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Addressing Water Scarcity in Rural Areas of the Souss-Massa Region of Morocco: Comparative Analysis of Desalination, Fog Harvesting, and Wastewater Treatment Methods with Considerations of Technical Viability and Human Rights

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Abstract

Water scarcity is one of the most pressing humanitarian challenges worldwide, most notably in arid and semi-arid regions like Morocco. This study conducts a comprehensive comparative analysis of three sustainable water management strategies currently being developed in the Souss Massa region of southern Morocco: fog harvesting, desalination, and wastewater treatment. Drawing upon empirical data, interviews, and existing scientific literature, the research explores the economic, environmental, and social dimensions of each approach. Fog harvesting is a locally driven solution that takes advantage of natural phenomena to collect water, albeit with limitations in reliability. Desalination is promising in addressing long-term water scarcity but requires significant energy consumption and has environmental concerns. Wastewater treatment is a viable option yet faces challenges in rural accessibility and environmental damage. The study discusses the factors shaping water management strategies, revealing the complexity inherent in addressing water scarcity. By approaching the topic through the lens of human rights and social justice, this research contributes to a deeper understanding of sustainable water management practices and the humanitarian crisis connected to it.

Keywords: Water scarcity, desalination, wastewater treatment, fog harvesting

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Chapter 1: Introduction

Background

Water scarcity is a critical global challenge with far-reaching implications for human health, economic development, and environmental sustainability. Nowhere is this challenge more prevalent than in regions like Souss-Massa in Morocco, where arid climates and growing populations strain the already limited water resources. As an aspiring environmental engineer with a passion for humanitarian work, I am determined to explore innovative solutions to addressing water scarcity and promoting social justice in these vulnerable communities.

1.1 Choice of Topic

My journey to studying water scarcity in Morocco began with my interest in environmental engineering and a desire to use my education in STEM and political science to helping communities in the MENA region, specifically. While pursuing my studies at college, I was deeply inspired by my Statics professor who conducted Fulbright research in India focused on environmental issues, particularly landslides. His multidisciplinary approach, which combined scientific research with community engagement, resonated with my own aspirations to make a tangible difference in the world.

During my time in Morocco, I was confronted with the stark realities of water scarcity, particularly during a southern excursion where NGOs and local residents emphasized the devastating impact of drought on their communities. When I took a trip to Fes, I further understood the importance of water in Moroccan culture, as locals celebrated the heavy rainfall – a stark contrast to the frustration of us tourists at the wet weather. Additionally, during our visit to the Museum of the Water Civilization in Marrakech, Morocco, I was fascinated by the engineering feats of villagers, who used hydraulic mills and harnessed water as a source of renewable energy. Witnessing how water intertwined with their culture and religion left a lasting impression on me. Learning that the Quran emphasizes water as a fundamental right of human beings motivated me to approach the topic of water scarcity through a human rights lens, and not just a scientific one.

Motivated by these experiences and guided by my academic interests, I decided to dive deeper into the issue of water scarcity in Morocco, focusing specifically on the Souss-Massa region. This region, characterized by its arid climate and heavy reliance on agriculture, serves as a microcosm of the broader challenges facing the country in terms of water management and sustainability. I wanted to compare three distinct methods for mitigating water scarcity because it provided a comprehensive and possible exploration of both engineering intricacies and their broader societal impacts. My three methods for analysis struck a balance between specificity and feasibility, allowing for a thorough examination of their effectiveness. By studying this region, I aim to contribute to our understanding of water scarcity and explore potential solutions that prioritize social justice and human rights.

The relevance of studying water scarcity in Morocco cannot be overdramatized, given the country's vulnerability to climate change and the governments list of legislative and institutional reforms aimed at battling it. In fact, Morocco has been classified as "insecure" in the Global Water Security Assessment by the United Nations and is said to be facing a “climate emergency”.

One of the key areas of focus for the Moroccan government is national water management, with efforts aimed at improving access to water resources, enhancing water quality, and promoting equitable distribution. A big part of the water scarcity problem in Morocco is uneven distribution – while urban cities are living life somewhat normally, rural villages are struggling immensely with watering crops that sustain their careers, accessing drinking and bathing water, and experiencing worse climate. In this context, exploring innovative solutions such as desalination, fog harvesting, and wastewater treatment is crucial for achieving the goals of the state.

Noura Amayous, a representative from the NGO Dar Si Hmad in Agadir, shared details about the severity of water scarcity in rural regions of Souss Massa. She described how natural water in these areas are becoming increasingly salty, which has led to the abandonment of agricultural practices such as watermelon cultivation due to excessive water consumption. The scene in the countryside of Souss Massa is “horrible” in her words – villagers can dig up to 120m underground and still find no water, and if they do, many times it has too much residue for

consumption. Even traditional irrigation systems like the Khettara[1] are no longer functional. Noura also described the hardships of communities in cities like Mririt, near Meknes, where undrinkable salty water from the river has become a reality, even affecting the taste of beverages like coffee.

1.2 Area of Study: Souss-Massa Region

The Souss-Massa region, encompassing over 12,000 square kilometers, is characterized by its arid to semi-arid climate and rare rainfall. The region is divided into the Souss plain and the Massa plain, with mountainous areas in the High Atlas. Despite its limited water resources, the region is experiencing rapid population growth and urban expansion, further exacerbating the strain on water supplies.

In Souss Massa, water resources primarily come from groundwater and surface water. The region has two significant aquifers: the Souss aquifer and the Chtouka aquifer, covering surface areas of 4150 and 940 square kilometers (see figure). Additionally, the region relies on surface water sources, which are facilitated by eight dams with a combined capacity of 800 cubic meters (Choukr-Allah, 2004).

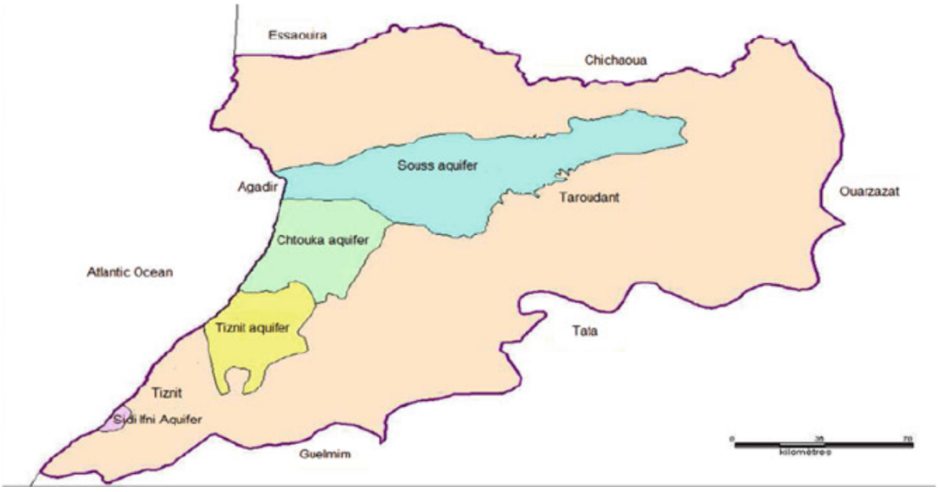

Figure 1. Geographic location of aquifers in Souss Massa, "Feasibility of Using Desalination for Irrigation in the Souss Massa Region in the South of Morocco"

[1] The Khettara is a traditional irrigation system used by indigenous Berber communities in Morocco. It's comprimsed of subterranean canals that harnesses groundwater through vertical shafts.

Agriculture is the primary economic activity in the Souss-Massa region, with crops such as argan trees playing a vital role in the local economy. However, agriculture is also the main consumer of water, accounting for 90-95% of water demand in the region. This heavy reliance on agriculture, coupled with factors such as saline intrusion into aquifers, pollution, and climate change, poses significant challenges to water sustainability in the region (Malki, 2017).

The impact of water scarcity in the Souss-Massa region is arguably the worst in the country, with urban communities experiencing hours of shortages and disruptions in water supply. Public amenities such as hammams, which were once operational seven days a week, now operate only four days a week due to water shortages. Additionally, rural areas face significant challenges, with some communities relying on saline or undrinkable water sources for their daily needs.

1.3 Morocco's Policy Responses

The Kingdom of Morocco has introduced new developments in water policy aimed at mitigating the economic and social impacts of water scarcity. These include addressing issues such as the inflation of agricultural product prices and low yields of food crops.

Morocco has outlined several key objectives, as stated by King Mohammed VI. These objectives include constructing more dams, installing hydraulic technologies, building seawater desalination plants, and improving the irrigation water economy. Additionally, there is a focus on launching initiatives and projects leveraging new technologies for wastewater reuse, as well as monitoring the exploitation of groundwater resources while combatting illegal pumping and anarchic well drilling (Taouil, 2024).

The National Water Commission, tasked with implementing the National Drinking Water Supply and Irrigation Programme, plays an important role in achieving these objectives. This program is designed around five essential goals, including supply development, demand management, rural drinking water strengthening, wastewater reuse, and communication and awareness-raising. With an total cost of 143 billion dirhams, the program aims to accelerate the development of projects to use conventional and non-conventional water resources (Taouil, 2024).

Morocco's water infrastructure, consisting of 153 large dams and 141 medium and small dams, forms the backbone of its water management system. Despite decreasing water reserves, the country has acknowledged seawater desalination as a solution, particularly in coastal regions (Taouil, 2024).

However, the water scarcity crisis in Morocco is not solely a result of natural phenomena but also stems from governmental mismanagement, particularly in the agricultural sector. Subsidized farming practices, focused on water-intensive crops like watermelon or avocado, and inefficient irrigation methods, have worsened the issue (Moutii, 2024).

1.4 General Parameters of the Study

While defining the parameters of this study, I will consider both technical and social dimensions of water scarcity and management. This approach will touch on the historical context, current challenges, and potential solutions related to water scarcity in the Souss-Massa region.

Key objectives of the study include:

1. Investigating the impact of three water management methods—desalination, fog harvesting, and wastewater treatment—on addressing water scarcity in the Souss-Massa region.
2. Analyzing the effectiveness and challenges of these methods in the context of rural water scarcity and agricultural sustainability.
3. Assessing the implications of water management strategies on human rights, social dynamics, and political governance in the region.
4. Exploring a variety of perspectives to develop region-specific recommendations for sustainable water management in the Souss-Massa region.

1.5 Hypothesis

In addressing water scarcity in rural areas of Souss-Massa, desalination, wastewater treatment, and fog harvesting each have unique advantages and challenges. While desalination is promising for long-term sustainability and scale, its success depends on overcoming large barriers related to

maintenance costs and environmental waste. Similarly, wastewater treatment offers environmental sustainability and agricultural productivity benefits but may face limitations in farmer participation and technology adoption. Fog harvesting, although theoretically sustainable, may currently lack the technological advancements required for large-scale use in the region.

Rationale

The rationale for this hypothesis is based mostly on in-class lectures, day-to-day observations, and observations made during excursions.

The significant investments made by the government of Morocco in expanding desalination infrastructure across various cities, such as Laayoune, Oujda, Casablanca, and Agadir, demonstrate its potential as a key solution to water scarcity in the country. One of Morocco's strongest geological assets is its extensive coastline, due to this, desalination offers a sustainable long-term strategy to harness abundant seawater resources for agricultural and domestic purposes.

While wastewater treatment is commonly used for addressing water scarcity in rural communities, construction and implementation of the large-scale projects required for proper use may face many logistical challenges. These challenges include the need for significant machinery, infrastructure, and skilled labor, which has constraints in the rural villages of Souss Massa.

Although fog harvesting is a promising concept for water resource management, its practical application may be limited by technological and monetary advancements. While the initiative has gained attention, it remains relatively new and may require further refinement and development to achieve widespread feasibility and effectiveness in addressing rural water scarcity.

Expected Outcomes

1. The desalination plant is expected to demonstrate the greatest potential for long-term water security and agricultural sustainability in the region if measures are taken to address maintenance costs and environmental damage.
2. Wastewater treatment initiatives will encounter challenges related to farmer acceptance and technology adoption, requiring targeted efforts to promote participation and large-scale construction.
3. While fog harvesting holds promise as a sustainable water source, it needs further research and development to reach its full potential.

Guiding Questions

1. How do the environmental impacts, cost-effectiveness, and social benefits of wastewater treatment, fog harvesting, and desalination compare in the context of rural water scarcity mitigation in Souss-Massa?
2. What are the effects of each water management strategy on agricultural productivity and community livelihoods in the region?
3. How do factors such as local climate conditions, geographical features, and community preferences influence the feasibility and adoption of wastewater treatment, fog harvesting, and desalination technologies?
4. To what extent do policy frameworks, government interventions, and community engagement strategies facilitate the implementation and scalability of these solutions?

Useful Terms

Water scarcity: the concept of insufficient water resources to supply a population
Desalination: the removal of salt and other contaminants from seawater by the use of different methods, including reverse osmosis, which is a technique that pushes water through a semipermeable membrane to remove impurities
Fog Harvesting: the collection of water droplets from fog into mesh nets and gutters
Wastewater treatment: the removal of contaminants from wastewater for human use or agriculture

1.6 Theoretical Framework

Theoretical framework: This study will adopt a human rights framework that emphasizes equitable distribution of water resources between urban and rural communities. This will be done by analyzing the three water management methods in the context of their impact on villages.

1.7 Scholarly Context

Previous research conducted by professors such as Redouane Choukrallah from Ibn Zohr University in Agadir, has explored the connection between water scarcity and agricultural sustainability in the Souss-Massa region. Their studies have highlighted the challenges facing the region, including over-pumping of groundwater and salinization. By building upon these ideas, this study will contribute to current discussion on water management and sustainability in Morocco.

Chapter 2: Literature Review

In this paper, literature is the foundation of all thoughts and analysis. However, this literature review does not go into theoretical discussions or critiques, focusing instead on the role of select literature sources in shaping this project. Each cited paper contributes unique perspectives, data sets, and insights that will be compared and analyzed.

2.1 Review of Choukr-Allah's (2004) Study on the Feasibility of Desalination for Irrigation in Souss Massa, Morocco

The feasibility of implementing desalination projects for irrigation in the Souss Massa region is a topic of significant interest and debate – in fact many research journals already exist discussing this topic. The source describes a study conducted among farmers aimed to gauge their willingness to agree to the added cost of desalinated water for their irrigation. Surprisingly, only 42% of the surveyed farmers agreed to pay the extra price, which raises concerns about the economic feasibility of desalination projects, especially among poor farmers who constitute a significant portion of the agricultural community in the region. However, the study also states that 92% of the surveyed farmers accepted the desalination project overall, showcasing a general acknowledgment of the water scarcity problem and the need for new solutions. Moreover, the study suggests that as desalination technology progresses, the costs are expected to decrease, making desalinated water more affordable and accessible to farmers in the future.

One interesting aspect of the study is the author's approach to assessing the feasibility of desalination projects by consulting with different types of stakeholders, particularly greenhouse operators, to determine their needs. This approach provides a realistic perspective into the implications of desalination for agricultural users in the region. However, it is essential to note that this is an older study, and it is based on hypothetical scenarios, as it predicts and makes assumptions about the actual implementation of desalination projects in the region. Despite this limitation, the study serves as a fundamental piece of research for this paper.

This study will serve as a critical reference point for evaluating the qualitative feasibility of desalination projects in the region. Quantitatively, the findings of this study will be compared with real-world data from operational desalination plants.

2.2 Review of "Desalination in Morocco: Status and Prospects" by Soufian El-Ghzizel, Mustapha Tahaik, Driss Dhiba, Azzeddine Elmidaoui, Mohamed Taky

This paper has two primary sections, each offering unique insights to this study. Firstly, it analyzes the economic and environmental implications and constraints associated with desalination. This analysis is important in contextualizing the financial viability and ecological sustainability of desalination projects, particularly within the socio-economic landscape of the Souss Massa region. The exploration of economic factors is particularly useful, shedding light on the affordability challenges that may occur if the widespread adoption of desalination among local farmers happens. Secondly, the paper uses the Agadir desalination plant as a case study, examining its operation and water distribution mechanisms for irrigation. This examination is directly relevant to the present study. Additionally, the paper offers potential solutions to battle these limitations, such as leveraging renewable energy sources to power desalination processes, thereby reducing operational costs. However, it the paper's discussion predominantly revolves around the scientific and sustainability aspects of desalination, overlooking the urgency of addressing water scarcity in the region. While proposing sustainable alternatives for brine disposal, the paper downplays the pressing need for immediate action, given the ability of desalination to alleviate water scarcity in coastal areas like the Souss Massa region.

2.3 Review of Dodson and Bargach (2015): Harvesting Fresh Water from Fog in Rural Morocco

Jamila Bargach's paper, written by the head of the NGO I had the opportunity to visit in Agadir, offers a unique perspective on addressing water scarcity through a new innovation. The paper uses the narrative of water scarcity with that of feminism, highlighting the disproportionate burden borne by women in water collection. By analyzing the impact of her NGO's project on the community, Bargach discusses the socio-economic and human rights dimensions of water scarcity, particularly emphasizing the issues that can be experienced by women and children.

However, there are potential biases in the paper, given that it's written by the project directorate. The paper may overlook certain limitations or challenges associated with fog harvesting.

2.4 Review of "Women entrepreneurs catalyzing change in wastewater treatment sector in Morocco" Shumilova, D., & Mordaszewska, K. (2023, March 21).

This initiative presents an interesting case study. The discussion surrounding decentralized wastewater treatment leads into its potential integration into rural regions, discussing ideas like practical solutions tailored to specific community needs. The literature provides a glimpse into the many startups in Africa dedicated to cleantech and sanitation, also discussing collaborative efforts across countries within the continent. By exploring the mechanical side of wastewater technology, the literature also offers a technical perspective into the topic. They also approach the issue of water sanitation as a human rights issue, particularly for vulnerable groups such as children and women, which leads this research paper into the broader socio-economic and ethical dimensions of water scarcity.

2.5 Review of "Wastewater treatment and reuse for irrigation as alternative resource for water safeguarding in Souss-Massa region, Morocco" Malki, M., Bouchaou, L., Mansir, I., Benlouali, H., Abdessadek, N., & Choukr-Allah, R. (2017).

While this paper focuses on Tiznit as a case study rather than Agadir, it still applies to understanding wastewater treatment for irrigation in the Souss Massa region. Professor Bouchaou's perspective influences this project a lot, and one of his PhD students was interviewed as well. The analysis of the costs, benefits, and impacts of wastewater treatment, albeit with an urban focus, reflects the potential success of the Agadir plant. However, the limited exploration of strategies for extending wastewater treatment benefits to rural communities represents a gap in a lot of the current research concerning desalination in Morocco.

2.6 Review of High Atlas Foundation's Blog Post: "A Moroccan Woman's Burden: Water Scarcity" by Jasiah Hasan (2021)

This study discusses the critical role of NGOs and organizations dedicated to humanitarian work and human rights in addressing water scarcity issues, particularly in rural communities. It highlights the disproportionate impact of water scarcity on women and children, who often bear the burden of traveling long distances to collect water, thereby limiting their access to education

and economic opportunities. The citation discusses the significance of international investments in rural Moroccan villages to improve water infrastructure, such as constructing pipelines, pumping stations, wells, gravity flow systems, and water towers. These initiatives aim to alleviate the emotional and physical labor associated with water collection, particularly for women.

Chapter 3: Methodology

3.1 Research Overview

The ISP period was quite the journey, characterized by constant reevaluation and discovery. It began with creating a research question: "To what extent have desalination plants effectively alleviated water scarcity issues in Morocco, specifically within the Chtouka region, and what factors contribute to their success or limitations in addressing this critical challenge?" This initial idea was somewhat arbitrary, influenced by concerns in Rabat regarding desalination as a potential solution, which I heard about on a day-to-day basis. However, my focus shifted when I came across the NGO Dar Si Hmad and their innovative fog harvesting initiative. Fascinated by this approach, I made the decision to broaden my scope and compare three water methods to gain a more comprehensive understanding of the topic of water technologies, all the while shallowing the depth in which I study each specific method. I created a hypothesis based on my assumptions, and then embarked on the research journey. I used an array of sources including academic journals, discussions with professors, NGOs, and interviews with students, and was able to collect many different types of data. The scientific method was my guiding compass – first, I analyzed the gathered information and processed my findings. Through this process, my understanding of environmental engineering broadened, particularly in how it connects to human rights and social justice. Ultimately, this ISP period proved to be extremely transformative, sparking a strong commitment in me to support environmental sustainability with my engineering background.

3.2 Participant selection

In the initial stages of planning my research, I understood that I had to select a diverse array of interviewees and participants in order to approach my topic in multiple dimensions. Professor Dalila Loudyi, with her expertise in civil and environmental engineering, was my first point of contact. I was introduced to her last summer through my civil engineering professor at Vanderbilt, who suggested we collaborate based on our similar interests. After meeting with her in Mohammedia this semester, I outlined my ideas and she helped me narrow down my research topic and provided many contacts to help me get started. These connections included a PhD student based in Agadir and professionals working directly in the desalination plant in Chtouka.

To explore the human rights and social justice dimensions, of my topic, I asked for guidance from Professor Taieb, whose expertise in politics and human rights offered a complementary perspective to Dr. Loudyi's. Professor Taieb introduced me to Dar Si Hmad, an NGO working to empower rural women in Morocco. Their projects, situated in Souss Massa, provided a unique lens to examine the intersection of water scarcity and gender equality and community development.

3.3 Choice of location

The choice of location for my research was a carefully considered decision. Agadir, located in the Souss Massa region in southern Morocco, emerged as an ideal research hub for several reasons. Firstly, the region's reputation for high agricultural productivity, particularly in horticultural exports, made it a focal point for existing water management studies. Additionally, significant advancements and research initiatives in water management had already been developed in this specific area, providing abundant opportunities for fieldwork and data collection.

Geographically, Agadir's proximity to the Sahara Desert presented a unique opportunity to study firsthand the challenges posed by drought and water scarcity, which were central themes of my research. Furthermore, the accessibility and logistical ease of conducting fieldwork in Agadir were important factors in my decision-making process. The city's infrastructure and proximity to other research sites within the Souss Massa region minimized logistical challenges. Admittedly, Agadir's beautiful beaches, nearby surf resorts, and popularity in the tourist scene, tempted me to use it as my base. As I conclude my research project, I can safely say that my expectations for Agadir were fully fulfilled – I had an amazing time.

3.4 Data collection strategies

During my research, I used the triangulation approach, using multiple methods to ensure the validity and comprehensiveness of my research findings. This involved conducting interviews with a diverse range of participants, including students, professionals, and academics, to gather data from various perspectives. Additionally, I paid attention to how water scarcity was discussed around me, to gather authentic data. For instance, I learned about the drastic increase

in avocado prices, which sparked conversations about water usage and abandoning the production of them. I complimented these qualitative methods with quantitative data from research journals, allowing for a well-rounded analysis of the research topic.

A critical aspect of my methodological approach was reflexivity and acknowledging my own positionality as a researcher. I recognized the potential for bias stemming from my formal education, which may prioritize certain solutions to water scarcity over others. For instance, I may subconsciously downplay the importance of having sufficient funding since I'm not fully exposed to the poverty in many of the studied areas. I also may prioritize long-term and sustainable solutions, as opposed to effective, cheap, yet unsustainable solutions, which inherently downplays the urgency of the water scarcity situation. To limit this bias, I remained conscious of the broader contextual factors influencing my perspectives and interpretations.

Ethical considerations played an important role in shaping my data collection. I took measures to protect the identity and integrity of participants by obtaining informed consent, ensuring confidentiality, and anonymizing data when necessary. This involved organizing consent forms and clearly communicating the purpose and scope of the research to interviewees.

3.5 Obstacles

My research journey was far from smooth and straightforward, dealing with numerous obstacles along the way. As an independent student researcher working in a country where I am not fully fluent in the language or culture, I faced several challenges.

One major obstacle was conducting remote work, given that my focus was on Agadir and the Souss-Massa region while I was based in Rabat. Communication had to be conducted primarily through text, calls, and emails, creating many delays as I waited for responses from individuals involved in my research. This was the biggest challenge I faced – I am used to fast-paced American culture and became impatient when interviews were delayed, cancelled, or never scheduled. Due to this, I was only able to conduct one in-person interview.

Additionally, being an independent student presented its own set of difficulties. Attempting to navigate an academic and professional environment without university affiliation was challenging, especially when dealing with unresponsive professors. However, I found that communication was more effective when initiated through my advisor.

Time constraint was the last major obstacle in my research. With interviews and meetings taking time to plan, most occurred during the final week of my ISP. Consequently, the bulk of my writing was delayed until I had gathered all necessary data, resulting in a condensed period of intense activity towards the end of the research period.

3.6 Depth, and scope

Initially, I had ambitious plans for my field research, intending to intern at the desalination plant, visit rural communities in Souss Massa, observe the khettara, and explore the fog harvesting site. However, as an independent researcher, organizing these visits was very challenging, especially considering the slower pace of business operations in Morocco. Consequently, I found myself with only a week for a field excursion, which was insufficient to cover all the planned locations.

Faced with time and logistical constraints, I had to adjust my approach. Instead of pursuing extensive field research, I shifted towards conducting a comparative analysis of three different water management methods. This adaptation allowed me to gain a basic general overview of each method within the limited timeframe and resources available.

Relying on existing online research journals for data had implications for the quality, depth, and scope of my research. The comparative analysis provided a general understanding of each water management method, potentially limiting the depth of analysis, and understanding of specific cases or contexts. However, this shift also broadened the scope of my research, allowing me to explore a wider range of factors and considerations, albeit at a less detailed level.

Chapter 4: Limitations

One significant limitation of this study is the reliance on outdated research journals for data collection. Many of these publications date back several years and may not accurately reflect the current landscape of water scarcity initiatives and technologies in Morocco. Given the rapid pace of government initiatives and technological advancements in recent years, the data may be outdated and fail to capture the latest developments in the field. Additionally, the heavy reliance on online research introduces concerns regarding the credibility and reliability of the sources used. While efforts were made to select reputable sources, the inherent variability in source credibility poses a challenge to the validity of the overall findings.

Spatial variability was also a limitation of this study. The effectiveness of the three water management methods examined may vary across different regions of Morocco, each characterized by unique climates, agricultural needs, cultural norms, and funding. Therefore, while the findings of this study may offer insights into the Souss Massa region, they may not be directly applicable to other areas without careful consideration of contextual differences.

Another limitation relates to stakeholder perspectives, particularly those of NGOs and professionals working in the field. There is a risk of bias inherent in individuals who are deeply invested in specific technologies or projects, leading to potentially skewed interpretations of effectiveness and impact. For example, interviewees affiliated with the fog harvesting NGO exhibited a strong attachment to their work and may have downplayed certain limitations or challenges associated with the project. Furthermore, the study overlooks the importance of social acceptance and community perspectives in assessing the suitability of new technologies. While the focus remains primarily on scientific efficacy, it is crucial to consider how these innovations may disrupt existing social dynamics and routines within rural communities. For instance, Dr. Jamila Bargach mentioned in her interview that when she proposed her fog harvesting initiative to women in villages, many did not want to be liberated from the water collection chore. Instead, they wanted to keep their life routine the same as it had always been. Failure to account for social factors may undermine the success and sustainability of water management initiatives in practice.

Chapter 5: Findings

5.1 Fog harvesting

5.1.1 Dar Si Hmad Overview

Fog harvesting is becoming a promising approach to combating water scarcity in arid and rural regions, particularly in Souss Massa, Morocco. The NGO foundation, Dar Si Hmad[2], was connected for an interview, with Executive Director, Dr. Jamila Bargach, and the Educational Program Manager, Noura Amayous, as the two points of contacts. The following findings were collected from their interviews.

Dar Si Hmad is a prominent and well known non-governmental organization in the Souss Massa region and in the world of fog harvesting. They created the largest fog harvesting project in the world, based in the rural agricultural community of Sidi Ifni. The initiative began with Dr. Bargach's husband, who read about Chile's fog harvesting project 15 years before the start of Dar Si Hmad. The fog harvesting plant in Chile, located in the northern Coquimbo region, is a benchmark in fog water collection initiatives. Comprising seven activated sludge systems, this facility demonstrates the potential of harnessing fog as a vital water source in arid, rural landscapes. When visiting his hometown in Souss Massa, the immense and constant fog sparked an idea based on his past readings about Chile. In that moment, Dar Si Hmad's groundbreaking project began.

The organization itself is a beacon of hope for rural communities in the region. They address water scarcity while also fostering sustainable livelihoods and equality for indigenous communities. Founded with a commitment to human rights, they tackle socio-economic challenges through approaches grounded in local culture and gender equality. Their notable fog harvesting project provides a solution to water scarcity in a communal level, leveraging community engagement strategies to alleviate water-related burdens for women, and ensure that the project can be sustained remotely.

[2] This research was carried with the full knowledge and support of Dar Si Hmad, Dar Si Hmad is, however not responsible for the results which only engage its authors.

5.1.2 Community Empowerment and Humanitarian Focus

By focusing on the needs of Berber communities in the Air Baamrane region, one of the poorest in Morocco, Dar Si Hmad addresses water scarcity through a feminist lens, aiming to transform the lives of women and children who often bear the burden of water collection. Women in this region spend up to 4 hours a day collecting water: they walk to well together as early as 4am in the morning, wait for the water table to rise, and use physical labor to collect it and carry it back to villages. Often, these women barely consume that water to allow their families to nourish. To say the least, water anxiety levels are at an all-time high.

Dar Si Hmad also hosts educational programs. The Water School hosts the children that consume their fog water. They educate them on how to preserve the water, where it comes from, and why it is so important to protect – all for the end goal of ensuring that future generations will preserve their technology. The NGO also hosts programs to teach Amazigh women math so they can properly maintain the systems.

5.1.3 Operational Framework and Technological Design

The fog harvesting system, on an international level, is a new upcoming method for capturing, filtering, and distributing water. It takes advantage of the Souss Massa community's largest environmental asset: its fog. For half a year, the village receives dense advection fog. Their fog is created by cold currents that run through the Canary Islands. When the water evaporates and pressurizes, fog (defined by a cloud that touches Earth's surface), is created. While there are many types of fog, this harvesting system only works with one: advection. This type of fog exists when warm and moist air is blown horizontally over a cold surface – it creates larger and thicker droplets that contain large amounts of water.

The fog water catchment system is comprised of two poles with a mesh-like net suspended between them. It is a porous surface that captures water droplets suspended in the moist air in fog. When wind pushes it horizontally towards the mesh, it is captured, condensed, and drips into gutters below. Next, a UV filter processes the water for human use.

Figure 2. One fog harvesting unit with components: mesh net, gutter, poles. Captured at Dar Si Hmad Annex, Agadir

Each net unit costs around $200 per unit with little maintenance cost after. The minimum collection amount for each of these units is 5L per m2, but often exceeding this amount.

5.1.4 Impact and Results

The fog harvesting project has yielded significant results, providing fresh water to approximately 1000 people across 16 villages in Souss Massa. With an initial mesh area of 1700m2, the project has demonstrated impressive water collection rates, with 6300 liters per day collected as of 2015, when the mesh area was only 600m2. These outcomes show the project's effectiveness in addressing water scarcity and improving the quality of life for small local communities.

Advantages:

1. The project is low maintenance and able to be locally managed which ensures the sustainability and effectiveness of the technology. There is no need for large installations, huge facilities, and many employees. The nets run using natural conditions (wind, fog, and gravity), and will only ever so often need their water meters, water flow, or pipes

checked. Additionally, there is an Infromation and Communications Technology for Development (ICTD) component of the project that local Berber women were educated to use through Dar Si Hmad's technological literacy program. The ICTD allows women to use their phones to monitor and report problems with the system.

2. No brine is created with fog water catchment systems, unlike most water cleaning technologies. Therefore, the environmental impact is small as the nets do not deposit any materials, nor does it take.
3. The system requires little energy or money – it is passively powered by the environment.

Limitations:

1. It is only applicable for areas with advection fog. The community must be perfectly situated to receive these large drop molecules, otherwise the cost to benefit ratio of the system will not be sufficient.
2. The community must have enough storage space for the water. Since fog may only appear half the year, and usually only at night, it is encouraged to collect as much water as possible when it does appear.
3. The project will only be effective for part of the year. In these communities, fog will usually appear around 95 days out of the year – although even this number is not guaranteed.
4. Residents in the villages, although poor and underprivileged, are required to pay for the water they receive. While Dar Si Hmad advocates for clean water as a fundamental human right, it acknowledges the importance of assigning monetary value to water resources. This approach is exemplified by a trial where 30 tonnes of water were provided to a village for piping testing, resulting in wastage by community members, revealing the repercussions of free water distribution. To mitigate such inefficiencies, a nominal fee of about 20 dirhams per month is enforced. However, apart from this charge, the community is not burdened with additional obligations. Notably, governmental assistance is absent, and voluntary contributions from residents primarily existed in project implementation, helping with construction tasks, water transportation, and mesh installation efforts.

5.1.5 Future Plans and Sustainability

Looking ahead, Dar Si Hmad's future objectives align with the Moroccan government's initiative to interconnect villages within the region and link them to urban centers by 2027, facilitating equitable access to clean water for all populations. In tandem with this broader aim, Dar Si Hmad envisions expanding its mesh area from 1700m2 to 2500m2 and extending its services to help 12 villages. With the provision of drinking water secured for these communities, the focus would shift towards supporting local agriculture by diverting water resources for irrigation purposes. This approach aims to foster agricultural sustainability and enhance the livelihoods of rural farmers, thereby contributing to the overall prosperity of the region.

5.2 Wastewater treatment

5.2.1 Overview

According to Malki et al. (2017), the study focusing on Souss Massa highlights water scarcity and pollution from waste as two critical challenges to clean drinking water. Specifically, the case study of Tiznit demonstrates the implementation of natural lagoon systems for wastewater treatment. With a significant investment of 41 million MAD, this project has the capacity to handle a flow of up to 5300m3. This approach not only addresses pollution but also reverses environmental damage caused by sewage discharge, which offers a promising solution that integrates the issues of water scarcity and pollution (Malki et al., 2017).

Currently, wastewater treatment is operational in various regions of northwest Morocco, serving different purposes. In Kenitra, treated wastewater is utilized for irrigating eucalyptus trees, while in Marrakech, it supports the irrigation needs of golf courses. This practice is now extending to Souss Massa. Despite the presence of sewage treatment plants in the region, the connection network is inadequate, particularly for rural areas.

The use of treated wastewater has many positive outcomes, particularly in Drarga city, where it has led to increased crop yields. The additional nitrogen supply present in treated wastewater reduces the need for additional fertilizers. Another example of this is found in a study conducted by Belabhir et al. (2022) in the Agadir area which focuses on two varieties of sweetcorn and two irrigation methods: sub-surface drippers (SSD) and surface drippers (SD), with varying irrigation

dosage levels. The results indicated an increase in grain yield for sweetcorn irrigated with treated wastewater. This presents significant economic advantages by reducing the need for fertilizers (Attar et al., 2022).

In Morocco, there also exists the M'Zar wastewater treatment plant, located in Agadir, serves as a critical infrastructure for addressing water scarcity and ensuring public health in urban Agadir, Morocco. Built in 2002, this facility plays a significant role in recycling wastewater in the city and communities including Inezgane, Dcheira, Aït Melloul, Tikiouine, and contributing to 70% of Agadir's water supply. Using an ultraviolet water disinfection system, the plant eliminates pathogenic microorganisms, making the treated water safe for irrigation purposes, but not necessarily for human use. The ultraviolet disinfection process involves reproducing UV-C type rays in a reactor, which target and deactivate microorganisms by disrupting their DNA replication. Despite its effectiveness in treating wastewater and supporting irrigation for golf courses and green spaces in urban Agadir, the applicability of the M'Zar plant to rural areas of Morocco may be limited. Rural regions lack the necessary infrastructure and resources to implement and maintain such large-scale treatment facilities. Additionally, the high cost and maintenance requirements associated with ultraviolet disinfection may pose challenges in rural settings with limited financial resources and technical expertise. The treatment facility does not disperse its water to rural communities, but instead supplies the urban population to alleviate stress on rural water tables. Therefore, it indirectly reduces water stress for rural communities (Bio UV Group, n.d.).

5.2.2 International Case Studies

1. Poland: The case study conducted in rural Poland can be adapted to the Souss Massa region in Morocco. While the specifics of Poland's infrastructure may differ from those in Morocco, the overarching principles and challenges resonate across geographies. Drawing from the lessons learned in Poland, there is a clear imperative to adapt and implement decentralized wastewater treatment systems in rural areas of Morocco. Unlike urban centers where centralized collection and treatment systems are prevalent, rural villages often lack access to such infrastructure, needing localized solutions (Boguniewicz-Zabłocka, 2017).

One promising solution highlighted in the case study is the use of Membrane Bio-Reactors (MBRs) for wastewater treatment. MBRs use biological degradation and membrane filtration processes to effectively remove pollutants, including micropollutants, from wastewater. This environmentally friendly approach offers a high loading rate and can be installed in rural areas where centralized treatment facilities may be impractical. However, it is important to acknowledge the limitations of MBRs, including their initial cost and ongoing maintenance requirements, which may pose challenges in resource-constrained settings like Souss Massa.

Morocco can address the dual imperatives of improving water quality and expanding access to sanitation services in rural communities. Adopting a context-specific approach that integrates technological innovation with local expertise and community engagement will be critical to the success of wastewater management initiatives in the Souss Massa region and beyond (Boguniewicz-Zabłocka, 2017).

2. Egypt: In Cairo, the Upflow Anaerobic Sludge Blanket (UASB) system has become a prominent method for treating domestic wastewater, particularly in areas with hotter temperatures. This anaerobic digestion process offers several advantages, including relatively low maintenance and construction costs compared to conventional treatment methods. However, it is essential to consider both advantages and limitations:

   Temperature Adaptability: The UASB system's effectiveness in warmer climates aligns with Egypt's environmental conditions, making it a viable option for wastewater treatment in the region. The anaerobic digestion process operates optimally in hotter temperatures, facilitating the breakdown of organic matter present in domestic wastewater. This, however, will be more of an advantage than a limitation in the context of Souss Massa (Boguniewicz-Zabłocka, 2017).

   Low Maintenance and Construction Costs: One of the key advantages of the UASB system is its cost-effectiveness, both in terms of initial construction and ongoing

maintenance. This affordability makes it an attractive option for wastewater treatment infrastructure development, particularly in resource-constrained settings.

Nutrient Filtration Challenges: While effective in removing organic pollutants, it may not adequately address nutrient removal requirements for human use.

Methane Production: An inherent characteristic of anaerobic digestion processes is the production of methane gas as a byproduct.

While the UASB system offers several advantages, its suitability for rural areas may be limited because the process requires extensive facilities and employees.

3. Chile: Chile faces similar environmental conditions to Morocco, characterized by aridity and rural landscapes, making efficient wastewater treatment essential for addressing water scarcity challenges and supporting agricultural activities.

   In the Coquimbo region, wastewater treatment infrastructure includes seven activated sludge systems. However, there exists sensitivity and high needs in operation and maintenance requirements. Despite these challenges, successful operation of these plants has successfully facilitated the irrigation of many farms.

   The plant is divided into two parts: one for accumulating dehydrated sludge and the other for chlorinating water. Subsequent treatment involves reverse osmosis desalination, resulting in water suitable for consumption. Perhaps a similar approach can be attempted in Souss Massa (Milesi, 2023).

4. Palestine: West Bank hosts a wastewater treatment facility catered for a semi-arid region. Legal hurdles are a significant obstacle, as the community struggles to establish the criteria to measure the cleanliness and safety of treated water. Moreover, despite the willingness of farmers to embrace wastewater treatment for irrigation, discrepancies exist between their preferences and policymakers' recommendations. Addressing this disparity

requires two crucial measures: firstly, enhancing education and awareness among local communities to foster understanding of the benefits and risks associated with treated wastewater reuse, and secondly, fostering greater empathy from policymakers to align their decisions with the practical needs and socio-economic realities of farmers. (Mizyed, 2013).

5.2.3 Challenges in Wastewater Treatment

1. Urban vs. Rural Disparities: Disparities in wastewater treatment infrastructure between urban and rural areas prove the need for decentralized methods
2. Technological Limitations: While promising technologies like Membrane Bio-Reactors (MBRs) and Upflow Anaerobic Sludge Blanket (UASB) systems have many benefits, challenges such as high initial costs and limited suitability for rural communities must be addressed.
3. Limitations in Use: As demonstrated by the Tiznit wastewater treatment plant, water cleanliness levels are not sufficient for water to be used by humans

5.2.4 Future Developments

The Green WATECH initiative offers a promising approach to wastewater treatment. This African startup focuses on clean tech and sanitation, using gravity-driven methods to transform wastewater into irrigation water using soil, gravel, and sawdust. With successful experiments in the High Atlas Mountains, Green WATECH demonstrates the potential for economically feasible and environmentally sustainable wastewater treatment solutions to combat water scarcity (Water and Energy for Food, n.d.).

5.3 Desalination

5.3.1 Overview

Desalination is a multi-phase process that converts seawater into freshwater suitable for various uses. It begins with a pretreatment phase which removes hydrocarbons, algae, and reduces turbidity. Then, in the desalination phase, seawater is subjected to increased pressure across multiple cylindrical layers, separating salt from water. Finally, in the post-treatment phase, the

water undergoes conditioning to meet specific requirements, whether for human consumption or irrigation purposes.

5.3.2 Feasibility in Morocco

Desalination is a promising solution to alleviating water scarcity in Morocco, particularly in regions like Agadir where groundwater pumping strains already depleted water tables and invites seawater intrusion. In fact, the method is arguably the most important and discussed water treatment method in the country. The feasibility of desalination is influenced by its economic viability, with the cost per unit surpassing that of groundwater pumping. The Agadir desalination plant, employing reverse osmosis technology, commands installation costs averaging $700 to $900 per cubic meter. Despite these costs, an impressive 92% of surveyed farmers express agreement with the project, signaling widespread recognition of its potential benefits (Choukr-Allah, 2004). Luckily, as the method becomes more commonly used, the overall cost of use will lower. In fact, in Arrifi's study from 2013 on "Projet d'irrigation a partir de dessalement de l'eau de mer dans la plaine de chtouka– maroc," he mentions that not popularizing desalination will lead to much more monetary loss in the long run, stating, "The worst-case scenario in the project zone predicts the disappearance of the aquifer and a loss of about 9 billion DH of added value […] and more than 2830 permanent jobs by 2035" (Arrifi, 2013).

5.3.3 Environmental Challenges and Solutions

Environmental concerns are large, particularly regarding the production of brine waste. Constituting 50-65% of intake water flow and being 1.6-2 time more salty than intake water (El-Ghzizel, 2021) brine disposal is a significant concern, with implications for marine ecosystems and coastal environments. Efforts to address this challenge include energy recovery from brine waste, careful site selection to mitigate environmental impacts on sensitive areas, diluting brine with seawater before releasing it, and powering the plants with renewable energy (Aglagal, C., 2020).

5.3.4 Policies

Moroccan government policies regarding desalination and water scarcity have increased notably in the past few decades. Decree No. 2-17-596 designates the zone of Chtouka for water protection, imposing restrictions on groundwater withdrawal and advocating for desalination as a sustainable alternative. In Souss Massa, governmental initiatives prioritize wastewater treatment for non-potable uses, safeguarding groundwater resources and supporting agricultural activities. Financial contributions from the government further alleviate the economic burden of desalination, fostering community engagement and ability to participate in water conservation efforts (Aglagal, C., 2020).

5.3.5 Technological Advancements

Reverse osmosis is the preferred desalination method, being the most efficient and cost-effective solution with a purification rate ranging from 96% to 99%. This technology uses several layers of semipermeable membrane to remove impurities.

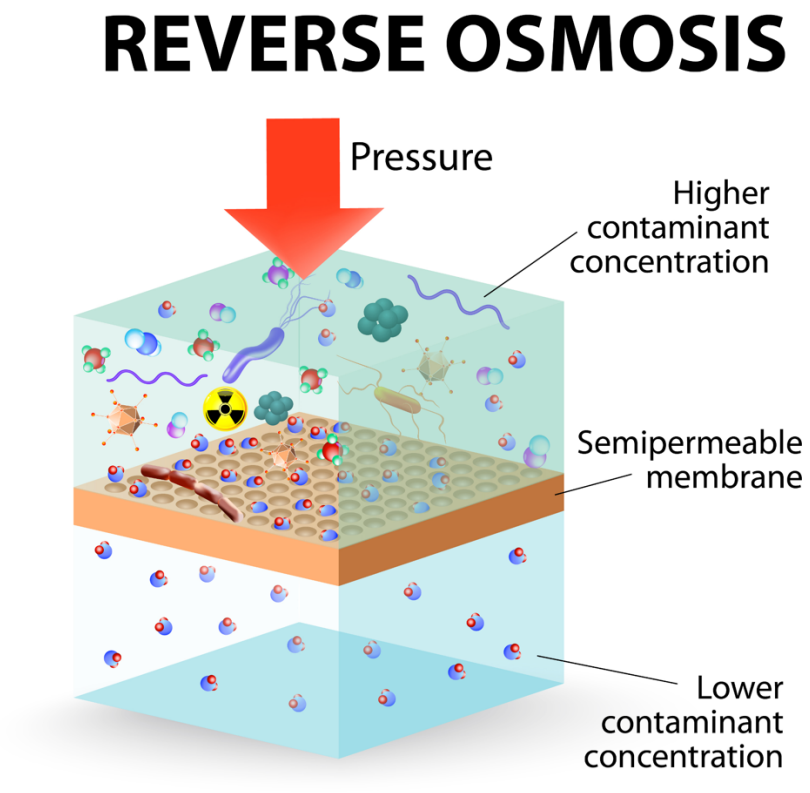

Figure 3. Diagram of Reverse Osmosis Process ("Advanced Water Inc.," n.d.)

Despite concerns about energy consumption, many advancements in renewable energy sources are being developed to mitigate operational costs and reduce environmental impacts (Citation 3).

5.3.6 Scope and Potential

The Agadir desalination plant aims to supply over 3000 farmers, covering 15,000 hectares of agricultural land. With current production at 298,000 cubic meters per day, split evenly between drinking water and irrigation, expansion plans targeting 400,000 cubic meters per day by 2044 show the show desalination's success and effectiveness, as well as the government's insistence in growing the method (Aglagal, Chaima, 2020).

Chapter 6: Conclusion

In this comparative analysis, I have evaluated the three methods for addressing water scarcity in Morocco: fog harvesting, desalination, and wastewater treatment. Fog harvesting stands out for its low environmental impact and minimal energy requirements, although its reliance on climatic conditions raises concerns about reliability. Desalination addresses water scarcity with high efficiency but requires significant energy consumption and environmental impact, while wastewater treatment offers a sustainable solution but requires extensive infrastructure and ongoing maintenance.

1. Environmental Impact

   When considering environmental impact, fog harvesting is the most environmentally friendly option among the three methods. Unlike desalination and wastewater treatment, which require significant energy inputs and produce harmful brine or byproducts, fog harvesting operates passively, relying on natural phenomena such as wind and fog to collect water droplets from the air.

   To compare desalination with wastewater treatment, address the following figure. It reveals that desalination is overall better at improving the condition (depth) of the Chtouka aquifer, and therefore has a better environmental impact.

Projected Effects of DES (Desalination Plant, Agadir) and WWR (Agadir Wastewater Treatment Facility) on Chtouka Aquifier Water Table Level (m) vs. Year

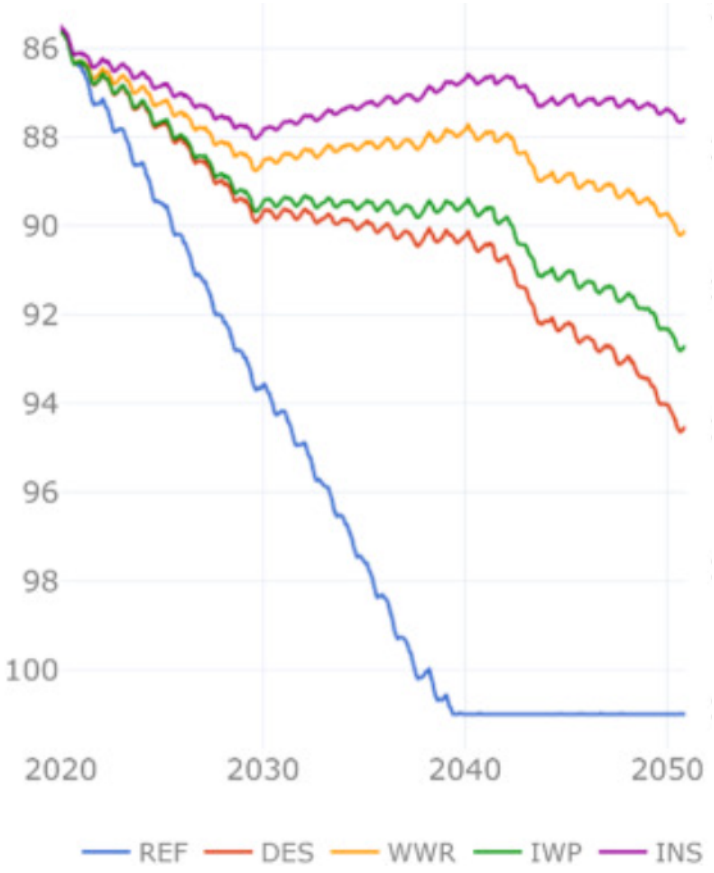

Figure 4. Chtouka Aquifer Water Table Levels in meters, (Almulla et al., 2022)

Furthermore, fog harvesting systems have minimal disruption to surrounding ecosystems compared to desalination and wastewater treatment plants. While desalination plants can disturb coastal environments through seawater extraction and brine disposal, and wastewater treatment plants may discharge pollutants into water bodies, fog harvesting systems operate in harmony with existing ecosystems. By capturing moisture from fog, fog harvesting systems provide an additional water source without altering local hydrological cycles or habitats.

To conclude, fog harvesting stands out as the most environmentally friendly option for addressing water scarcity in arid regions like Souss Massa. Its passive operation, minimal

environmental impact, and low cost make it a sustainable and eco-friendly alternative to traditional water supply methods.

2. Cost Effectiveness

In terms of cost effectiveness, fog harvesting has clear advantages over desalination and wastewater treatment. Fog harvesting systems have relatively low upfront costs (20MAD/month) compared to the infrastructure-intensive desalination plants and wastewater treatment facilities. With simple mesh nets and minimal maintenance requirements, fog harvesting offers a cost-effective solution for poor communities.

Furthermore, fog harvesting operates passively, relying on natural phenomena such as wind and fog to collect water droplets, eliminating the need for ongoing energy consumption. On the other hand, desalination and wastewater treatment are associated with high operational costs due to energy consumption, maintenance, and infrastructure requirements. Desalination plants require significant energy inputs to desalinate seawater, driving up operational costs and contributing to environmental impacts. Similarly, wastewater treatment facilities require ongoing maintenance and operational expenses to treat and manage wastewater, adding to the overall cost burden.

Desalination and wastewater treatment often require extensive infrastructure, including pipelines, treatment plants, and distribution networks, which can cause significant capital expense. In contrast, fog harvesting systems have minimal infrastructure requirements, making them a cost-effective option.

3. Water Quality

In terms of water quality, desalination is the most effective method for producing clean, potable water. Reverse osmosis desalination plants, such as the one in Agadir, use advanced filtration technologies to remove salt and impurities from seawater, producing high-quality freshwater suitable for human consumption. These plants can achieve

purification rates ranging from 96% to 99%, ensuring that the treated water meets quality standards and is safe for drinking and other domestic uses.

Wastewater treatment also removes contaminants and pollutants from urban wastewater. Treatment processes such as biological treatment, chemical disinfection, and filtration can effectively reduce the concentration of harmful substances in wastewater, making it safe for discharge into surface water bodies or reuse for non-potable purposes. However, the quality of treated wastewater may not always meet the same standards as desalinated water, particularly in terms of salt content and mineral composition. While treated wastewater is suitable for irrigation and industrial uses, additional treatment will be required to meet drinking water standards.

Fog harvesting can provide both non-potable and potable water, but its water quality may not always meet the standards required for direct human consumption. While fog water can be treated and filtered to improve its quality, it still requires mixing with mineral water to ensure safety for drinking.

4. Energy Consumption

   Desalination demands substantial energy for water treatment, contributing to high operational costs and environmental impacts. In contrast, fog harvesting operates without external power sources, only natural resources like wind and fog, making it highly energy-efficient.

5. Reliability

   Fog harvesting is the least reliable method due to its dependence on natural phenomena. The sporadic occurrence of fog poses a risk to consistent water availability, making fog harvesting vulnerable to fluctuations in weather patterns. In contrast, desalination and wastewater treatment offer greater reliability, with predictable water production unaffected by environmental conditions. Desalination and wastewater treatment plants

operate continuously, ensuring a steady supply of freshwater regardless of weather variations.

6. Long-term Viability

   This category considers the sustainability and durability of water supply solutions over extended periods. Desalination is a highly viable option due to its reliable infrastructure and proven effectiveness in addressing water scarcity challenges. With advancements in technology and ongoing maintenance, desalination plants can sustainably produce freshwater for decades. Additionally, as the method popularizes, the cost of use for civilians decreasing, possibly making the popularity of it grow exponentially over time.

   In fact, in Chaima Aglagal's PFE (2020), she states that in a scenario where desalination is not widely used, Souss Massa would not receive sufficient resources from its existing dam infrastructure and would require the abandonment of crops that need significant water.

   Wastewater treatment can demonstrate long-term viability if properly developed and improved. Souss Massa currently hosts many of these plants, however they are not fully effective given the ongoing water crisis. See Figure 5 below.

Table 4. Existing and planned wastewater treatment plants in the Souss-Massa basin.

Community	Capacity (m^3/day)		Irrigation perimeter
	Existing	New	
Agadir	62,430		Moderne Public Massa
Ait Baha	398	520	PMH Anti Atlas Ait Baha
Ait Iazza	1100		Moderne Public Souss Amont
Aoulouz		675	Traditionel Rehabilite du Souss 1ere
Biougra	1156	3800	Moderne Prive Massa
Drargua	1000	3335	Traditionel Rehabilite Issen
El Guerdane		935	El Guerdane
Lqliaa		9800	Moderne Public Massa
Oulad Berhil	1530		Traditionel Rehabilite Souss Amont
Oulad Teima	6000	8000	Moderne Public Issen
Tafraout	312	661	N/A
Tiznit	4900	9104	N/A
Total	78,826	36,830	

Figure 5. Existing and planned wastewater treatment plants in Souss Massa, (Almulla et al., 2022)

Fog harvesting requires a more complex discussion of long-term viability. Historical data indicates that fog has been a reliable water source in many communities for generations, suggesting its enduring potential as a sustainable solution to water scarcity. However, the evolving nature of climate patterns introduces uncertainties about the future availability of fog.

7. Accessibility for rural populations

In terms of rural populations being able to access potable and non-potable water, fog harvesting is the most favorable option due to its decentralized nature and adaptability to local conditions and environments. Unlike wastewater treatment, which typically serves

urban populations and requires centralized infrastructure, fog harvesting can be implemented on a smaller scale and tailored to the specific needs of rural villages. In contrast, desalination plants, while effective in addressing water scarcity, often prioritize urban areas and agriculture.

One of the key findings of this study is the recognition of the multifaceted nature of water scarcity solutions. While each method has its advantages and limitations, understanding how they compare can affect resource allocation efforts.

This study also highlights the importance of considering environmental, social, and economic factors in water management strategies. By evaluating not only the technical feasibility but also the environmental impact, cost-effectiveness, and social equity implications of each method, this research paper provides a comprehensive framework for evaluating water supply options.

As I reflect on my research, I found myself coming up with several questions. I'm interested in the abilities of small NGOs and grassroots initiatives compared to government-funded programs. Despite the efficacy of fog harvesting, will it ever attain the necessary scale without substantial government backing? Secondly, I'm interested in exploring the perspectives of residents in rural communities. Do they prefer a particular water supply method, and are they open to changes in their daily dynamics? Additionally, I'm curious about how other countries facing similar environmental challenges perceive the comparison of these methods. Lastly, I'm interested in learning how the cultural values of Morocco impacts water management practices.

This paper aims to illuminate the possible challenges and solutions surrounding water scarcity. It has discussed diverse perspectives, obstacles, and dimensions of this critical issue. Yet, amidst this exploration, it becomes evident that there's no one-size-fits-all solution. Instead, the complexity of water scarcity demands a nuanced understanding of local contexts, environmental dynamics, and community needs. Ultimately, this research highlights the need for adaptive approaches that acknowledge the variability and unpredictability inherent in addressing water scarcity challenges.

Recommendations for Further Study

1. Policy Analysis: Approach the topic from water scarcity through a political lens - conduct governmental policy analyses to evaluate the impact of government regulations, incentives, and investments on the adoption and implementation of sustainable water management practices. Comparative analyses of policy frameworks across different regions can help form policy recommendations for promoting effective water governance and resource management.

2. Socio-Economic Impacts: Investigate the socio-economic impacts of fog harvesting, desalination, and wastewater treatment initiatives on local communities, including livelihoods, gender dynamics, and social equity. By examining the social effects and unintended consequences of water management methods, we can enhance the inclusivity and sustainability of water governance systems.

3. Technological Innovations: Explore emerging technologies and innovations in water treatment, renewable energy, and information communication technology to improve the efficiency, affordability, and environmental sustainability of fog harvesting, desalination, and wastewater treatment processes.

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Appendixes

Written Consent Form

PARTICIPANT INFORMED CONSENT FORM

Title of the Study: Addressing Water Scarcity in Rural Areas of the Souss-Massa Region of Morocco: Comparative Analysis of Desalination, Fog Harvesting, and Wastewater Treatment Methods with Considerations of Technical Viability and Human Rights

Researcher Name: Lina Migliore

My name is Lina Migliore I am a student with the SIT Morocco: Human Rights, Social Movements, and Cultural Transformations program.

I would like to invite you to participate in a study I am conducting as part of the SIT Study Abroad program. Your participation is voluntary. Please read the information below, and ask questions about anything you do not understand, before consenting to allow me to use your words in my paper.

PURPOSE OF THE STUDY

My research project is primarily focused on conducting a comparative analysis of desalination, fog harvesting, and wastewater treatment methods in the Souss-Massa region of Morocco. I aim to delve into the effectiveness, feasibility, and practicality of these water resource management techniques within the specific context of the region. By examining both the technical and engineering aspects as well as the socio-political implications, I hope to gain insights into how these methods can address water scarcity while considering equitable distribution and human rights concerns. Additionally, I seek to explore policy frameworks, government interventions, and community engagement strategies to better understand the integrated implementation of these approaches.

STUDY PROCEDURES

I ask the respondent to engage in an interview, wherein they will be required to answer questions and share insights about their work. The interview is expected to last approximately 1 hour. The meeting will take place virtually. It is important to note that participants will not be photographed or audio/video recorded during the interview. Participation in the research study is not contingent upon consent for audio/video recording or photography; individuals can still participate even if they decline to be recorded or photographed.

POTENTIAL BENEFITS TO PARTICIPANTS AND/OR TO SOCIETY

Spreading awareness about desalination is crucial to address water scarcity by highlighting an innovative solution to provide freshwater in arid regions like Morocco. It educates communities

about sustainable water management practices, promotes technological advancements, and fosters collaboration towards ensuring water security for present and future generations.

CONFIDENTIALITY

I will ensure confidentiality and anonymity by allowing participants to choose what information they share.

PARTICIPATION AND WITHDRAWAL

Your participation is voluntary. Your refusal to participate will involve no penalty or loss of benefits to which you are otherwise entitled. You may withdraw your consent at any time and discontinue participation without penalty. You are not waiving any legal claims, rights or remedies because of your participation in this research study.

"I have read the above and I understand its contents and I agree to participate in the study. I acknowledge that I am 18 years of age or older."

Participant's signature _____*Date*_____

Researcher's signature _____*Date*_____

Initial one of the following to indicate your choice:
_____ (initial) I agree to…
_____ (initial) I do not agree to…

Consent to Quote from Interview
I may wish to quote from the interview with your child either in the presentations or articles resulting from this work.

RESEARCHER'S CONTACT INFORMATION

If you have any questions or want to get more information about this study, please contact me at *lina.l.migliore@vanderbilt.edu*.

RIGHTS OF RESEARCH PARTICIPANT – IRB CONTACT INFORMATION

In an endeavor to uphold the ethical standards of all SIT proposals, this study has been reviewed and approved by an SIT Study Abroad Local Review Board or SIT Institutional Review Board. If you have questions, concerns, or complaints about your rights as a research participant or the research in general and are unable to contact the researcher please contact the Institutional Review Board at:

School for International Training
Institutional Review Board
1 Kipling Road, PO Box 676
Brattleboro, VT 05302-0676 USA
irb@sit.edu
802-258-3132

Dar Si Hmad Questionnaire

"This research was carried with the full knowledge and support of Dar Si Hmad, Dar Si Hmad is, however not responsible for the results which only engage its authors."

My Project Title:
Addressing Water Scarcity in Rural Areas of the Souss-Massa Region of Morocco: Comparative Analysis of Desalination, Fog Harvesting, and Wastewater Treatment Methods with Considerations of Technical Viability and Human Rights

Interview Goals:
1. Assess the practicality, effectiveness, and feasibility of fog harvesting in the Souss Massa region, particularly in comparison to desalination and wastewater treatment methods.
2. Understand the technical and engineering aspects of fog harvesting, including its adaptability to the local climate and geography.
3. Explore the integration of fog harvesting projects into local communities, considering socio-political implications, community engagement, and sustainability.

Topics to Cover:
1. Introduction to Dar Si Hmad and its fog harvesting initiative.
2. Engineering aspects of fog harvesting: technology used, maintenance requirements, and scalability.
3. Feasibility of fog harvesting in the Souss Massa region: climatic conditions, water quality, and community acceptance.
4. Comparison of fog harvesting with desalination and wastewater treatment methods.
5. Socio-political aspects: government policies, regulations, and community involvement in fog harvesting projects.
6. Human rights considerations: access to clean water, gender dynamics, and marginalized communities.

Possible Interview Questions:
1. Can you provide an overview of Dar Si Hmad's fog harvesting initiative and its objectives?
2. What engineering techniques or technologies are employed in fog harvesting – can you walk me through how it works?
3. In your opinion, what are the main advantages and limitations of fog harvesting in the Souss Massa region?
4. How does Dar Si Hmad engage with local communities in implementing fog harvesting projects? Are they accepting of this initiative?
5. What role do government policies and regulations play in supporting or hindering fog harvesting initiatives in Morocco?
6. Can you share any insights into the socio-political challenges faced by fog harvesting projects, especially regarding access to clean water and community empowerment?

7. From a human rights perspective, how does fog harvesting address issues of water scarcity and inequality, particularly for marginalized communities?
8. Are there any ongoing research or development projects aimed at improving fog harvesting technology?
9. Are there ongoing development projects aimed at expanding the use of fog harvesting in Morocco or elsewhere? Is this possible?
10. In your experience, what are the key factors for the success of fog harvesting projects?
12. How do you envision the future of fog harvesting in Morocco, considering both engineering advancements and socio-political dynamics? Ideally, how would you want the future to look?

Questions regarding the project:

1. What is the maintenance process like for the nets? Time, cost, labor, etc.
2. What are the unique advantages of fog harvesting?
3. What challenges or barriers were faced during the integration of ICTD (Information and Communications Technology for Development?) Maybe regarding accessibility or education?

Dar Si Hmad Confidentiality Agreement

CONFIDENTIALITY AGREEMENT

Association Dar Si Hmad hosts diverse internship programs and the following agreement is between the intern and Dar Si Hmad.

The undersigned acknowledge that all internal Dar Si Hmad information made accessible to the intern must remain **confidential** and not be disclosed to any third party under any conditions. In case of a breach of this agreement, legal action will be taken with the intern and their home institution.

For student interns a copy of their final product must be handed to the organization with the motion that this "research was carried with the full knowledge and support of Dar Si Hmad, Dar Si Hmad is, however not responsible for the results which only engage its authors"

Dar Si Hmad and intern confirm by the signature not to knowingly disclose any of the provided information.

It is agreed that intern and DSH, until engagement is terminated, will respect the mutually agreed upon time for meetings and work sessions.

This Confidentiality Agreement is effective as of

05/13/2024

UNDERSTOOD AND AGREED:

By: Lina Migliore

Title: Student Researcher of School for International Training, Rabat

By:

Title:

Witness: ….....

June 5, 21/JB