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An Investigation into Morocco's Water Crisis

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An Exploration into the Causes of Morocco's Water Scarcity, the Plans to Mitigate it, and its Effect on Moroccans.

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1.0 Introduction:

The city of Ifrane in the Middle Atlas Mountains is home to Al Akhawayn University, one of the most prestigious universities in Morocco, and the Michlifen golf course with its coinciding luxury resort. The university regularly runs sprinklers over its lawn in the rain, and the golf course is known throughout Ifrane as being a major water consumer. Ain Ifrane, a bottled water company many consider the "freshest" water available in Morocco, is sourced about 10 kilometers from the city. About a five-minute drive from the university is the small village of Tarmilat, where families do not have access to running water; they bring it up from a communal well, which requires hiking down a steep hill to access it. While traveling through the country, I head of people's struggles to find clean water, either for their homes or for agriculture. The town of Zagora erupted in protests becauses their taps in their homes were running dry but neighboring watermelon farms were using millions of gallons of water per year. The people from the town of Imiter have been sitting in on the gounds of a mine which they accuse of taking their water source, and polluting the water they are left with. Though this is a stark example of inequality, it is also the tip of the water management crisis occurring in Morocco.

The Kingdom of Morocco is a parliamentary constitutional monarchy, where the Kingdom (currently King Mohammed VI) is inherited, but legislative members are indirectly elected[1]. While a relatively stable country, Morocco ranks low on indices of government integrity[2] and suffers from minor political instability due to the low levels of political rights and civil liberties which people are afforded[3]. Morocco is a developing country, with some cities that

[1] "Morocco: Government" global EDGE: Your Source for Global Business Knowledge, accessed 3/20/20. https://globaledge.msu.edu/countries/morocco/government
[2] "2020 Index of Ecomonic Freedom" The Heritage Foundation, accessed 3/20/20. https://www.heritage.org/index/heatmap
[3] "Freedom in the World 2020: Morocco" Freedom House, accessed 3/20/20. https://freedomhouse.org/country/morocco/freedom-world/2020

are highly industrialized while rural areas suffer from lack of economic opportunity. As in most developing nations, agriculture is a cornerstone to development[4]. States generally take one of two approaches, or a mixture of the two, when deciding where to focus resources for development; the two approaches are "industrialization and high-value agriculture production"[5] and the other is a "small-scale agriculture-led ecological farming strategy"[6]. Taking the former approach can better allow the nation to "secure foreign exchange over food crops"[7], but this prioritizes development in a purely economic sense. The latter, on the other hand, better allows for "development through articulation of internal markets to satisfy the needs of the local populations first"[8]. The Moroccan government's decision on how to continue with development in the agriculture sector will impact how they plan to manage a limited freshwater resource.

This project aims to investigate why stark inequalities in accessing freshwater resources exist in Morocco, how the government has approached fixing this problem, and if their solutions have had a positive impact on people's access to freshwater resources. According to the United Nations Department of Economic and Social Affairs, there are two types of water scarcity a state can experience: physical water scarcity, where "water resources development is approaching or has exceeded sustainable limits"[9], or economic water scarcity, where "human, institutional, and financial capital limit access to water even though water in nature is available locally to meet

[4] Benamar, Jihane, "In the Shadows of Colonial Agricultureal Policies: Morocco's Political Failure in Building a Successful Model for Development", The Journal of North African Studies, Jan 20, 2020. https://doi.org/10.1080/13629387.2020.1713759
[5] Ibid.
[6] Ibid.
[7] Ibid.
[8] Ibid.
[9] United Nations Department of Economic and Social Affairs, *Supporting Morocco's Water Scarcity and Drought Management and Mitigation Plan*, Sami Areikat, New York, NY, USA: https://sustainabledevelopment.un.org/content/documents/18763043Mission%20to%20Morocco%20presentation.pdf (accessed February 4, 2020).

human demands"[10]. Determining the type of water scarcity and the primary causes is a critical step in finding sustainable solutions to the problem.

2.0: Methods:

This project consisted of two research phases. The first was completed in Morocco, from August 26th through December 13th 2019, which primarily consisted of observations, and formal and informal interviews. The formal interviews were organized beforehand, and I went into them with a list of questions that I built off during the interview. I conducted formal interviews with the Head of Local Investing of the city of Dakhla, and the owners of a farm in Dakhla. The remainder of the interviews were informal, meaning I spontaneously engaged in conversations with people without a set of questions beforehand. I informally interviews Ismail Barda, a resident and local tour guide at Zaouiat Ahansal, and Chloe Erickson, the founder of the Atlas Cultural Foundation, Observations were made inlocations around the country when the opportunity presented itself. The observations took place in both an informal setting, such as taking notes on things seen while traveling, and a formal setting, while on organized field trips. The second phase of research consisted of a review of government documents and a review of news articles from credible sources. This was completed from December 13th 2019 through February 2020. Credibility of news sources was affirmed when they had been cited in news articles on internationally trusted platforms, such as the New York Times, British Broadcasting Corporation (BBC), and National Public Radio (NPR). The combination of all these sources were used to systematically answer the following questions:

[10] Ibid.

1. What are the primary causes of the water scarcity in Morocco, including both physical and economic causes?
2. What actions are the Moroccan government or non-governmental organizations taking to remedy the problem?
3. Have the actions taken by the Moroccan government or by non-governmental organizations been effective in improving conditions in people's lives?

This was a project born of opportunity, which means that by its nature it was limited in scope to situations I was able to observe and the people the I was able to speak with while in Morocco. I made my observations while attending Al Akhawayn University in Ifrane, Morocco. I took guided field trips for two of my classes, called *Women, Gender, and Economic Development*, and *Development in Dakhla*. The examples of Zaouiat Ahansal and Dakhla were used because I was given the opportunity to observe the areas and to speak with people involved in the community. The stories of Imiter and Zagora were chosen as examples because they were well-covered news events. The selection process may have introduced some bias into the narrative, as there are many stories of people affected by the water scarcity, or by people who may not feel there is a water scarcity, whose stories were not told.

Relying heavily on government documents, including those produced both by Morocco's government and international institutions, such as the United Nations, and on news articles poses its own set of limitations. According to Reporters Without Borders, Morocco ranks 135th in the world for freedom of the press[11]. The Moroccan government is not entirely tolerant of criticism, which creates room to question the claims made on government documents.

[11] "2019 World Freedom Index" Reporters Without Borders, accessed February 3, 2020, https://rsf.org/en/ranking.

A final major limitation of this project is that the researcher did not speak the primary languages of people in Morocco, which are French, Arabic, and Tamazight. The researcher was unable to speak directly to some of the interviewees, including the Head of Regional Investment for Dakhla. In this case, the researcher was with a partner who acted as the translator. In other instances where the interviewees did speak English as a third or fourth language, the researcher may have been unable to have as complex of conversations as would have been ideal, in the interest of ensuring both the researcher and the interviewee were clear on what was being discussed. Navigating the language barrier created opportunities for misunderstandings. Additionally, the researcher was unable to use social media, such as local environmental advocacy groups, as a source, because the social media pages were all in French or Arabic. The researcher was unable to connect with people in this way, which narrowed the scope of the research.

3.0 Results:

3.1 Causes of the water shortage

Morocco has four primary causes for the lack of accessible, fresh water available to people for drinking and other minor uses. These four causes are: the dry climate, global climate change, pollution of the existing water sources, and mismanagement of existing freshwater sources, largely involving agriculture.

3.2 Causes of the water shortage: Arid Climate

Morocco's first cause of freshwater scarcity is a physical lack of freshwater, caused by Morocco's position in a semi-arid climate[12]. Morocco is categorized as a freshwater scarcity country by the UN Department of Economic and Social Affairs, The report differentiates between physical and economic water scarce countries, with Morocco being a physical water scarce country[13]. Morocco has a widely variable climate. I experienced this while in the city of Marrakech for a weekend, where it was around 70 degrees ferienheit, but at my university in Ifrane it snowed a foot during the same weekend. with Annual precipitation ranges from 1200 mm in some northern areas and in the Atlas Mountains, to less than 100 mm per year in the areas on the eastern side of the Atlas Mountains, near Morocco's border with Algeria[14].

3.3 Causes of the water shortage: Global Climate Change

A second reason for Morocco's lack of freshwater is global climate change resulting in less rainfall and more serious droughts. Morocco has already experienced "a mean annual precipitation decreases" by seven percent in the past thirty years[15]"In Morocco, droughts are recurrent and becoming more frequent, and perhaps, more severe"[16]. One effect of increased drought, and less precipitation in general, is that the aquifers may not be able to recharge as

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[12] Simone Bregaglio, Nicolo Frasso, Valentina Pagani, Tommaso Stella, Caterina Francone, Giovanni Cappelli, Marco Acutis, Riad Balaghi, Hassan Ouabbou, Livia Paleari, and Roberto Confalonieri, "New Multi-Model Appraoch Gives Good Estimations of Wheat Yield Under Semi-Arid Climate in Morocco," *Agronomy for Sustainable Development*, 35, April 4, 2014: 157-167, https://doi.org/10.1007/s13593-014-0225-6.

[13] United Nations Department of Economic and Social Affairs, *Morocco's Water Scarcity*

[14] Ibid.

[15] Vera Tekken, Jurgen P. Kropp, "Climate-Driven or Human-Induced: Indicating Severe Water Scarcity in the Moulouya River Basin (Morocco)," Water, 4, December 3, 2012: 959-982, https://doi.org/10.3390

[16] World Bank Group, Climate Variability, Drought, ad Drought Management in Morocco's Agriculture Sector, Dorte Verner, David Treguer, John Redwood, Jens Christensen, Rachel MdDonnell, Christing Elbert, Yasou Konishi, and Saad Belghazi. http://documents.worldbank.org/curated/en/353801538414553978/pdf/130404-WP-P159851-Morocco-WEB.pdf, (accessed February 4, 2020).

quickly, depleting this capacity as a renewable resource. This was found in a study on the Saida aquifer, which predicted a possible 50-60% decrease in the aquifer's capacity compared to current values. Additionally, due to reduced recharge of the aquifer and anticipated sea-level rise, the salinity in the aquifer could increase up to 30 g/L[17]. This is compared to the average salinity of the Mediterranean of 38 g/L[18]

3.4 Causes of the water shortage: Pollution of Freshwater

A third reason for the lack of usable freshwater resources in Morocco, because it is reducing water quality rather than quantity, as the previous two causes were, is the pollution of the existing water resources. Pollution of freshwater resources in Morocco can come in many forms, including "municipal wastewater discharge, industrial effluents and agricultural activities"[19]. Currently, municipal wastewater is discharged without being treated first, and thirty percent of the wastewater is discharged directly into "natural water bodies"[20]. Much of the available groundwater has been made unusable "due to high salinity and nitrate concentrations"[21]. Many rivers, lakes, and even groundwater sources have high levels of nitrogen and phosphates, due to fertilizer runoff from agriculture areas. A study in the region of Mnasra, a region known for dense agricultural activity, Marouane et al.[22] found that 89.7% of tested water samples exceeded 50 mg/L of nitrates, which is the standard limit of nitrate concentrations for groundwater.

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[17] Bregaglio et al., "Estimations of Wheat Yeild in Morocco," 157-167.
[18] "Ocean Salinity," Science Learning Hub, published June 3, 2010, https://www.sciencelearn.org.nz/resources/686-ocean-salinity
[19] Mediterranean Environmental Technical Assistance Program, Water Quality Management, Washington DC, USA, http://siteresources.worldbank.org/EXTMETAP/Resources/WQM-MoroccoP.pdf, (accessed February 4, 2020).
[20] Ibid.
[21] Ibid.
[22] B. Marouane, A. Dahchour, S. Dousset, Monitoring of Nitrate and Pesticide Pollution in Mnasra, Morocco Soil and Groundwater, *Water Environment Research*, 87, No. 6, 2015, 567-575, https://doi.org/10.2175

Mining is another major industry in Morocco which contributes to pollution of freshwater resources. Two examples of this occurring are in the towns of Zaouait Ahansal and Imider, both in the High Atlas Mountains. I visited the small town of Zaouiat Ahansal on a field trip with my university in Morocco. We learned about the development initiatives taken in the town, such as a water association bringing clean drinking water to almost every house in the village for a manageable cost, but we were also told about a lead and zinc mine which was almost built near the village.[24] This mine was eventually halted before it was able to be built, because the mine never went through the required environmental assessment process before the beginning of work on the site. The potential impacts of the mine included: "contamination of [the area's] potable water source"[25], and polluting the Ahansal River which "is a source of drinking water and irrigation for thousands of people"[26]. Because the mine was an illegal operation from the beginning, and because it did not obtain the required environmental assessment prior to beginning work, it was able to be stopped. Unfortunately, a similar situation with a different outcome occurred in the town of Imiter. Imiter is similar to Zaouiat Ahansal, because it is a small village relying on small locally owned farms for an income and for food[27] [28]. When the largest operational silver mine in Africa was built above Imider, it faced the impacts that were predicted in Zaouiat Ahansal. According to the residents of Imider, when the mine began operation, the water used by the local farmers for irrigation dried up, and their water sources were polluted. Much of this information is refuted by the mining company. In protest, many people from the

[24] Trip to Zawiya Ahansal, Al Akhawayn University, October 17-20, 2019.
[25] Ismail Barda, Email to author, January 18, 2020.
[26] Ibid.
[27] Aida Alami, "On a Moroccan Hill, Villagers Make Stand Against a Mine," The New York Times, January 23, 2014, https://www.nytimes.com/2014/01/24/world/africa/on-moroccan-hill-villagers-make-stand-against-a-mine.html
[28] Trip to Zawiya Ahansal, 2019.

village "climbed up the hill and cut the water supply to the mine"[29]. Since this, some of their water has returned, but the protestors are claiming that they are still suffering from pollution from the mine. An important side note here, and an important difference between the situation in these two villages is that King Muhammed the VI is the "principle owner"[30] of the mine in Imider. It may not be a drastic jump to suggest that this mine was allowed to continue to pollute the water sources of the farmers in Imider because the King is the owner.

3.5 Causes of the water shortage: Agriculture

The history, and the current management of the agriculture sector in Morocco is a fourth reason for the shortage of freshwater resources. The agricultural policies of the French Protectorate in Morocco created the infrastructure for Morocco to experience future water shortages. The French Protectorate period in Morocco lasted from 1912-1956. The French came to Morocco as colonizers with the goal of "accumulating wealth through any means"[31]. The French saw Morocco as an opportunity to grow exports of food, specifically wheat. The plan for agricultural expansion began with an emphasis on creating farms larger than 400 acers[32]. The focus on grains resulted in a failure, which prompted the French to turn to the California Policy.It was called the California Policy because it was modeled after the irrigation agriculture and soil conservation in the United States; itfocused the agriculture on growing citrus fruits for exportation to Europe[33]. The California Policy resulted in building dams for irrigation, with the

[29] Alami, "Villagers Make Stand"
[30] Ibid
[31] Benamar, J. "Colonial Agricultural Policies"
[32] Swearingen, Will D. "In Pursuit of the Granary of Rome: France's Wheat Policy in Morocco, 1915-1931" Cambridge University Press, Vol. 17, No. 3, pgs. 347-363. https://www.jstor.org/stable/pdf/163504.pdf?refreqid=excelsior%3Aa80414597e31a36a3bc7af6059c2d1b7
[33] Benamar, J. "Colonial Agricultural Policies"

plan that "not a drop of water would flow to the sea"[34]. This system of large farms utilizing irrigation and exporting crops abroad is largely still in place as a result of this policy and will be addressed again in this report (what section?).

Agriculture is a major industry in Morocco, making up 15-20% of the GDP and employs 40-45% of the workforce[35] [36]. It is prioritized by the government as an area with potential for growth. There are three main types of agriculture in Morocco: modern and private farms, which generally grow fruits and vegetables for exportation, farms located within dam irrigated areas, which generally produce dairy products, seeds, and sugar, and finally rain-fed agriculture, particularly located in the north-west region, which produce grains, olives, meat and dairy products[37]. Between these areas of agriculture, there is large variation in resources available. Agriculture is a critical player in the conversation of water use in Morocco because agricultural uses account for 80% of the water used in the country[38]. The majority of the water used for agriculture is used in the private farms which export their products. Many Moroccans with smaller farms, those who do not rely on rain fall, use surface irrigation, "which has very high evaporation rates"[39]. Not all small farms rely on surface irrigation, but the majority of them do because it is cheaper option. Larger, private farms tend to get priority in terms of use of water resources, which can have detrimental effects on the people with less power who also need access to the water.

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[34] Ibid.
[35] International Trade Administration, Morocco: Agriculture Sector, Rabat, Morocco: 2019, https://www.export.gov/article?id=Morocco-Agricultural-Sector, (accessed February 4, 2020).
[36] Jocelyn Kurtze, Matt Morais, Evelyn Platko, Hannah Tompson, "Advancing Water Management Strategies in Morocco," *Association Ribat Al Fath Pour le Development Durable*, October 16, 2015, https://digitalcommons.wpi.edu/cgi/viewcontent.cgi?article=3726&context=iqp-all
[37] International Trade Administration, Morocco: Agriculture, 2019
[38] Kurtze et al. 2015
[39] Ibid.

Zagora is a town of about 35,000 people in the south-east of Morocco, on the edge of the Sahara Dester. Tourism and watermelon farming are the areas where most people work. The situation in Zagora is an example of larger, private farms which are growing products mainly for export, over-using the water resources of the area and damaging the resource for the local people. Zagora is situated to the east of the city of Marrakech in the south-east of Morocco. The area around Zagora has been undergoing desertification and a period of drought in recent years, which has been largely blamed on global climate change. According to Jamal Alchbab, the president of the Association of the Friends of the Environment (Zagora), "the most important manifestations of climate change that the region is facing are record high temperatures, low rainfall, increasing desertification, soil salinity, and the risk of seasonal flooding"[40]. This is a place which experiences 2-3 days with rainfall during the growing season.[41] The people surrounding this town, with a population of around 30,000, have been purchasing bottled water for their drinking water for the past 15 years because the tap water is undrinkable because it is too saline[42]. The dire situation has prompted people to take to the streets in protest, causing instability in the region when seven protesters were arrested and future protests "descended into violence[43]". It is largely agreed that the problem with the tap water in Zagora is due to both the extended period of drought and the over-use of the groundwater by an "adoption of agriculture that is unsustainable and unsuitable"[44]. The nearby watermelon farms are the agriculture being blamed here. Watermelons are grown in the Zagora region for export to Europe. The watermelon

[40] Aida Alami, "Water Shortage in the Maghreb: Morocco's Thirst Revolution," Goethe-Institut, accessed Feburary 4, 2020, https://www.goethe.de/prj/ruy/en/m/watlife/21718884.html
[41] Alami, "Water Shortage in the Magreb"
[42] "Watermelon Farming Main Cause of Water Shortage in Morocco," Gulf News, November 5, 2017 https://gulfnews.com/world/mena/watermelon-farming-main-cause-of-water-shortage-in-morocco-1.2119047
[43] "'Thirsty Protests' Hit Morocco Over Water Shortages" Arab News, October 15, 2017. https://www.arabnews.com/node/1178076/middle-east
[44] Alami, "Water Shortage in the Magreb"

farms consume 7 million cubic meters of groundwater per year, which has resulted in people in Zagora having their taps run dry for many hours to days at a time.[45]. The connection between the two is still unclear, but the locals have been speaking out about how, since the watermelon farms began operation, their taps have run dry and the water has been too saline when they are running.

Another reason the agriculture sector is problematic in the allocation of freshwater resources is due to the inefficient irrigation systems employed by smaller farmers who cannot afford to use underground irrigation. Most Moroccan farms, especially the smaller farms, use surface irrigation, "which has very high evaporation rates"[46]. The inefficiency of the modes of irrigation further reduce the quantity of available freshwater. This can be due to the fact that more efficient irrigation systems can be too expensive for the average small farmer to afford, despite the fact that it may save them money or enable them to earn more money through their produce in the long run.

3.6 Government Initiatives: Reducing the Effects of Global Climate Change

The Moroccan government has taken many initiatives with the intent of preparing for and mitigating the effects of global climate change, better managing the water resources they have access to, and finding new, sustainable water resources to take advantage of. To begin, in a broader sense, the Moroccan government has committed to reduce greenhouse gas emissions by thirty-two percent by 2030, compared to the "business as usual projections"[47]. The primary ways in which the government plans to achieve this goal is by "reaching over 50% of installed

[45] "Watermelon Farming," 2017.
[46] Kurtze et al. 2015
[47] United Nations Convention in Climate Change, *Morocco: Intended Nationally Determined Contribution*, https://www4.unfccc.int/sites/submissions/INDC/Published%20Documents/Morocco/1/Morocco%20INDC%20submitted%20to%20UNFCCC%20-%205%20june%202015.pdf, (accessed February 4, 2020)

electricity production capacity from renewable sources by 2025"[48], reducing overall energy consumption by 15% by the year 2030, and reducing fossil fuel subsidies while increasing the use of natural gas through infrastructure projects[49]. It should be noted that these goals were made in June of 2015 as part of Morocco's National Strategy for Sustainable Development, which means these goals strive for a quick transition.[50] These goals are a necessary step in mitigating the effects which global climate change will have on the rainfall in Morocco.

3.7 Government Initiatives: Desalination Plants

To take advantage of non-traditional water resources, the Moroccan government has been exploring desalination plants. The best use for desalination plants would be in "urban, coastal cities" in dry areas, where the sea may be the only reliable water source[51]. The city of Laayounne, "where it is so dry that the only reliable water source is the sea"[52], has the largest desalination plant in Morocco[53], and the option is being explored for similar cities, such as Dakhla. The plants can use either membrane filtration or distillation as a filtration method. There are two main concerns with desalination plants: their cost and their effect on the surrounding environment. It can be extremely expensive to install these plants and they are not cheap to maintain. For example, the Laayoune plant cost $23 million USD to build: energy costs of running and maintainiing the plant can be a limiting factor, but there has been research into using

[48] United Nations Convention in Climate Change, *Morocco*
[49] Ibid.
[50] Ibid.
[51] Kurtze et al. 2015
[52] Kurtze et al. 2015
[53] H Zidouri, "Desalination in Morocco and Presentation of Design and Operation of the Laayoune Seawater Reverse Osmosis Plant," Desalination, 131, December 2000, 137-15, 10.1016/S0011-9164(00)90014-6

solar power as a cheaper substitute[54]. Additionally, the plants "release brine back into the ocean, which changes the salinity of the ocean"[55].

3.8 Government Initiatives: Wastewater Treatment

As discussed previously, one of the reasons for diminishing freshwater in Morocco is due to pollution and a lack of wastewater treatment. Though the urban areas of Morocco have had wastewater treatment facilities for many years, prior to 2009 they were largely ineffective. The treatment facilities were forced to stop operations and to close to due high running costs because the majority of them were privately owned and so were unable to fund the facilities. T The Moroccan government centralized the wastewater treatment facilities in 2009 under Office National de l'Electricitie et de l'Eau Potable (ONEE). After this, ONEE built 43 additional water treatment plants in rural settings. The new plants, which used water treatment ponds, cost less to run and maintain because they use stabilization ponds. Using the new wastewater treatment facilities, the Moroccan government has a goal of treating and recycling one-hundred percent of waste water by 2030. This will require building many more wastewater treatment facilities, on top of the 43 new facilities already built[56] [57]. On the topic of wastewater, pollution from mining is an issue which was discussed earlier. According to Amina Benkhadra of the Office National des Hydrocarbures et des Mines (ONHYM), "the mines always dispose of the water that is

[54] Kurtze et al. 2015
[55] Kurtze et al. 2015
[56] Kurtze et al. 2015
[57] United Nations Economic Commission for Europe, Environmental Performance Reviews: Morocco, United Nations, 2012, https://www.unece.org/fileadmin/DAM/env/epr/epr_studies/Synopsis/ECE.CEP.170_Synopsis_English.pdf, (accessed February 4, 2020)

used"[58], but this assertion may be questionable because of the situation of Imiter, where some have said that their water has been polluted by the upstream mine.

3.9 Government Initiatives: Plan Maroc Vert

To make the use of available water sources more efficiently while also prioritizing economic growth, the Moroccan government has announced the Green Morocco Plan (Plan Maroc Vert). The Green Morocco Plan aims to "make agriculture a lever of growth during the next five to fifteen years"[59]. It was inaugurated in 2008 by King Mohammed VI and outlines an infrastructure program for Morocco's agriculture sector while prioritizing economic growth in the sector and reducing water stress.[60] The Green Morocco Plan includes plans to focus on the development of crops which are not water intensive in more arid areas of the country, such as the south, plans to aid local farmers in being better able to manage their farms and make a greater profit, and in using newer agricultural technologies to increase efficiency in water use[61]. I have been unable to find information on the progress of the country in meeting these goals.

3.10 Government Initiatives: Changes to Irrigation Systems

One goal in increasing water use efficiency is that they aim to "increase the use of drip irrigation from 114,000 hectares to 250,000 hectares by 2020 through the provision of drip irrigation subsidies to farmers"[62]. This goal includes the smaller farms mentioned earlier. The

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[58] Kurtze et al. 2015
[59] Ministry of Agriculture, Fisheries, Rural Development, Water, and Forests, *A Strategy for Saving and Enhancing Water*, http://www.agriculture.gov.ma/en/pages/water-saving, (accessed February 4, 2020).
[60] Kawtar Ennaji, "The 'Green Morocco Plan' Strengthens Localized Irrigation," Morocco World News, August 21, 2019, https://www.moroccoworldnews.com/2019/08/280816/green-morocco-plan-localized-irrigation/.
[61] Ministry of Agriculture, Fisheries, Rural Development, Water, and Forests, *Saving and Enhancing Water*
[62] Kurtze et al. 2015

most common method of irrigation for farms of this size is some sort of surface irrigation, which, in the extremely arid climates that some of these farms are located, the evaporation rates can be very high. Drip irrigation offers a solution to the problem. Drip irrigation only dispenses the amount of water needed by the plant, rather than uncontrollably dispensing water. Additionally, the water is dispensed either underground or directly onto the surface of the soil, which reduces water wasted to evaporation. Under the plan to switch small farmers to drip irrigation, farmers with less than five hectares would be able to be refunded for the entire cost of installing drip irrigation on their farms. For the government to refund the cost of the project, the farmer first has to front the cost of the new irrigation system, fill out complex paperwork to be submitted to the local government, and, if qualified up to this point, the local government will send an official to inspect the farm[63].

In the city of Dakhla in the territory of Western Sahara, with a class on a research trip, I examined, through observations and interviews, how the government developed the local agriculture sector under the Green Morocco Plan, specifically focusing on the greenhouse farms which use drip irrigation. It is important to understand how arid the area around Dakhla is in order to understand the challenges of developing large farms there. Dakhla is situated between the Sahara Desert and the Atlantic Ocean and receives an average of only 4.5 cm of rainfall each year[64]. These were massive farms which produced tomatoes and watermelons. All the produce is exported to Europe, Asia, or North America. Some of the farms are owned by groups of local people, but the vast majority of them are owned by large companies and benefit from private international investors.[65]

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[63] Kurtze et al. 2015

[64] "Dakhla Climate," Climate-Data.org, accessed February 3, 2020, https://en.climate-data.org/africa/morocco/dakhla/dakhla-34046/.

[65] Head of Regional Investment, Dakhla, Morocco, October 30, 2019.

These farms were touted as the environmentally friendly solution for the economic growth of the region of Dakhla[66], and on the surface they did appear to live up to he talk of the local government officials. The farms use drip irrigation, making them much more water efficient than other types of irrigation. The farms are inside green houses, meaning that pesticides or herbicides are not needed and the climate-controlled area means increased productivity and greater water use efficiency. Each individual farm drills their own wells, using the groundwater reservoir as their only water source[67]. The local officials discussed this as though they were either trying to convince others, or were convinced themselves, that this was a limitless resource[68]. However, due to possible illegal well-drilling and over-use of this resource, "the underground water reserves of occupied Western Sahara are allegedly drained by the agricultural industry in the territory."[69] This is an example of an instance, farms are still contributing to the water shortage, despite the fact that the new technology described in the Green Morocco Plan was implemented

3.11 Non-Government Initiatives

In addition to government-run initiatives, there are some initiatives run by non-governmental organizations that are focused on alleviating Morocco's water-stress. These organizations tend to be focused on helping small farmers to use more efficient irrigation systems, to move towards less water-intensive crops, such as citrus trees, and to diversify their

[66] Ibid.
[67] Dakhla Field Trip, Al Akhawayn University, October 26-November 3, 2019.
[68] Elbachir Elghardgui, Discussion with author, October 30, 2019.
[69] "Dakhla Farms Depleting Underground Water Reserves?" Western Sahara Resource Watch, April 6, 2013, https://wsrw.org/a217x2557

crops to be more resilient against drought[70]. The best example of these organizations is the High Atlas Foundation, based out of Marrakech. The High Atlas Foundation recognizes an "urgent need to grow organic and endemic crops with the potential to produce high-quality, high-value food whose production required minimal water resources[71]". Through their efforts to use more efficient irrigation systems, the High Atlas Foundation attempts to extend where people can farm into previously non-arable land.[72]

3.12 Comparison with the American South-West

The water crisis in Morocco is not unique to Morocco, or the middle-east north-Africa region. There is similar situation in the American south-west. This is a region which has been in a fourteen-year drought, unparalleled for 1,250 years[73]. The American south-west is experiencing a drought for reasons similar to Morocco's reasons: global climate change compounded on an already arid climate, and overuse due to urban and agricultural needs[74]. The Rocky Mountains, which feed the Colorado River, the primary water source for this area, have experienced low snowpack in recent years, and increased summer temperatures mean greater evaporation rates[75]. After using the declining Colorado River as a water source, groundwater is depended on for remainder of the populations water needs.[76] Similar to the situation in Morocco, this is

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[70] "Agriculture," High Atlas Foundation, accessed February 3, 2020, https://highatlasfoundation.org/project/organic-agriculture/.
[71] Ibid.
[72] Ibid.
[73] Frances Weaver, "The Unprecedented Water Crisis in the American Southwest" The Week. February 1, 2014. https://theweek.com/articles/451876/unprecedented-water-crisis-american-southwest
[74] Ibid.
[75] Ibid.
[76] Daisy Simmons, "What a drier and hotter future means for the arid Southwest," Yale Climate Connections, August 8, 2019, https://www.yaleclimateconnections.org/2019/08/what-a-drier-and-hotter-future-means-for-the-arid-southwest/

problematic because the groundwater is withdrawn faster than it is replenished.[77] Areas like the American south-west and Morocco and the rest of north-Africa could benefit from working together to come up with solutions to their water shortages. The city of Phoenix, Arizona has employed some of the solutions that Morocco considered. They have begun recycling wastewater and using their gray water for agricultural purposes.[78] Though separated by culture, history, and geography, Morocco and the American south-west are just two of many other regions experiencing water shortages, exacerbated by global climate change and the increasing demands of population growth. Though each region will need a solution to cater to its unique needs, these regions could benefit from a dialogue of their ideas to lessen the impact of the water crisis and to prepare for the future.

4.0 Conclusion

It seems to be a straightforward conclusion that the rate at which water is being used in Morocco is unsustainable and may soon reach a breaking point. This can concluded from the combination of over-use by the industrial farms, pollution of existing water resources, and global climate change bringing less rain to replenish reserves. Though the massive industrial farms may bring money into the country and provide many jobs, they are also using the groundwater reserves at an unsustainable rate.

One of the severe limitations of this project is the inability to determine if the policies put in place by the government have had any of the desired effect, or if they are being implemented at all. It is important to note that the focus of sustainability alongside the goal of economic

[77] Zack Guido, "Groundwater in the Arid Southwest," Climate Assessment of the Southwest, September 15, 2008, https://www.climas.arizona.edu/blog/groundwater-arid-southwest
[78] Simmons, "The Arid Southwest," 2019.

growth, however real the sustainability may actually be, is only pertaining to large, private farms in this instance. This seems to be a theme of the ambitious Moroccan governmental policies aiming at relieving water stress: they are focused on large-scale projects to solve the problem.

When evaluating this problem, the implications on Morocco's development need to be considered. The industrial farms were supposed to be a way to develop Morocco, and by some standards they began to achieve this. The farms provide jobs, though mostly for people coming from major cities, and they provided an export for the country. People in rural areas, who are not connected to the systems of training workers for employment in agriculture, are not able to benefit from the economic opportunity provided by development through industrial agriculture. The current structure of development through agriculture in Morocco is not sustainable due to its over-use of freshwater resources, and it neglects to provide economic opportunity in terms of aiding smaller farms or alternative occupations, for the rural populations that are most affected by the shortage of freshwater resources.

Based on the findings of this research, the researcher suggests the following changes for Morocco to move forward with sustainable development. First, the large farms which export to Europe and beyond could focus on products which are more suited for the environment in which they are being grown to reduce water usage. It is not sustainable to grow watermelons on the edge of the Sahara Desert. Products which grow well in arid land would put less strain on local water stores while still providing a product for export. Second, it would be beneficial to the Moroccan government to create opportunities for people local to the farms . If the people in the areas of the farms were able to find jobs there, they would have less of a need to have their own farm, which could help to reduce the effects of droughts. On the other hand, the Moroccan government could create systems for people who had previously been pushed onto less fertile

land in the protectorate era to re-gain access to the desirable farm land. De-centralizing the farming system, in order to spur development in rural areas, cannot happen with a cookie-cutter solution for each community, as each has their own social, cultural, and economic context. The Moroccan government would benefit from listening to each community individually, and to ask of their own needs, to determine how they can best be aided to move forward sustainably, while still being provided the opportunity to grow local markets[79]. This is all to say that to quell recent and future protests over water-rights issues, it would be in the Moroccan government's interest to find solutions to the water crisis which emphasize the benefit to local economies.

[79] Offenheiser, Raymond C., Holcombe, Susan H., "Challenges and Opportunities in Implementing a Rights-Based Approach to Development: An Oxfam America Perspective", Association for Research on Non-Profit Organizations and Voluntary Action. Vol. 32, No. 2. June 2003. pgs 268-306. DOI: 10.1177/0899764003251739

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