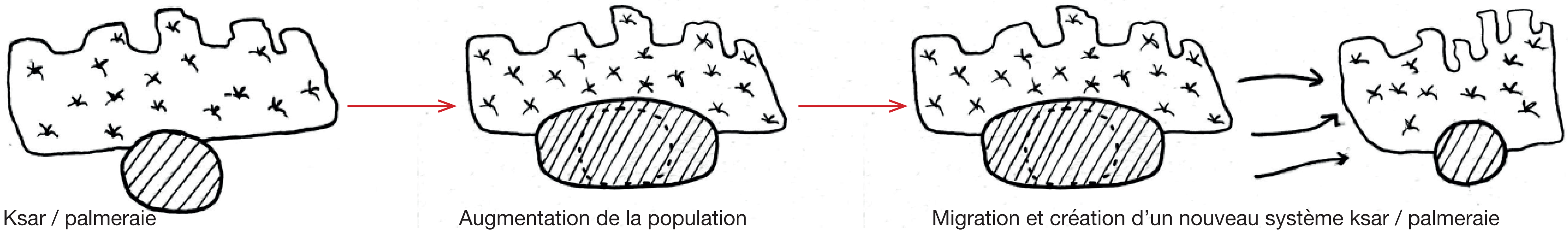


Figure 16 : Schéma d'évolution urbaine entre le Ksar et la palmeraie de Timimoun. Illustration de l'auteur

In terms of organization, the palmeraie unfolds in layered levels. The tall palm trees form a regular canopy, designed to maximize light shade, protect against wind and sand, and moderate temperature variations. The second layer consists of fruit trees, such as figs, apricots, pomegranates, and quinces, or young date palms, which benefit from the micro-climate created and receive softer sunlight. These trees provide stronger shade, allowing vegetable crops, such as cabbage, onions, turnips, beans, and watermelons, to grow in favorable conditions. Water distribution follows a network of gravity-fed channels, the seguias. Water is diverted to the plots according to precise calculations, offering exact control over irrigation.

Unlike other regions, such as Ghardaïa or Al-Ula, there is no semi-nomadic movement to the palmeraie in summer. In Timimoun, dwellings are located exclusively within the ksar. Agriculture structures the daily lives of inhabitants throughout the year. Within the agricultural plots, only small constructions are provided for storing livestock and harvests.

The agham and the djnen thus appear as the two founding pillars of the oasis: one provides shelter, the other sustains life. Their interaction gives rise to an architecture and landscape that are closely intertwined, where the soil, water, and dwellings form an inseparable whole. This constitutes the art of inhabiting the Sahara.

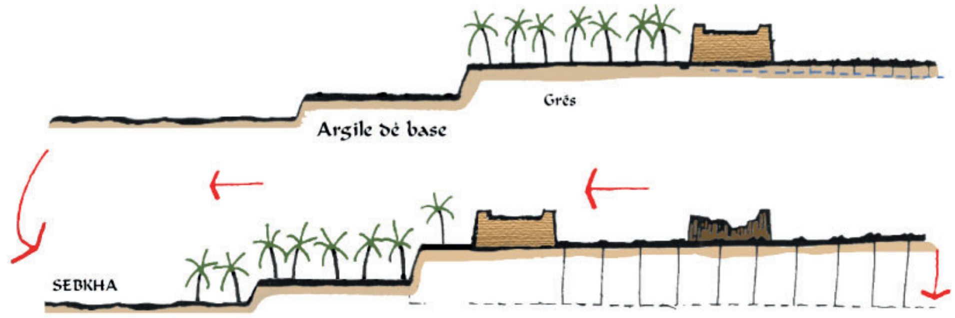


Figure 17 : Coupe de principe de déplacement du Ksar
Source : CAPterre

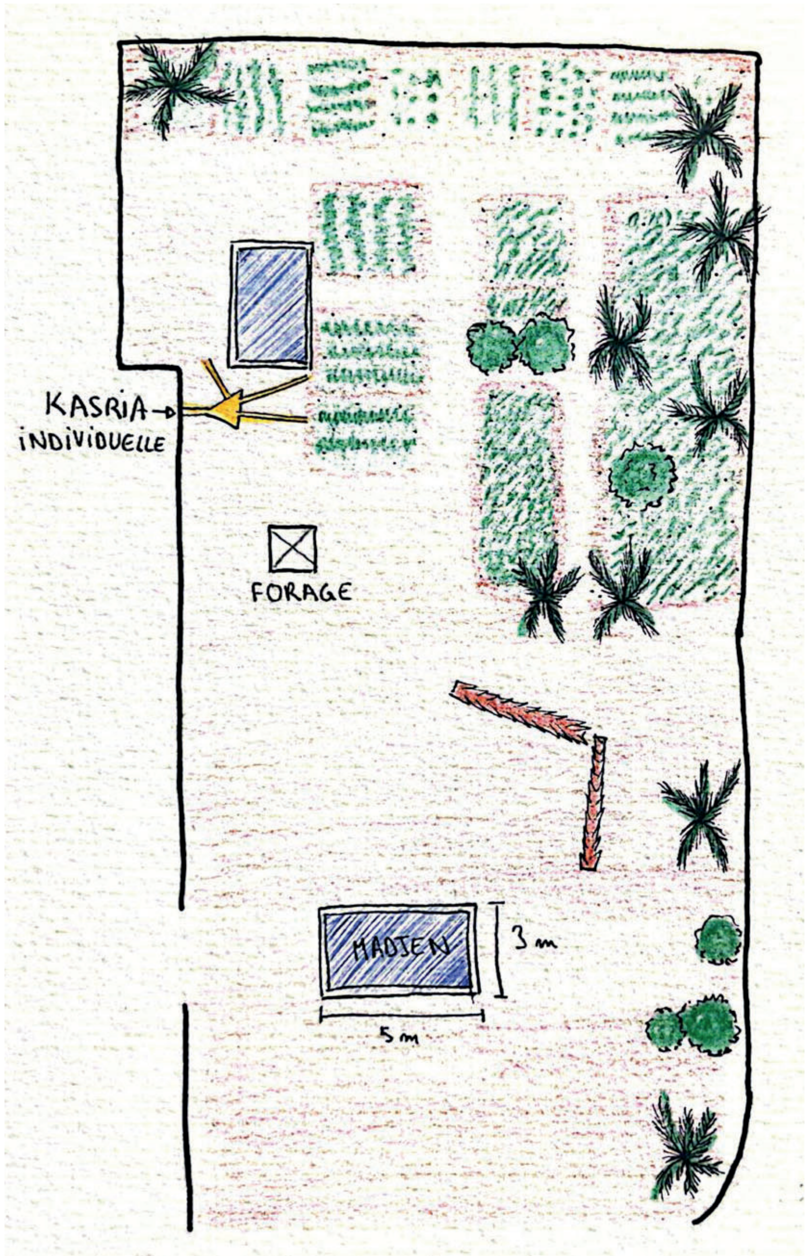


Figure 18 : Plan schématique d’un *Djnen*. Illustration de l’auteur.

2.2. Evolution of Housing in Timimoun

Colonial Period (1900–1962)

The occupation of Timimoun by the French army in 1900 was part of a strategy to economically penetrate the Sahara, aiming to connect the Algerian coast to the Sahel through the trans-Saharan network and the telegraph. This infrastructure project, motivated by territorial control, did not aim to improve the daily lives of the local population.

The first colonial act was to establish a military redoubt at the heart of Agham Sidi Brahim, thereby erasing the preexisting settlement. This fortress, located at the entrance of the ksar along the caravan route, symbolized domination and territorial surveillance. The French authorities then enforced a strict separation between the indigenous village and the new colonial zone. The grid-like layout, derived from the military model, reflected this desire for control.

However, unlike in northern Algeria, the French presence in Timimoun relied on local knowledge to survive in such a harsh environment. The settlers partially drew on vernacular expertise and used local materials. Merchants and camel drivers were integrated into the colonial village, profoundly altering the social balance. The creation of new avenues, replacing former caravan tracks or foggara lines, marked a rupture in the traditional urban structure. The regular plan favored order and visibility but undermined the human and spatial cohesion characteristic of the ksar.



Photographies de la ville coloniale
Auteur

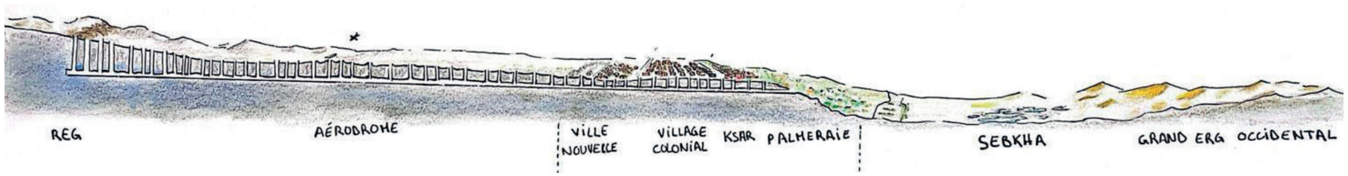


Figure 19 : Coupe paysagère de Timimoun. Illustration de l'auteur

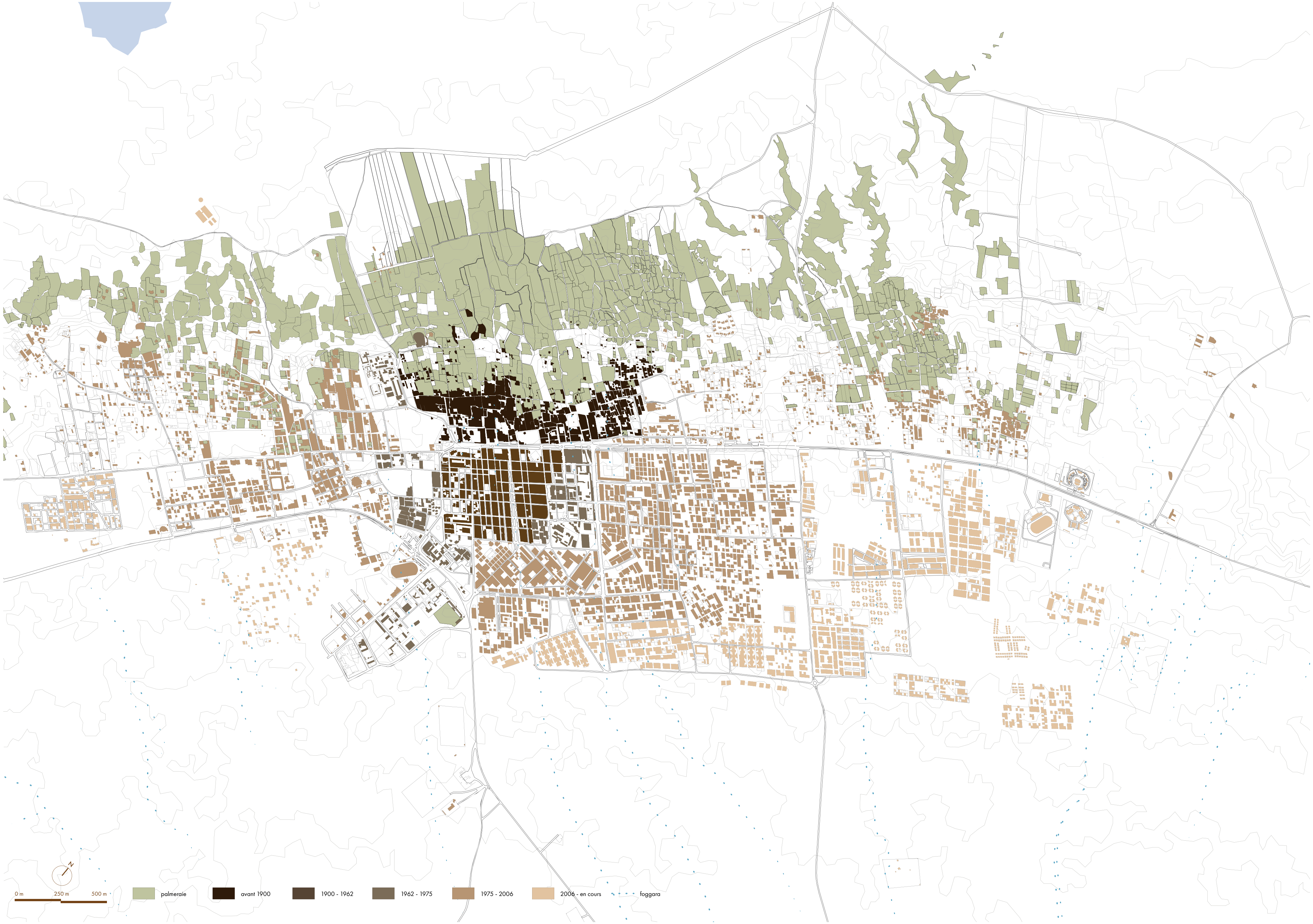


Figure 20 : Carte de l'évolution du tissu urbain de Timimoun depuis 1900. Illustration de l'auteur
Source : Otmane et Kouzmine (2009)

Post-Colonial Period (1962–2006)

After independence, Algeria undertook a large-scale administrative and urban restructuring. Timimoun became the capital of a daïra in 1974 and established itself as the center of the Gourara region. Rapid urbanization and economic diversification transformed the town. The formerly dominant rural organization gave way to broader growth guided by modernist planning principles.

The first large-scale housing projects and public facilities were constructed under the Constantine Plan, later extended according to standardized national models. These social housing developments, designed with rigid master plans, ignored the historical logics of the ksar and the colonial village. By neglecting the existing plot layout, such planning imposed land divisions based solely on quantitative and functional criteria, producing standardized housing disconnected from its context. The town was perceived as a space to be filled rather than a living organism.

As critics of colonial implantation have emphasized, each city must be approached according to its territory and inhabitants, in other words, according to its ecosystem. Studying the memory of the soil thus became a crucial step in the architectural and urban design process.

This technocratic approach disrupted the relationship between residents and their territory. New neighborhoods, built in concrete and cinder block, embodied a uniform modernity, disconnected from context. The collective foggara system was gradually abandoned in favor of individual wells. This individualization, perceived as progress, exacerbated ecological degradation: saline intrusion from the groundwater led to soil mineralization and the gradual loss of the palmeraie.

Despite these changes, agricultural practices persisted in modest and spontaneous forms. Informal gardens emerged in the gaps of the planned city, recalling the nourishing function of the djnen. These spaces, created by the most resourceful inhabitants, reflect the persistence of the link to the soil, despite the rupture imposed by modern urban models.

Photographie d’une maison et son jardin informel
Auteur

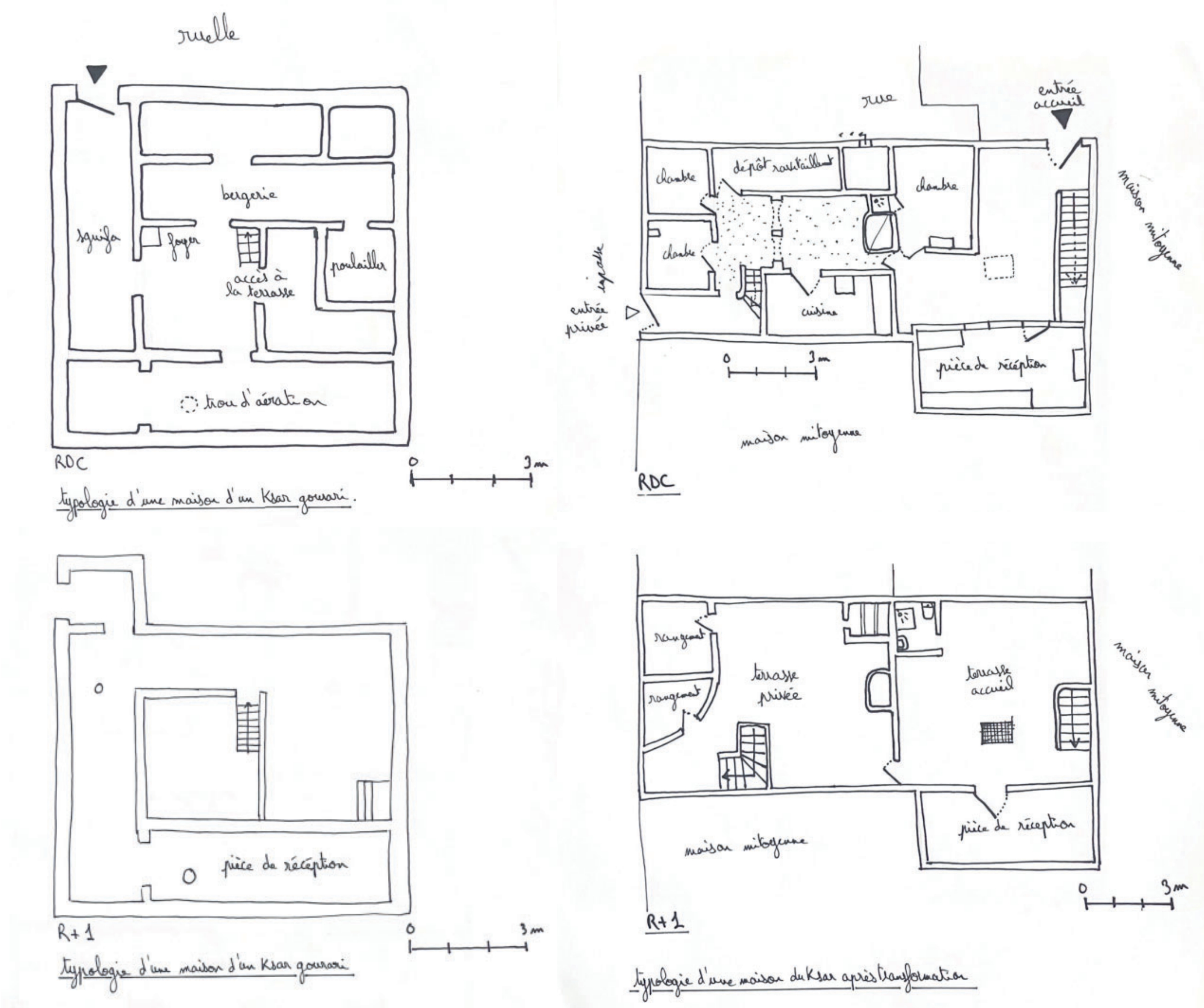


Figure 21 : Plans d'une typologie de maison d'un Ksar gourari et du Ksar de Timimoun. Illustration de l'auteur
Source : CAPterre

Contemporary Period

Since its promotion to wilaya status in 2019, Timimoun has experienced rapid transformation. Population growth, intensified economic exchanges, and its emergence as a regional hub have reshaped the town. However, this dynamic has been accompanied by a gradual detachment of residents from their territory. With nearly 40,000 inhabitants, a predominantly young population, and a high unemployment rate, the economy, once based on oasis agriculture, has shifted toward oil exploitation and tourism.

The palm grove, formerly a productive system, is being transformed into a tourist setting. Fernand Pouillon's Gourara Hotel exemplifies this trend, highlighting the Saharan landscape while simultaneously creating distance from it. Numerous establishments reproduce this aesthetic approach, promoting an image of authenticity without preserving its substance.

Urbanistically, this period marks a rupture between architectural form and urban form. The ksar, once coherent in its organic organization, has given way to neighborhoods planned according to zoning and profitability logics. New extensions, disconnected from preexisting structures, reveal standardized, repetitive architecture where soil memory and climatic intelligence have disappeared.

Thus, the oasis model, founded on the balance between habitat, soil, and water, is gradually disappearing in favor of generic urbanism, incapable of integrating lessons from the past.

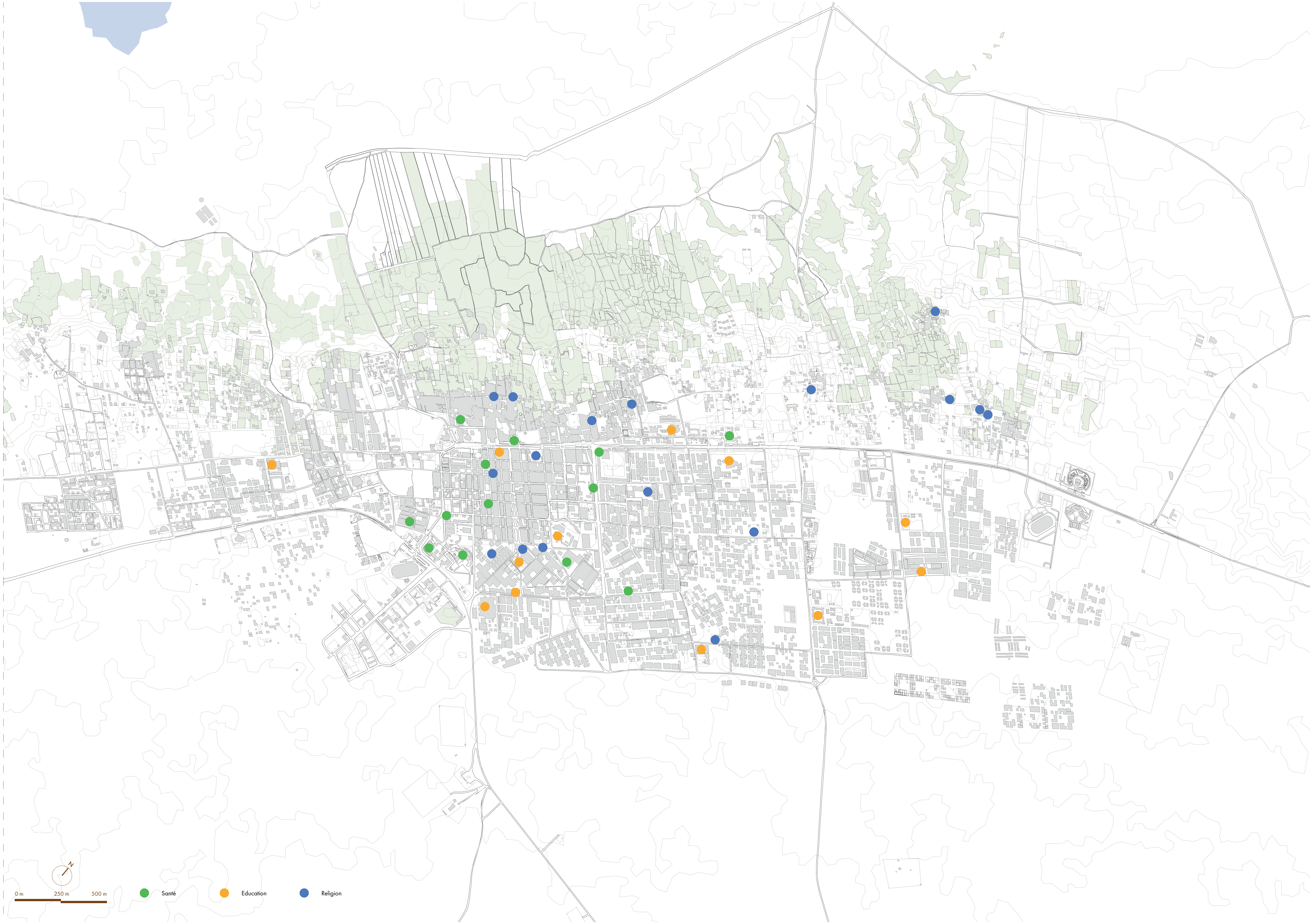


Figure 22 : Carte des infrastructures. Illustration de l'auteur
Source : Google maps

2.3. The New *Agham*

The project builds on reflections on Saharan forms of housing and their relationship with the community. It seeks to reinterpret the notion of agham, a protective and collective space, by giving it a contemporary dimension adapted to current needs.

The objective is to question the boundaries between public, communal, and private space, both at the scale of the building and at that of the individual dwelling unit. The housing units are organized according to different degrees of intimacy.

The new Agham proposes a way of living in which community life regains a central role. The dwellings are arranged around a shared djnen, a true urban palm grove integrated into the heart of the built fabric. This communal space, measuring 50 by 50 meters, contains twenty-five date palms, including one male, fruit trees, and various ground-level plants. It functions simultaneously as a productive garden, a meeting place, and a leisure area.

Pedestrian paths and resting areas punctuate the space, evoking the slow, calming strolls typical of traditional palm groves.

The cultivation of fruits and vegetables within this djnen provides sufficient yield for the collective maintenance of the space, establishing a human-scale model of self-management. Surrounding the garden, spaces intended for commercial, artisanal, cultural, or tourist activities animate the ground floor and enhance the neighborhood's attractiveness. This programmatic mix encourages residents to engage with their environment while opening new opportunities for local agro-tourism, fostering economic and social exchanges.

These new ighamawen also function as service hubs, incorporating infrastructure lacking in recent neighborhoods, such as a mosque, school, library, or community spaces. Their presence strengthens urban cohesion and helps to recreate a strong collective anchoring.

The architecture of the project draws inspiration from the introverted logic of the ksour. While the ground floor remains porous to invite circulation and encourage interaction, the overall ensemble preserves interior intimacy, centered around the garden. This arrangement symbolizes the return of the palm grove to the heart of communal life, no longer as mere decoration, but as a social, productive, and climatic matrix.

Figure 23 : Premieres intentions : p lan et coupe du nouvel *Agham type*.
Illustration de l'auteur

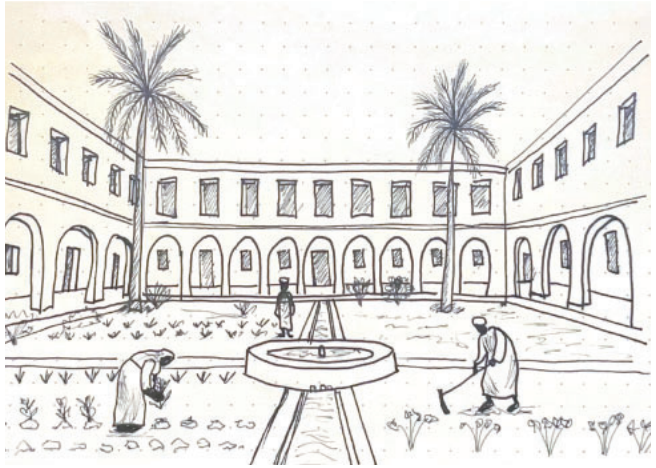


Figure 24 : Premieres intentions : perspective du coeur d'un *Agham*.
Illustration de l'auteur

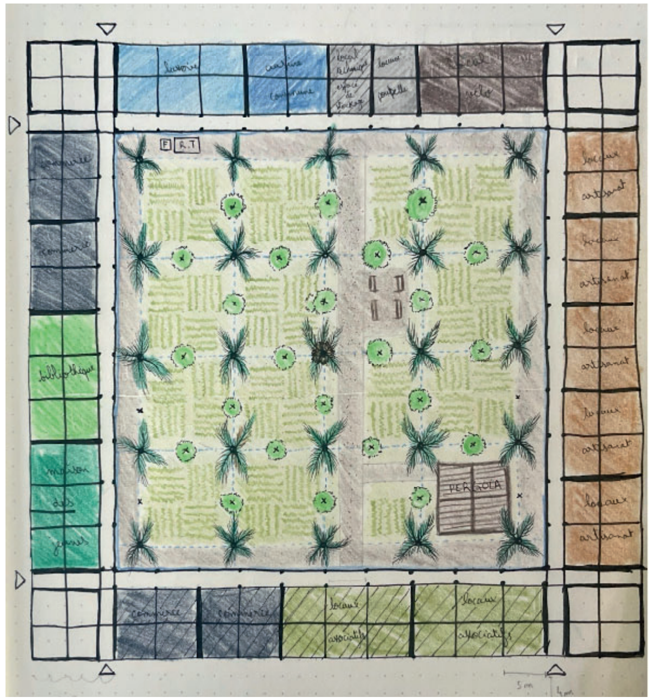
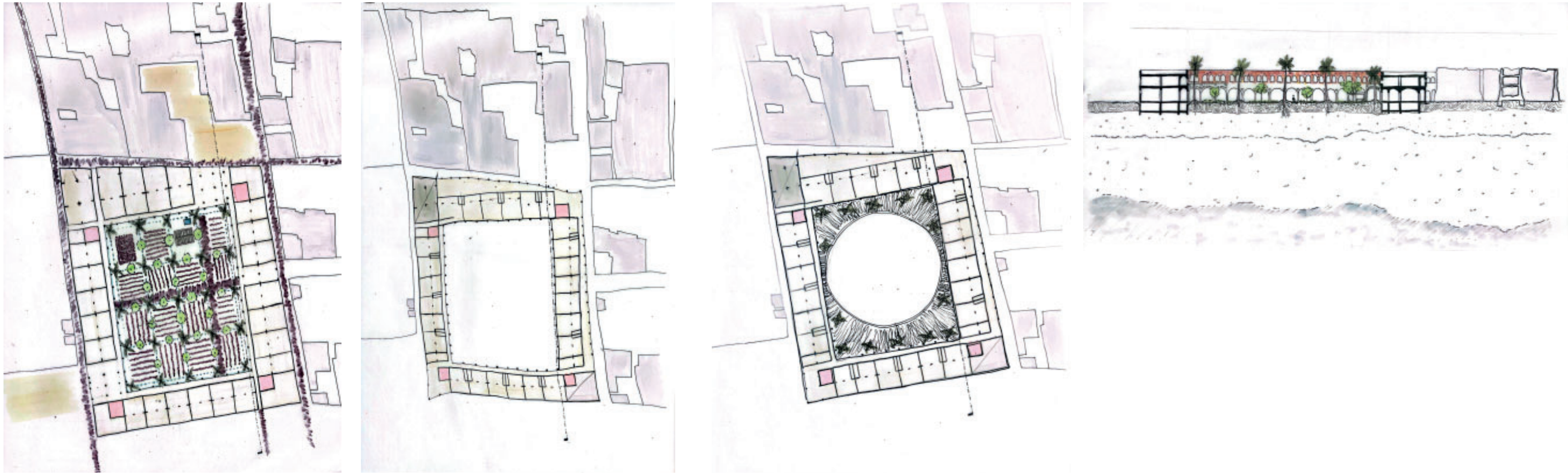


Figure 25 : Shéma directeur des dispositifs d'un *Djnen type*.
Illustration de l'auteur

Figure 26 : Plan de masse des implantations des nouveaux *Ighamawens*.
Illustration de l'auteur

Agham 04



Agham 02

Figure 27 : Premieres intentions : plans et coupes de différents types d'*Ighamawen* en fonction du tissu urbain.
Illustration de l'auteur

Each dwelling unit meets the needs of a younger population while preserving local values. The majlis open onto shared landings, walkways, or outdoor reception rooms, allowing residents to retain the sociability of traditional oasis homes while providing the flexibility required for contemporary domestic uses. (Figure 23)

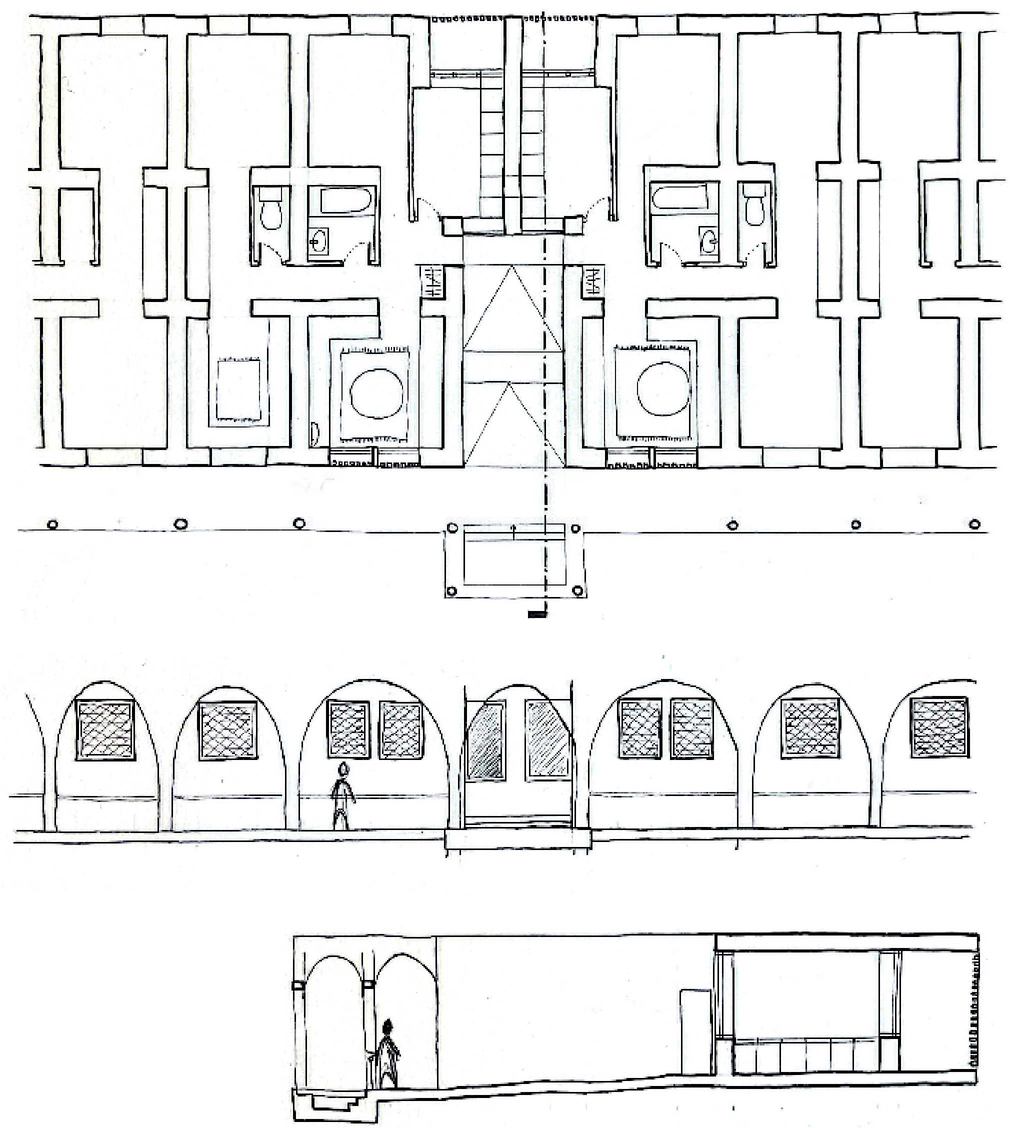
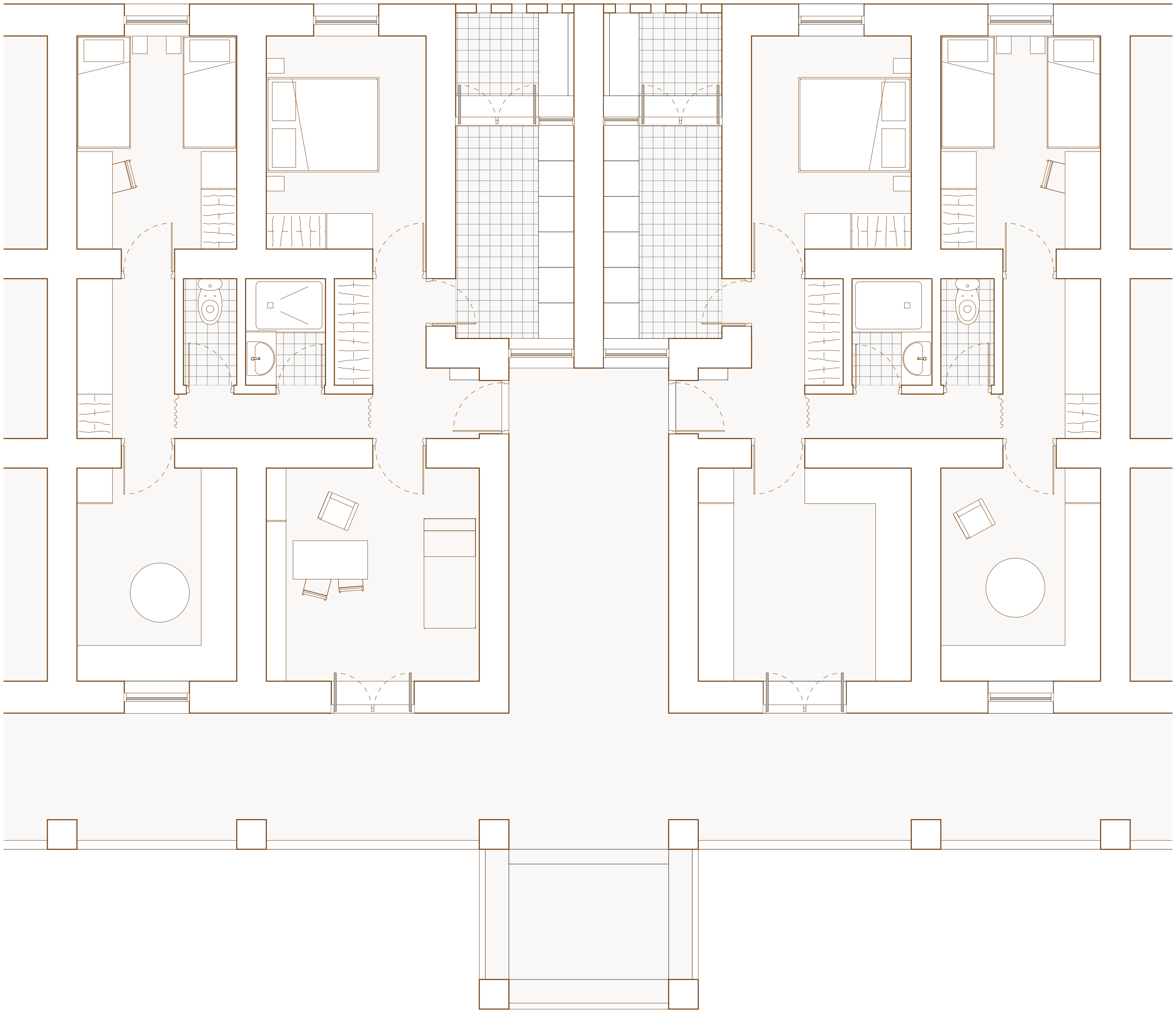


Figure 28 : Premieres intentions : plan, élévation et coupe d’un appartement type. Illustration de l’auteur



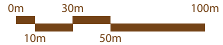


Figure 29 : Plan *typlogie appartement T4*, 1:100. Illustration de l'auteur

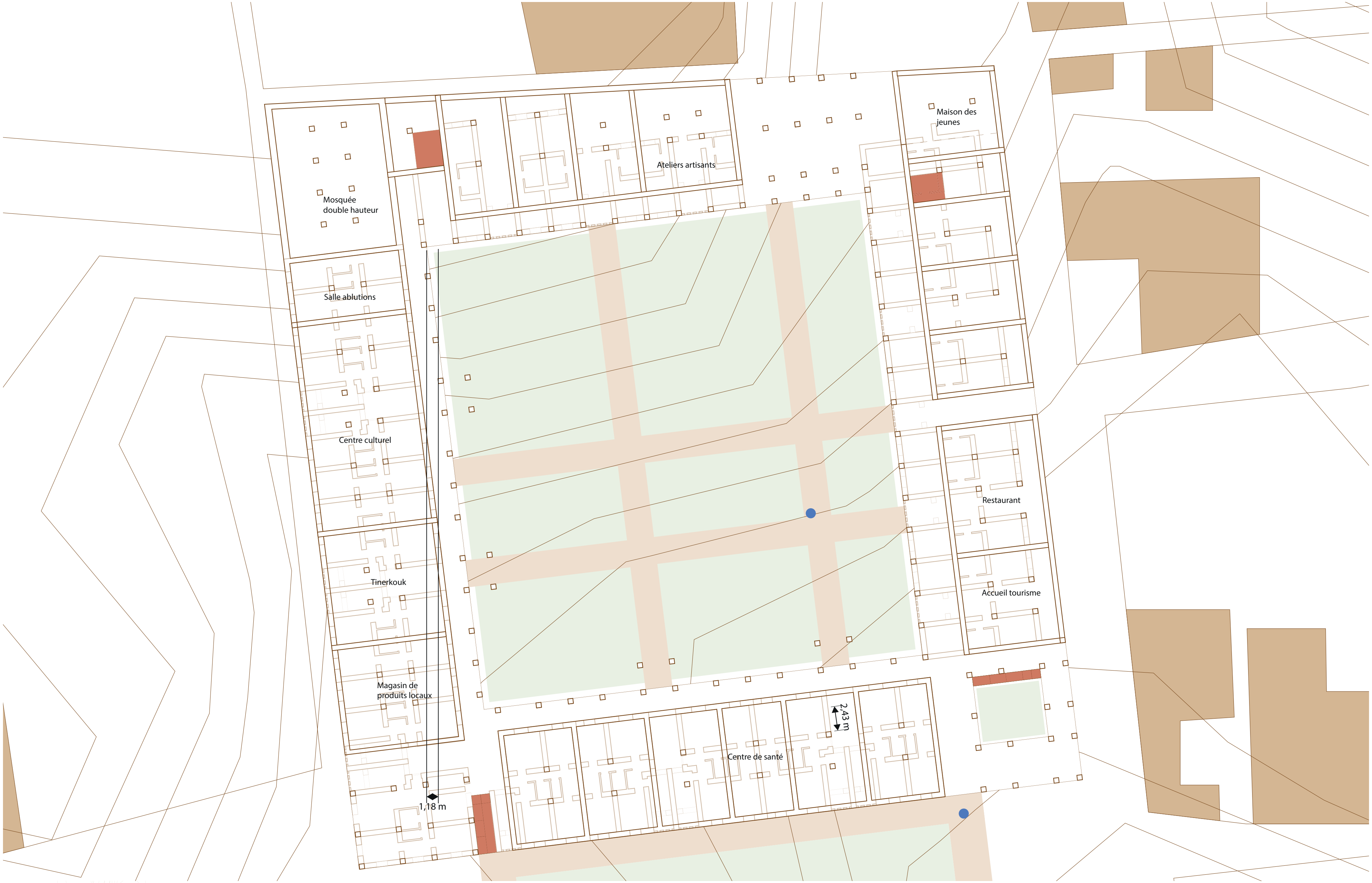


Figure 30 : Plan RDC du *Agham 04*, 1:500. Illustration de l'auteur

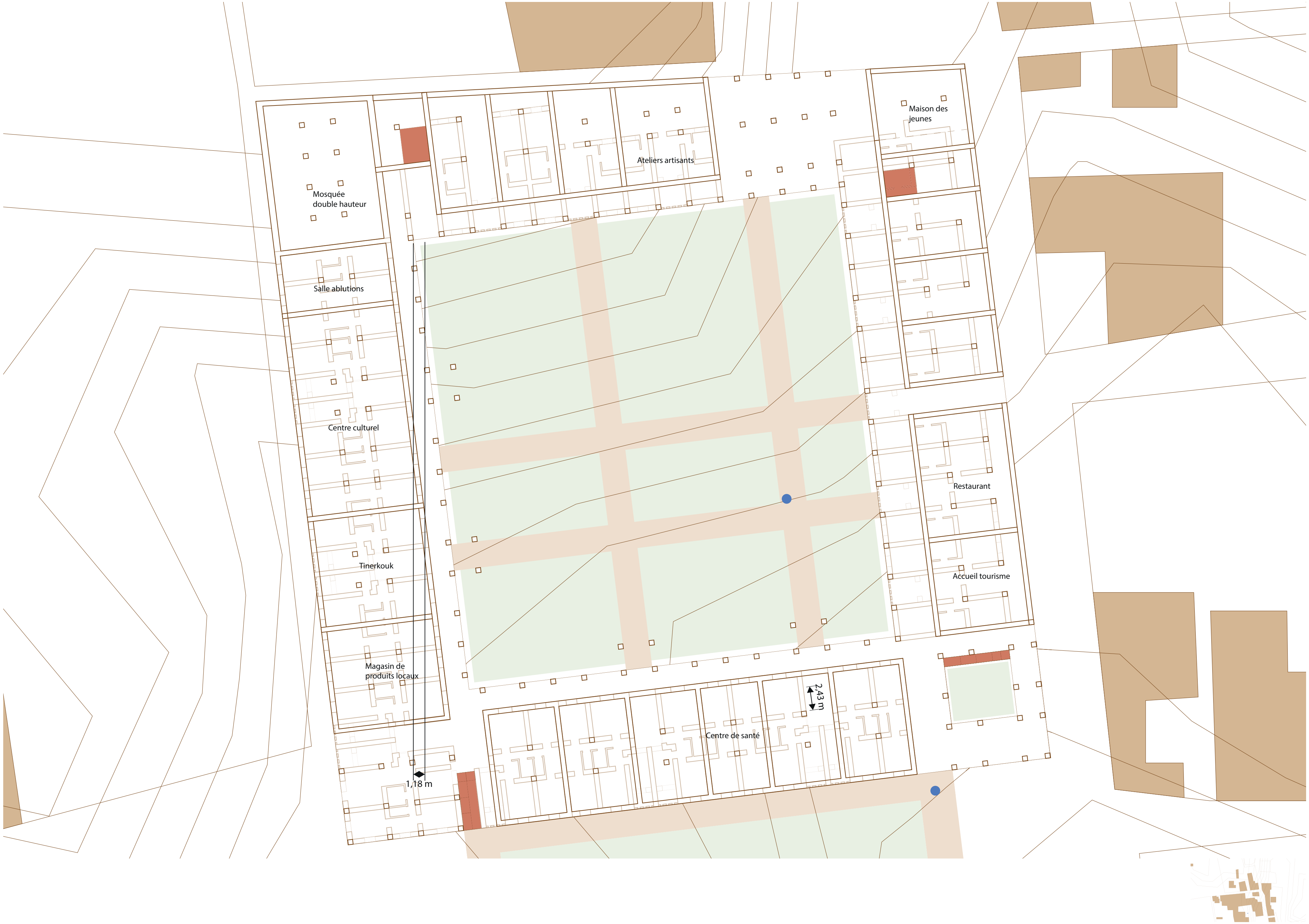


Figure 31 : Plan R+1 du *Agham 04*, 1:500. Illustration de l'auteur

Some undeveloped areas will be planted and kept in reserve, allowing for potential future urbanization. The project thus envisions several scenarios of evolution, reflecting its capacity to adapt over time and according to use:

First scenario: continuity. The Agham model functions and fully integrates into community life. Residents choose to replicate the concept around already planted areas and existing wells, extending the logic of the project.

Second scenario: verticality. Residents make use of the terraces of existing ighamawen, creating vertical extensions to free up ground space and increase the area available for agriculture.

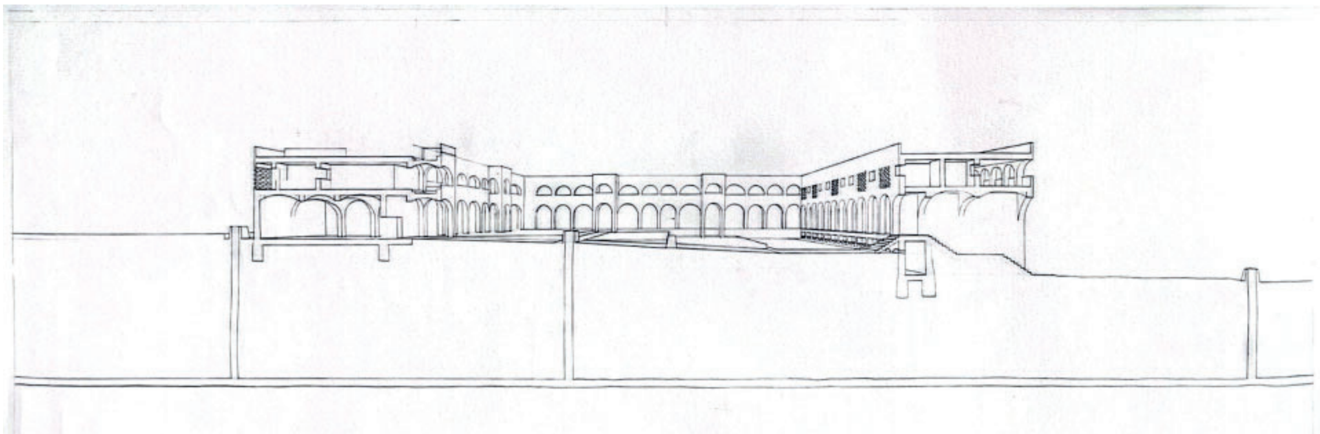
Third scenario: centrality. The Agham becomes a neighborhood core, around which residents build organically. The well and the palm grove remain at the center, echoing the rahba of the traditional ksar.

Fourth scenario: projection. The site serves as a testing ground for future architects, urban planners, or residents, who could attach their interventions either to the ighamawen or to the new blue and green network—designed as a tool for shaping the oasis city of the future.

Fifth scenario: hybridization. All these forms of appropriation coexist, reflecting a flexible urbanity, unplanned yet guided by intentions consistent with the territory and its memory.

This final scenario, that of hybridization, perhaps embodies the deeper meaning of the project: a living architecture, capable of evolving according to needs, faithful to the logic of adaptation that has always characterized Saharan societies.

The project thus draws on the three key notions that have guided it from the start: inhabiting the palm grove, fostering community, and honoring the memory of the place, imagining a future where water, soil, and humans regain their rightful balance.



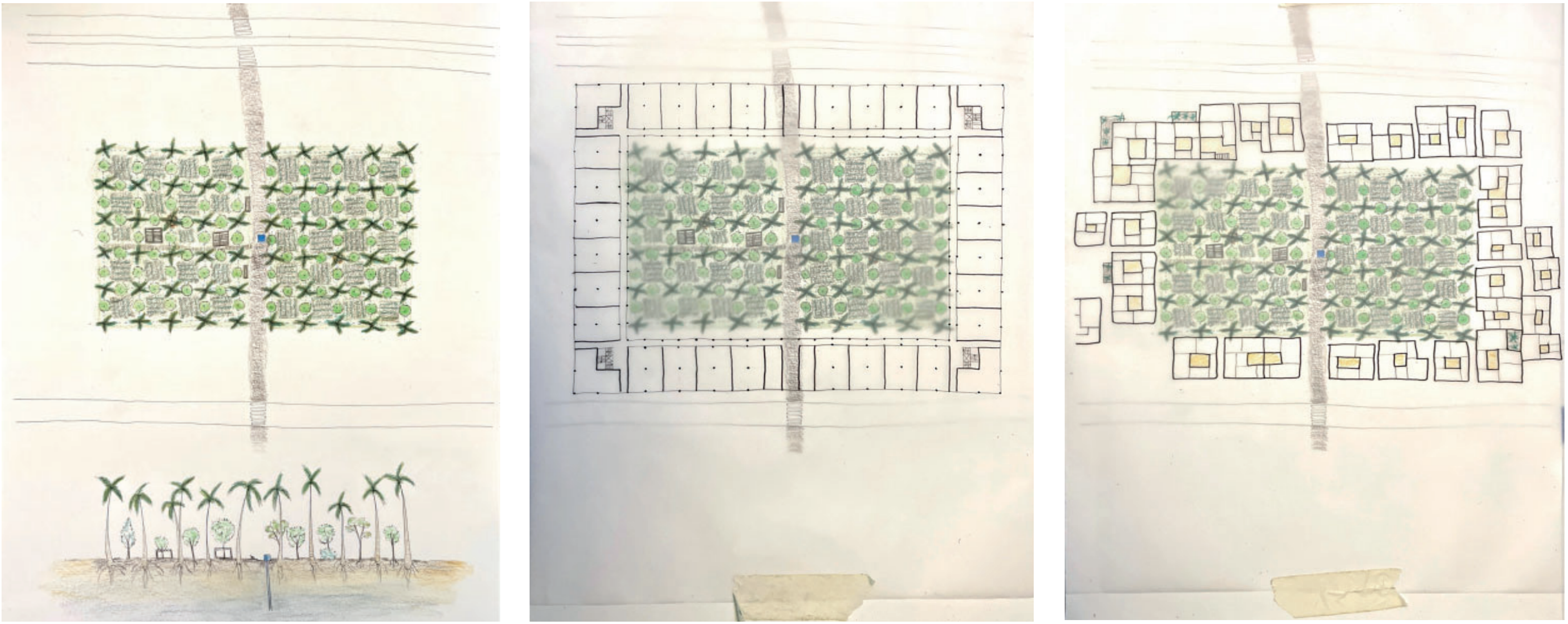


Figure 32 : Plans des deux types d'épaisseur habitées selon le scénario. Illustration de l'auteur

3. SUBSURFACE, THE BLUE GOLD

3.1. The Foggara System

The Saharan climate has shaped a landscape where access to water requires both ingenious water management and a deep understanding of soils.

The creation of foggaras arises from this context, reflecting the human will to survive in an environment where surface runoff has disappeared. A foggara is a system for exploiting underground water, typical of the oases of the Gourara, Touat, and Tidikelt regions.

This ancestral hydraulic work, which intelligently taps into underground aquifers, serves both as an irrigation tool and as a record of human-environment interaction. The network of underground galleries was designed to capture water from the Continental Intercalaire aquifer in a region where annual precipitation does not exceed 15 to 20 mm.

Similar systems exist in other arid regions of the world, including qanats in Iran and Saudi Arabia, and khettaras in Morocco. The operation of a foggara is based on a simple yet effective principle: a gently sloping underground gallery is dug to collect water from the aquifer. The galleries, 50 to 80 cm wide and 1 to 1.5 meters high, are manually excavated over several kilometers. The slope generally does not exceed 1 %, allowing water to flow slowly but steadily without causing excessive erosion.

Ventilation shafts, spaced every 5 to 10 meters, enable maintenance of the galleries and facilitate water movement while minimizing evaporation. Depending on the terrain and aquifer depth, these shafts can reach 20 to 30 meters deep.

The maintenance of foggaras relied on collective labor called touiza, a pooling of manpower dedicated to cleaning and repairing the galleries.

This hydraulic knowledge was passed down over generations, structuring both the social and spatial organization of Timimoun. As noted, "The classic organization of the oasis, composed of the ksar, the palm grove, and the foggara, represents the most suitable and historically enduring response to desert constraints." Similarly, "It is the foggara that determined the location of the ksar of Timimoun, structuring the inhabited space according to hydraulic constraints."

Rather than being distributed according to time, water is allocated volumetrically, with each co-owner receiving an amount proportional to their contribution to digging and maintaining the system. Upon exiting the gallery, the water is first directed to an element called the kasria (Photograph 9), a triangular stone comb that divides the flow into several channels called seguias. These channels lead the water to storage basins, or Madjens (Photograph 9), which regulate flow and provide accumulation points for periods of drought, before reaching the gardens, ensuring precise and uniform distribution. Once it reaches the surface, the emergent portion of the foggara, at the heart of Timimoun's palm grove, reveals the visible path of water.

Flow regulation relies on a traditional device called the Louh, a perforated copper plate that measures the flow based on the number and size of open holes. In the oases of central Timimoun, the unit of measurement, the tmen, is approximately 0.0416 l/s. Variants such as the habba, defining an average flow of 2.5 l/min, also allow for precise water quantification.

The essential role of the Kial El Ma, literally the water measurer, is recorded in registers called Zemmam, which document all distribution operations. The various elements, the kasria, seguias, Louh, Kial El Ma, and Madjens, play a crucial role in the equitable sharing of water. These devices ensure that each individual receives a precisely calibrated amount of water, enabling the coexistence of diverse agricultural activities.

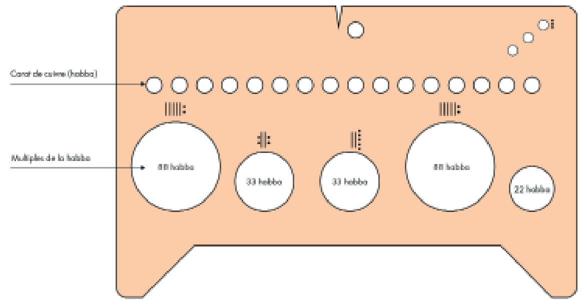


Figure 33 : Schéma du louh.
Illustration de l'auteur

Photographies de puits de foggara et séguias
Auteur

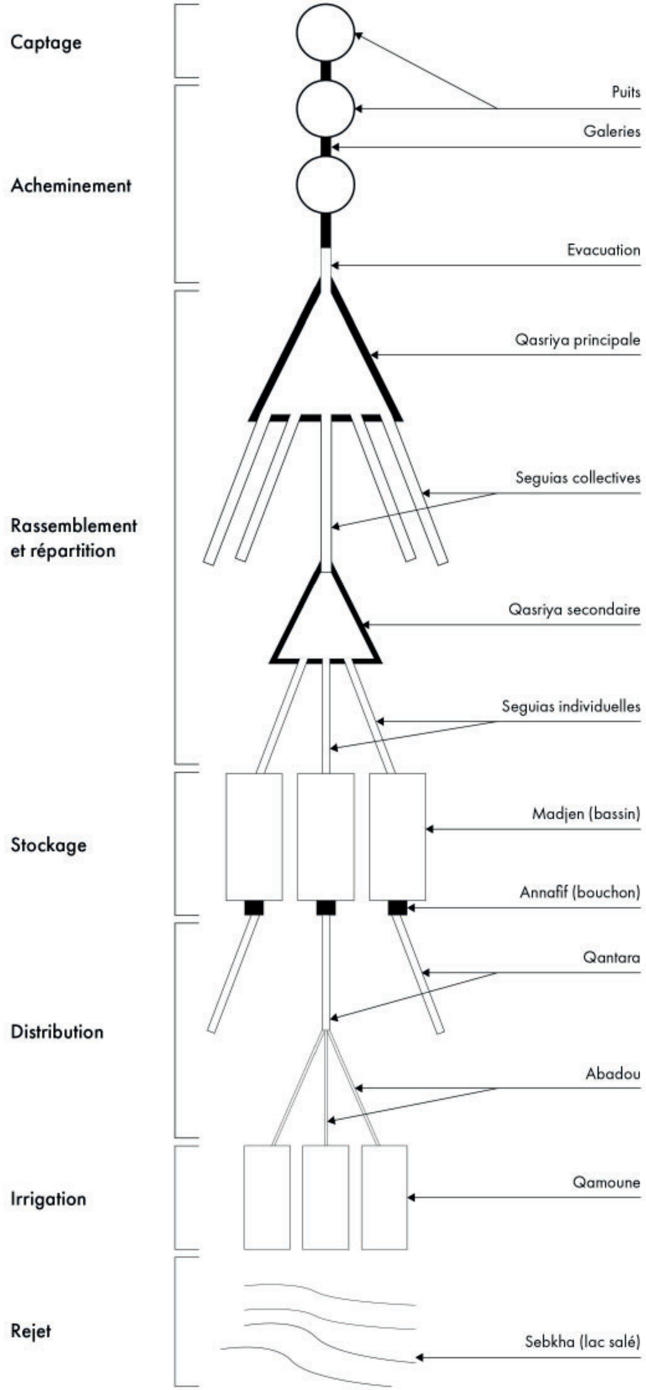


Figure 34 : Schéma du système de distribution de l'eau d'après la coupe schéma de P.Laureano. Illustration de l'auteur
Source : Sahara jardin méconnu p.42-43

3.2. The Transition to Boreholes

In Timimoun, the decline of foggaras is linked to several interconnected factors. First, the lowering of the water table significantly reduces the volume of water that foggaras can mobilize. This decrease is directly related to the drilling of boreholes to supply the city and other ksour, creating competition for groundwater resources.

The introduction and widespread use of modern boreholes disrupt the established balance. These contemporary solutions, while effective in extracting larger quantities of water, come at the expense of the collective management that previously characterized traditional systems. The use of pumps and drilling techniques, often privatized, has led to more selective and unequal access to water. Some seguias and kasria have completely dried up and have been replaced by modern wells.

The consequences for the local ecosystem are concerning and lead to a progressive degradation of both social and environmental balance. The drying up of foggaras reduces the cultivated area and shifts gardens toward the lowest, often saline zones near the sebkha. Water extraction through boreholes amplifies this phenomenon, increasing soil salinity and threatening date palms, which are otherwise well adapted to the Saharan climate. Every resident desires their own well while overlooking the potential impact on the overall ecosystem. Between 1985 and 2006, more than half of the Timimoun palm grove was lost. This is caused by several factors, with the primary one being soil mineralization. Water extracted directly from the Continental Intercalaire aquifer does not allow minerals to be filtered out through the underground channels. Capillary rise from the aquifer floods the sebkha and spreads onto the palm grove. In short, the soil becomes too saline for agriculture. Furthermore, the population, younger and more numerous, seeks education and wage labor. People hope for a promising future away from their native land, even if, paradoxically, they remain attached to it because this land provides new resources such as gas, oil, and minerals. Agricultural labor becomes scarce, traditional know-how is less transmitted, and the palm grove plots are gradually abandoned.

To deepen the reflection on water management in the oases, an interview was conducted with a specialist on the subject. This approach relied on the expertise of Jean Albergel, hydrologist and emeritus research director at the IRD (Institute for Research on Development), met on September 18, 2025. This discussion shed light on local issues from a global perspective, informed by concrete examples and long-term field research experience.

During the interview, Jean Albergel referred to the example of the Palmyra oasis in Syria to illustrate the major challenges faced by oasis systems. He emphasized that protecting the palm grove is a central objective in the face of soil salinization and degradation. Implementing a drainage system for the shallow water table appears essential to limit saline flooding. The interview also highlighted the strong disparity in water usage: the average daily consumption per resident is about 50 liters, while it can reach 120 liters per day per tourist, further increasing pressure on the resource.

Several technical solutions adapted to Saharan contexts were discussed, such as the use of solar treatment plants for domestic wastewater or solar pumps for boreholes. According to Jean Albergel, the date palm industry can contribute to the preservation of palm groves, provided it does not aim for self-sufficiency, which is not viable in projected oasis development scenarios. The goal is rather to maintain the palm grove as a source of income for residents, while preserving the basic agro-ecological model and mobilizing external resources when necessary.

Applied to Timimoun, these reflections go beyond agriculture alone. Oasis management must also address trade, transport, and political decisions, drawing inspiration from the operation of ancient caravan networks without falling into a nostalgic view of a now obsolete system. A warning was also issued regarding certain solutions presented as ecological, reminding that the disappearance or failure of a system often responds to structural causes. Intensive date palm agriculture also exposes the palm grove to health risks, including the emergence of invasive fungi.

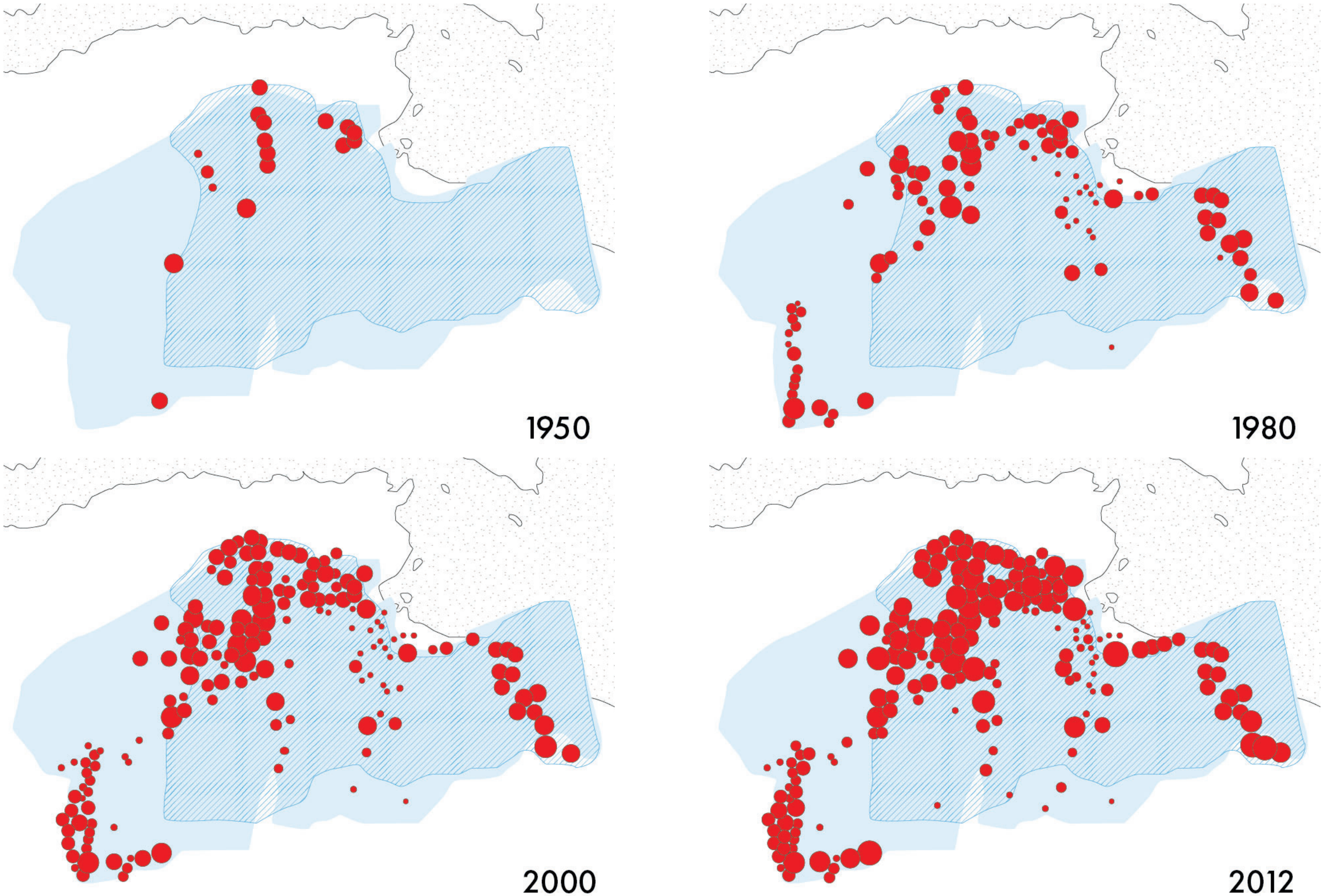


Figure 35 : Evoluation de la répartition des prélèvements par forages dans le SASS. La taille des cercle est proportionnelle à la quantité d'eau prélevée. Illustration de l'auteur
Source :OSS

Among the proposed solutions is the use of foggaras to convey water from boreholes, considered more appropriate than systematic plastic pipelines despite maintenance constraints. The discussion also highlighted the lack of measurement tools in Timimoun, particularly the absence of a flow tower to collect data on humidity, temperature, and the microclimatic functioning of the palm grove. In general, emphasis was placed on avoiding monoculture, over-irrigation, and excessive water use.

Finally, Jean Albergel recalled the three main trajectories for the future of oases, as presented at the World Water Forum in Bali: the development of date palm monoculture, the shift toward irrigated cereal or market gardening monocultures, or the preservation of the traditional oasis, supported by oasis tourism or other sources of income. This interview provides essential insight into the choices and trade-offs necessary for the long-term sustainability of oasis systems.

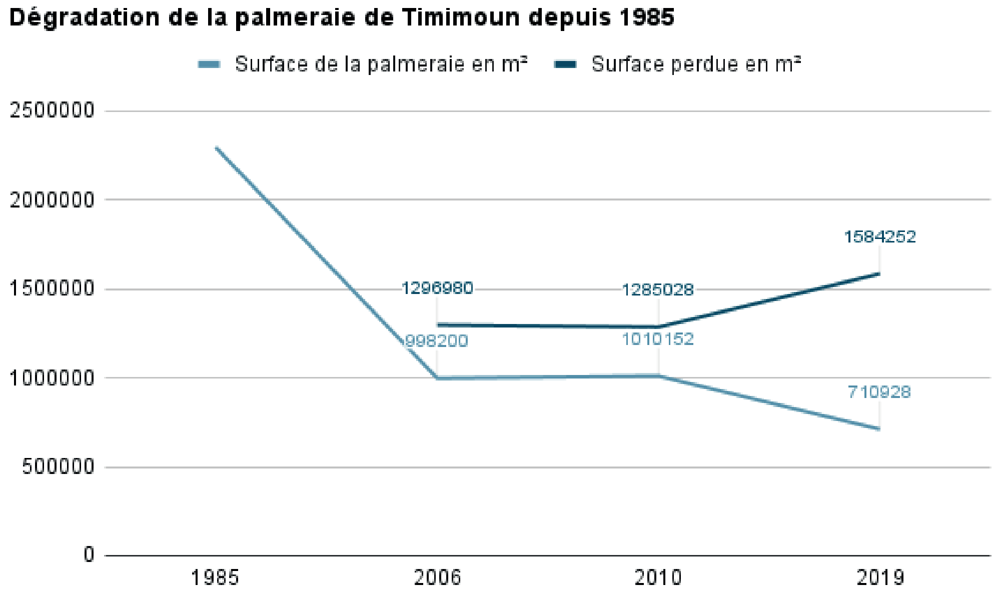


Figure 36 : Graphique de l'évolution de la palmeraie entre 1985 et 2019. Illustration de l'auteur
source : Guerrout

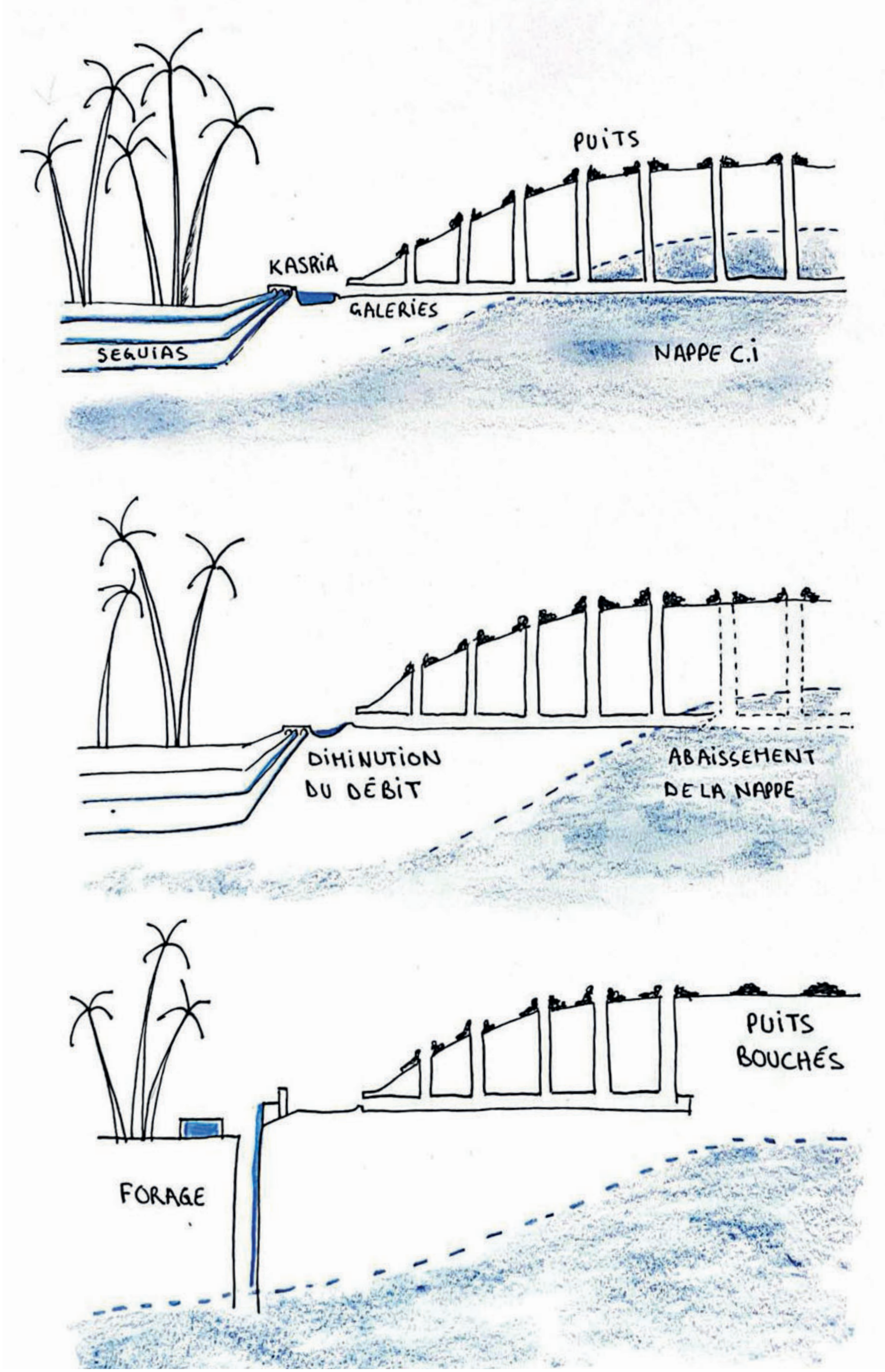


Figure 37 : Schéma du déclin de la foggara. Illustration de l'auteur

3.3. The blue network

In resonance with the memory of the place, the project reconnects with the founding element of any oasis: water. Just as the agham once followed the course of the foggara, the project is structured around this vital resource. Water becomes both material, structure, and symbol: it guides the urban composition and redefines the relationship between soil, habitat, and landscape.

Within the neighborhood, water supply is central to daily life and agriculture. The strategy is based on a complete system capable of serving domestic needs, communal activities, and irrigation for palm groves and ground-level plantations. The goal is to ensure reliable, continuous, and economically viable distribution while drawing inspiration from traditional practices of the Gourara region.

At the heart of the system is a water tower located at Agham 01, at the entrance of the neighborhood. Elevated approximately sixty meters above the lowest point of the site, this height creates natural pressure to feed homes and public infrastructure without the need for additional pumps. The reservoir holds 400 cubic meters, enough to cover the estimated daily consumption for roughly one thousand inhabitants, including auxiliary uses.

From the tower, water is conveyed to a central agricultural basin through closed pipes equipped with valves and meters to regulate flow and prevent losses. This 150 cubic meter basin acts as a buffer between the urban network and agricultural zones, moderates flow to the palm groves, and ensures equitable distribution throughout the day. It also reduces waste and protects water quality for domestic use.

From this central basin, water is distributed to the palm groves and ground-level plantations. The system combines traditional methods with modern solutions. Gravity-fed seguias carry water to the gardens and orchards, while drip irrigation networks provide precise watering. Each agricultural module, containing approximately twenty-five date palms, twenty-four fruit trees, and ground crops, requires seven to eight cubic meters of water per day. Small service basins are placed throughout some palm groves to facilitate nighttime irrigation and control.

This type of infrastructure already exists in the region, for example in Tinerkouk, where foggaras have proven less adapted to contemporary needs. With many foggaras no longer functioning, elevated storage and controlled gravity distribution have become essential. The water tower ensures a continuous and regulated supply, compatible with the site's constraints.

The strategy balances recovery, storage, and distribution, combining modern technologies with traditional inspiration. Each building integrates water management systems to collect and reuse rainwater and greywater from showers. These flows are routed separately from potable water, ensuring sanitary safety while providing a supplemental resource for irrigation and secondary domestic uses. Rainwater is captured from terraces into underground storage tanks. Greywater is filtered and collected in the same tanks, relying primarily on gravity, with solar energy providing minimal pumping if necessary.

For agricultural spaces, including the central djnens of each agham, drainage systems prevent flooding during rare but intense rainfalls. Gentle slopes and channels guide excess water toward storage basins, avoiding stagnation in cultivated areas. The result is an autonomous circuit at the building level, supplementing the neighborhood's main supply and supporting irrigation of green spaces and palm groves while integrating traditional management principles and Saharan resilience.

This water line redraws a new blue network, intersecting and occasionally emerging within the green network along a southeast to northwest axis, following the spatial and hydraulic logic of the ancient foggaras. Inspired by the Na Selma foggara, the blue network leverages soil and subsurface properties, combining natural gravity with deep-water resources. Rather than reproducing the foggara exactly, it extends its principles using elevated storage, controlled conduits, and regulation basins.

Water thus traverses the city as a living infrastructure, structuring inhabited spaces and allowing palm groves to be integrated into the urban fabric. This system reinterprets the hydraulic heritage of the Gourara, transforming it into a foundation for development, where water once again becomes a defining element of landscape, agriculture, and daily life.

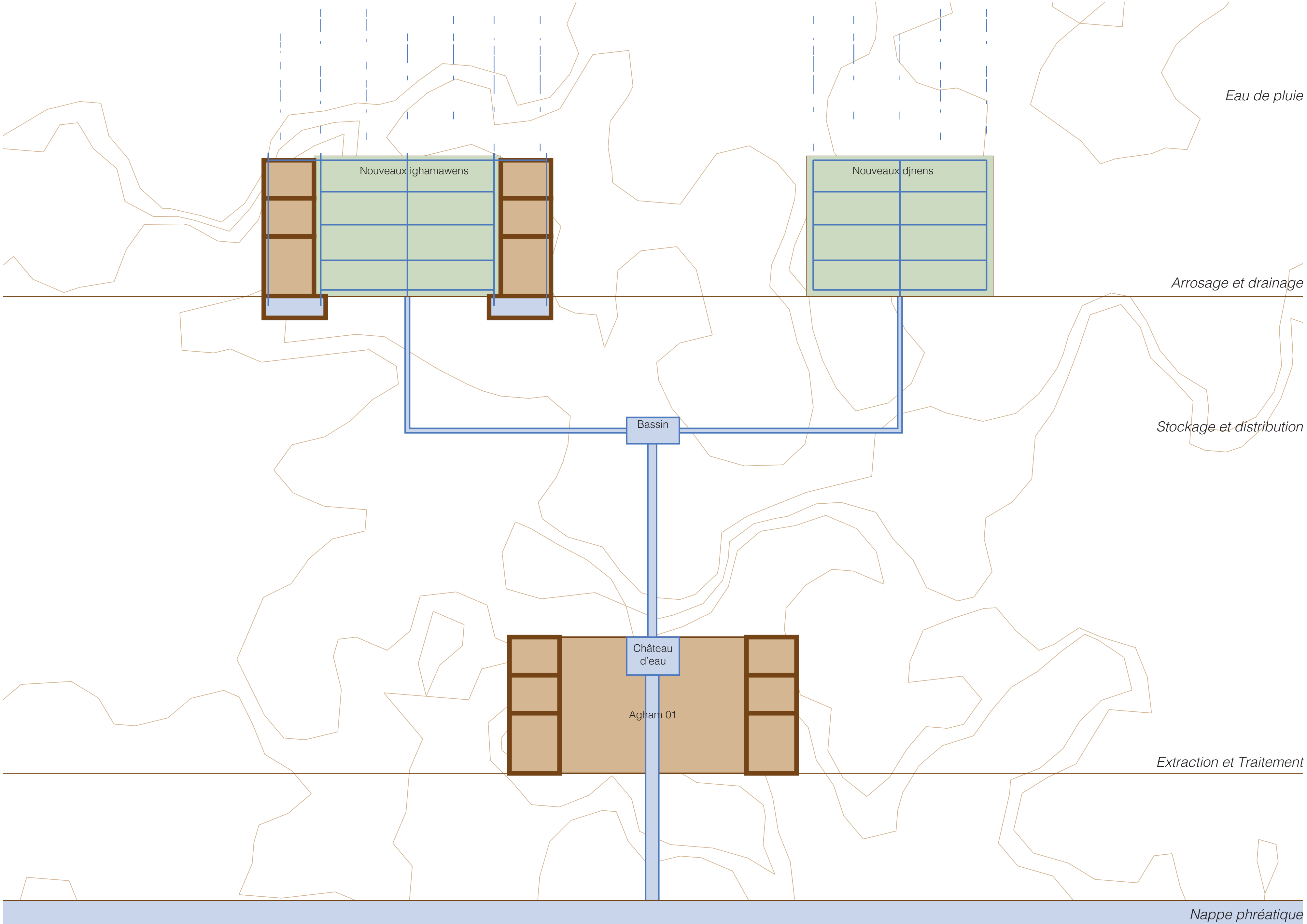


Figure 38 : Schéma stratégie de l'eau. Illustration de l'auteur

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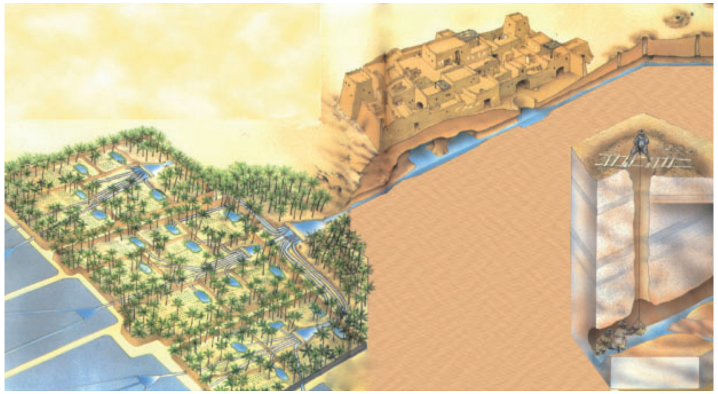
ANNEXES



Coupe-schéma du système de distribution de l'eau ©P.Laureano
Source : Sahara jardin méconnu p.42-43

Propriétés :

① Adobe

masse volumique $\rho = 1400\text{-}1600\ kg/m^3$
conductivité thermique $\lambda = 0{,}600\ W/m.K$
chaleur spécifique $C = 0{,}440\ Wh/kg.K$
capacité thermique $\rho C = 667\ Wh/m^3.K$
diffusivité thermique $a = 0{,}90 \times 10^{-3}\ m^2/h$
effusivité thermique $b = 20{,}0\ Wh^{1/2}/m^2.K$

② Enduit chaux

masse volumique $\rho = 1600\text{-}1800\ kg/m^3$
conductivité thermique $\lambda = 0{,}700\ W/m.K$
chaleur spécifique $C = 0{,}24\ Wh/kg.K$
capacité thermique $\rho C = 472\ Wh/m^3.K$
diffusivité thermique $a = 2{,}12 \times 10^{-3}\ m^2/h$
effusivité thermique $b = 21{,}7\ Wh^{1/2}/m^2.K$

Applications :

$R_{adobe} = \frac{0{,}48}{0{,}6} \rightarrow U_{adobe} = \frac{1}{0{,}8}$
$R_{adobe} = 0{,}8\ m^2.K/W$ $\quad U_{adobe} = 1{,}25\ W/m^2.K$

$R_{chaux} = \frac{0{,}02}{0{,}7} \rightarrow U_{chaux} = \frac{1}{0{,}29}$
$R_{chaux} \simeq 0{,}029\ m^2.K/W$ $\quad U_{chaux} = 34{,}48\ W/m^2.K$

$\Phi = \frac{-15}{0{,}999} \approx \frac{-15}{1} \approx -15 W$

$R_{int} = 0{,}3\ m^2.K/W$
$R_{ext} = 0{,}04\ m^2.K/W$
$T_{int} = 25°C$
$T_{ext} = 40°C$

Chute de température

ext = $-15 \times 0{,}04 = -0{,}06$
adobe = $-15 \times 0{,}8 = -12$
chaux = $-15 \times 0{,}029 = -0{,}435$
int = $-15 \times 0{,}13 = -1{,}95$

Déphasage

$\eta = 1{,}38 \sqrt{\frac{\rho C}{\lambda}} \times e$
$= 1{,}38 \sqrt{\frac{667}{0{,}600}} \times 0{,}48$
$\eta \approx 22h$

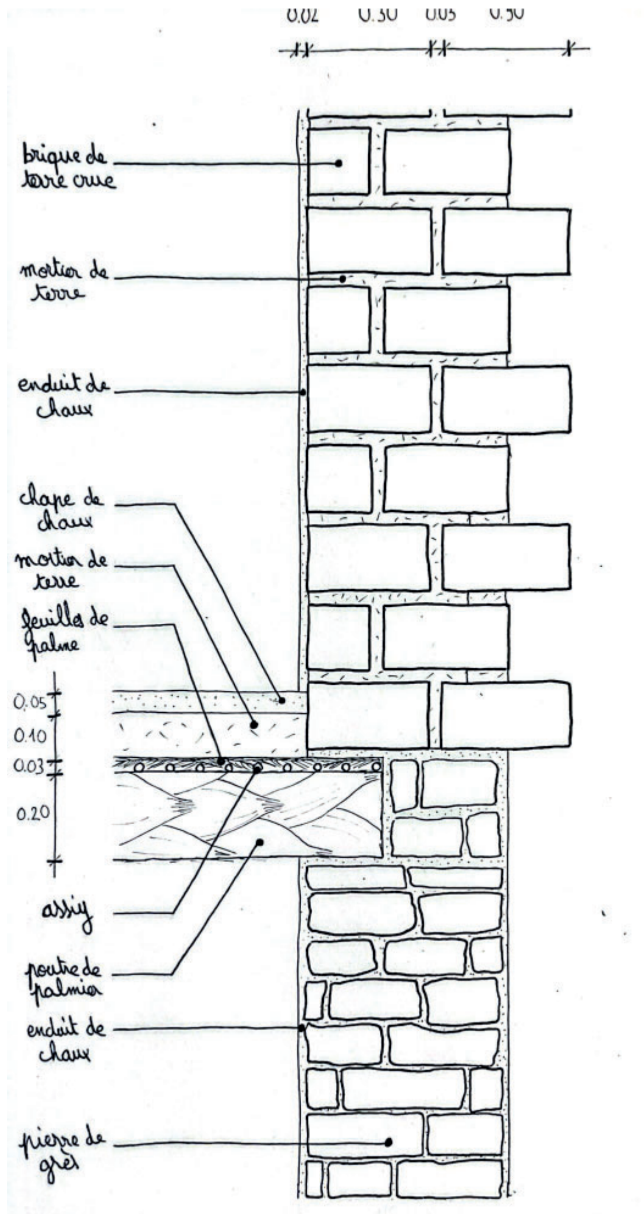
Formules :

$R = \frac{e}{\lambda}$ $\quad \Phi = \frac{Q}{t}$ $\quad \eta = 1{,}38 \sqrt{\frac{\rho C}{\lambda}} \times e$

$\eta = \frac{1{,}38 \times e}{\sqrt{D}}$

$U = \frac{1}{R}$ $\quad \Phi = \frac{(T_{int} - T_{ext})}{R_{tot}}$ $\quad D = \frac{\lambda}{\rho C}$

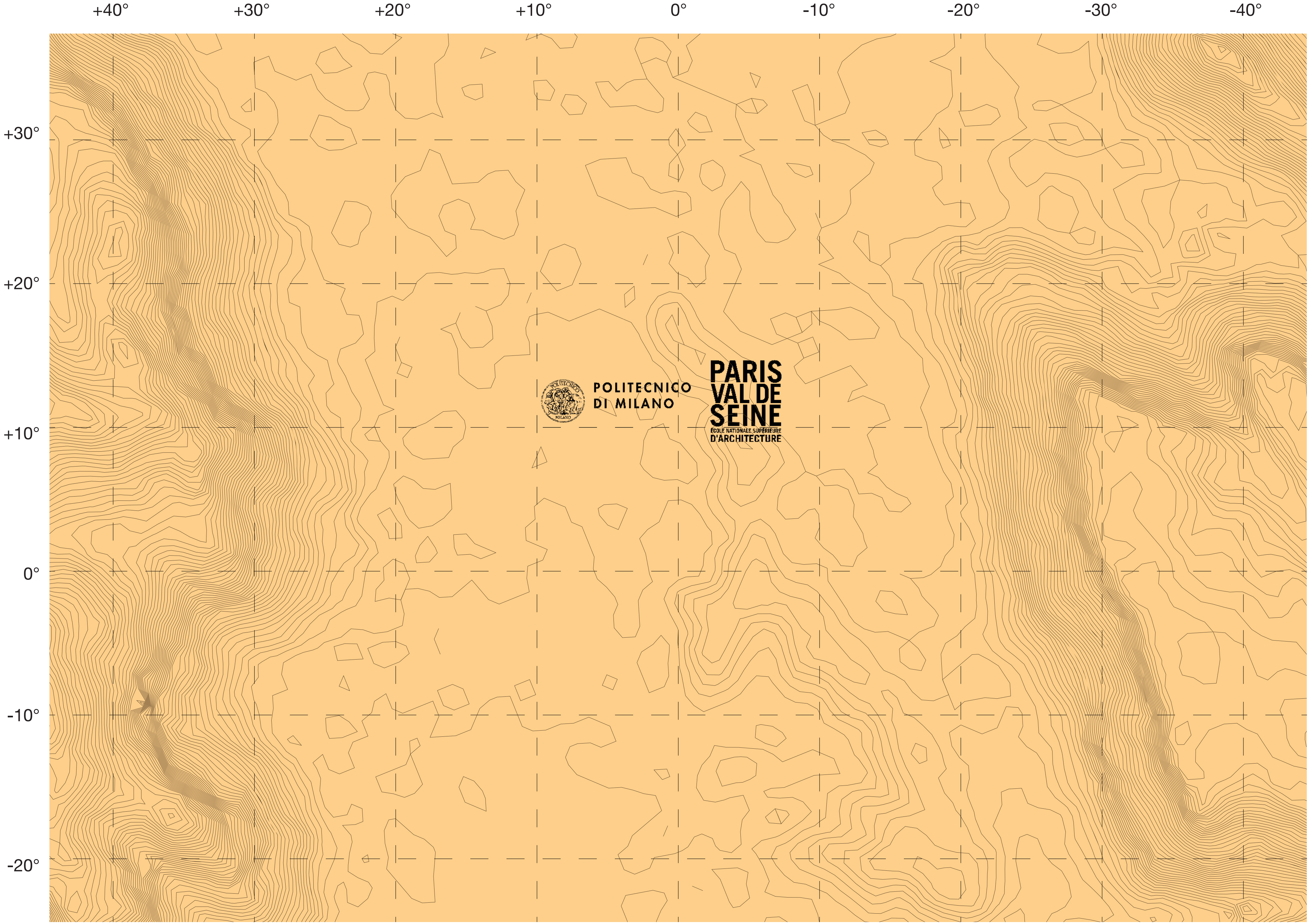
Calculs du déphasage d'un mur en adobe. Document de l'auteur



Premier essai de composition d'un mur en adobe. Document de l'auteur

Arabe	Phonétique	Français
تراب الميت	*trab el-mayet*	Terre morte
تقزة	*tqaza*	Terre vivante
تراب الحي	*trab el-ḥay*	Terre vivante
تافزة	*tafza*	Sous-sol / couche dure
أفق أ	*ofok A*	Horizon A
أفق ب	*ofok B*	Horizon B
أفق ج	*ofok C*	Horizon C
الصخرة الأم	*ṣ-ṣakhra el-omm*	Roche mère
الطبقة المتحجرة	*ṭ-ṭabaqa el-mutaḥajjira*	Nappe phréatique / couche consolidée
طوبة	*ṭoba*	Brique
طوبة ونص	*ṭoba w-nuṣṣ*	Brique et demie
جدار داخلي	*jdar dakhli*	Mur intérieur
جدار خارجي	*jdar khariji*	Mur extérieur
أعمدة	*aʿmda*	Colonnes
طين	*ṭin*	Terre / argile
جير	*jir*	Chaux
طلاء ترابي	*ṭilaʾ turabi*	Enduit de terre
طلاء بالجير	*ṭilaʾ bil-jir*	Enduit à la chaux

Lexique. Document de l’auteur


+40°
+30°
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-40°
+30°
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-10°
-20°
POLITECNICO
DI MILANO
PARIS
VAL DE
SEINE
ÉCOLE NATIONALE SUPÉRIEURE
D'ARCHITECTURE