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Recharging the Sahara Desert for a Peace Dividend: No Longer Victor Levasseur's 19th-Century Pipe Dream

Wangari Maathai, PhD, taught the world the importance of community-based tree planting to reverse environmental degradation and poverty. Her Green Belt Movement has matured into the Great Green Wall for the Sahara and Sahel, an African-led initiative to stop the expansion of the Sahara Desert by planting a four-thousand-mile, quarter of a billion-acre forest reaching from the Indian Ocean to the Atlantic. Not only will the forest restore soil quality and capture carbon, but it will also provide jobs and food security. Water security is also an issue in Kenya where solar-powered desalination plants are under construction. A \$15 million investment will yield potable water for 400,000 Kenyans. On the north side of the Sahara, Morocco and Algeria have built and are expanding numerous seawater desalination plants. Other African nations including Namibia, Botswana and Nigeria are exploring desalination to provide potable water. The scale and success of Libya's Great Man-Made River inspires African solutions to desertification and water security. In this era of the United Nations Sustainable Development Goals, the African Union aims to "Save Lake Chad" by constructing a 2,000 km canal from the Congo River to the Chari River that empties into the dwindling lake. World history courses should include the monumental water infrastructure projects around the Sahara Desert from the last four millennia because they represent worthy ancient political theories and historical knowledge that water security promotes peace and prosperity. Historical research like this makes world history classes more relevant to our STEM (science, technology, engineering and math) students in the UN Sustainable Development Goals era. This article presents selected examples with a focus on a canal proposed in the late nineteenth century by French lieutenant Victor Levasseur even though his goal was to promote domestic security in France rather than in West Africa.¹

Security of any definition requires water and, in this century, it is not only possible to eliminate that water insecurity in ways dreamed of in the nineteenth century, some nations are reviving earlier African science and technology to deliver water to their citizens. Water

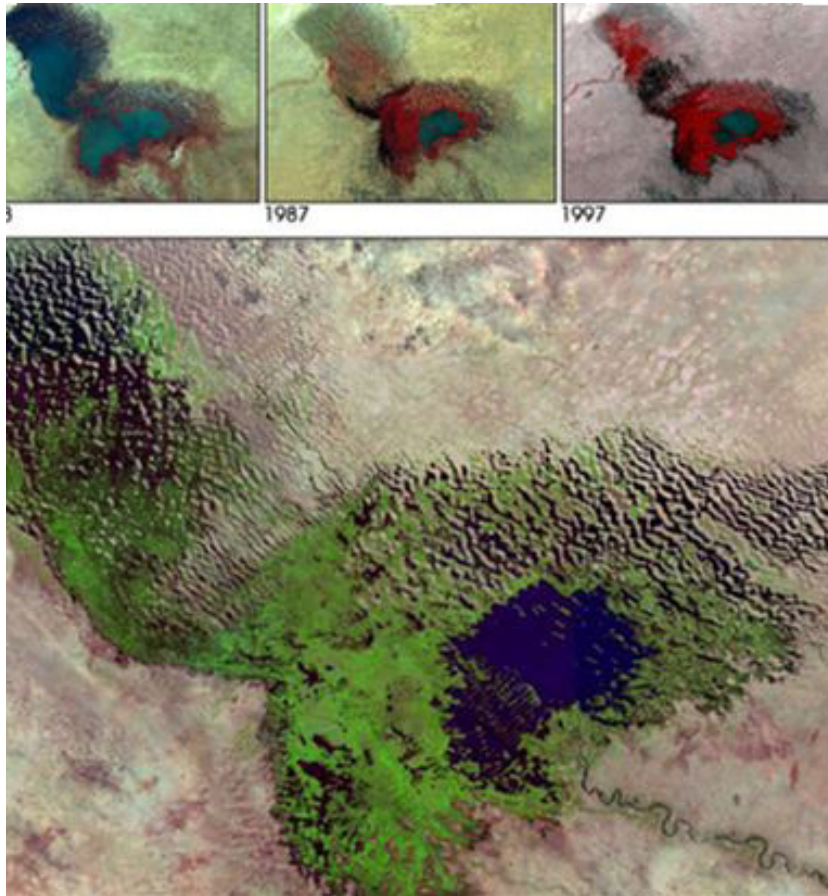


Image 1: NASA images showing the shrinkage of Lake Chad between 1973 and 2001. The lake, the dark blue area on the images, is now 1/20th its size in 1973. Source: Images available in the Public Domain at https://en.wikipedia.org/wiki/Lake_Chad#/media/File:ShrinkingLakeChad-1973-1997-EO.jpg.

announces life, whether found on Mars or in amniotic fluid. Terrorism, insurgencies and civil war like Al-Shabaab, Boko Haram, and Islamic State have been in my earlier publications as responses to zombie economics, those desperate situations where young men feel like walking dead because the elders and governments have not provided employment for the younger generation so that they can afford to marry and have children. Too many such young men see no future for their family lines and are vulnerable to extremist militia recruiters in the violent social eruptions on the expanding fringes of the Sahara Desert, the Arabian Desert, the Rigistan Desert in Afghanistan, and the informal economy around illegal drugs in the Great Basin Desert of North America.² Such responses that jeopardize domestic and international human and financial investments do not have to occur if the global family's will to pipe *semi-desalinated* water into deserts becomes stronger than its will to pipe petrocarbons from the same desert areas to the dockyards along our rising oceans. In other words, we have the technology now to begin restoring the Green Sahara. This paper explores a nineteenth-century idea to recharge the Sahara Desert and this author suggests that the sands of the Sahara can complete the desalination process, producing both potable water for arable land and salt for export.

The French Colonial Interlude and Water Management on the Senegal and Niger Rivers

Since France, under Presidents Sarkhozy, Hollande and Macron, takes a more active role in twenty-first century international politics, this article explores some nineteenth- and twentieth-century colonial French water infrastructure projects in North and West Africa. In order to appreciate the changes and continuities over time, three generations of water infrastructure are presented here. The goal is to shed light on how some policy makers arrived at the positions they took on developing water infrastructure in parts of Africa. The differences in the historical experience inform what seem to be contradictions in the 2010 World Bank report, *Africa's Infrastructure*.³ While acknowledging the need for massive irrigation and macro-scale water projects, readers are encouraged to invest in micro-scale projects because the near-term return on investment is slightly higher. By extension, this guide to Africa seems to promote further retardation of long-term investment and economic growth on the continent of Africa. This article traces the evolution of this shortsighted imperial value. Over the course of the nineteenth century, water resource management moved from hydrography to hydrology as French reliance on African products increased. Hunger in Europe determined the form of colonial water policy in frontier nations in Africa. One idea overlooked by France in the nineteenth century can now be implemented as an African Union-led multi-lateral project with global financial and peace dividends, setting a model for the desert regions of the world.

Continuities and changes exist in some European approaches to water-resource management in Africa from the seventeenth through the twenty-first century. In fact, the documents consulted suggest a pattern in the decision to deploy hydrologists to Africa that relates to a cycle of hunger and food insecurity in Western Europe. The results of these decisions obtained increased job security for European nobles by enhancing the continual transfer of food and wealth to European welfare states, the same states wherein citizens were rioting over economic austerity measures in 2011 and 2012.

Some Terminology

Stages of water resource management are marked herein by particular English and French vocabulary. Hydrography refers to exploring terrain and mapping the location of water. Hydrology refers to the scientific study of water and the technology of water conservation, relocation, recharge and quality. During a hydrography phase, water was mapped as roadways to existing markets. When the subject of water was treated by hydrologists, rather than hydrographers, more acreage was devoted to outputs for the purpose of trade and subsistence farming diminished. Humans were workers, paid workers at best and enslaved persons at worst. Early European colonial policy in Africa occurred in this stage.

After the 1884–1885 Berlin West Africa Conference agreements to coordinate further exploitation of African lands by European nations, a cadre of administrators moved along African waterways into northwest African valleys for the purpose of maximizing the extraction of resources from African soils by co-opting human labor hours there.⁴ Extraction of outputs at maximal levels often reached points of diminishing returns and depletion of human and material resources. What remained afterward was often as ruined as an area hit by floods and swarms of locusts. In plain words, under this extractive economic system, humans died due to unregulated speculating, cheating, shortsighted and irrational consumption of resources. It was rational if one can move to another location on the frontier for outputs the way that locusts do. In the late twentieth and early twenty-first century, the 1884–1885 definitions of rational economy failed because there are no more frontiers. The world has been finite for a long time, even by the standard of Frederick Jackson Turner’s frontier thesis.⁵

In a closed frontier phase, hydrology changes to serve a new economic order: the age of conservation. This word is politically charged. For some, it means supporting the monarchy or colonialism. For others, it means preserving the social order or working against a diffusion of power. There are additional words in French that carry some of the emotions related to this phase of the economic development in Africa. At this point, many humans were *cultivateurs* or farmers who traded their surplus after local subsistence needs were satisfied.⁶ Some scholars would call this horticulture. In English, horticulture is usually contrasted with agriculture based upon using a hoe or a plow. However, the word agriculture does not convey issues of morality that can be captured with French words. Nineteenth-century French compatriots were moving into a phase of *exploitateur*. In French, this does not have the negative connotation that it does in English. Rather, it recognizes a person as a worker or a mechanic in a farming process that is increasingly enhanced with machines into industrial farming or agriculture.⁷ The twenty-first-century conservative knows that long-term profitability in numerous industries is diminishing due to economic instabilities caused by diminishing amounts of surface water and increasing amounts of ocean water. What we need now, I argue, is a necessary alignment of the industrial *exploitateurs* with the *cultivateurs* for sustainable economies. In plain words, we have to complete the abandonment of the resource gathering systems that were based upon exploitation to the point of exhaustion because we have exhausted our frontiers. We do not have to wait for WWII to decide that these antiquated systems are lethal to humankind because they reward men who commit genocide in service to the nobles of Europe and Asia in addition to the investor elites of the southern and northern hemispheres, as seen in Syria, Sudan, Myanmar and elsewhere. For the average enlisted soldier and militia member, the wars of the twenty-first century are wars about the right to live. Some, as exemplified in the World Bank text, *Africa’s Infrastructure*, understand that these are wars of global justice.

France and Water in the Nineteenth-Century Sahara Desert and Senegal River Basin

In some aspects, French colonization of northern Africa was a young man's game of economic chess. Abd al-Qadir, the Amazigh leader and freedom fighter who defeated French armies on Amazigh soil in 1834 and 1837, and who led armies against French occupation of Algeria in 1841–1847, was only twenty-six years old when he first stopped the army that once dominated Europe.⁸ In 1822, Jean-François Champollion presented his translation of portions of the Rosetta Stone when he was thirty-one years old.⁹ However, younger than both was Henri Duveyrier, only nineteen years old when he set out to explore the Sahara in Algeria and Tunisia a dozen years after Abd al-Qadir was exiled to the Middle East.¹⁰

In 1859, Duveyrier set out on a twenty-nine-month journey into the Sahara, and he published his findings in 1864. His adventure was sponsored and/or endorsed by a "His Majesty, the Emperor Napoleon III, enlightened sovereign who is eager to spread the influence of French civilization," a group of field marshals, counts and even a cabinet-level advisor to the French emperor. Some of these gentlemen, where M. signifies Monsieur or Mister, were their "Excellences M. le maréchal Vaillant, M. le maréchal comte Randon, M. Rouhe, M. le comte de Chasseloup-Laubat, M. Thouvenal, ministre de Sa Majesté l'Empereur." Duveyrier maintained connections in North Africa with several French military colonels, lieutenants, and garrison commanders, among whom were "colonels Séroka, Lallemand, Wolf, Marguerite, le commandant de Forgemal, le lieutenant Aver, commandant la garnison de Tougourt." He even met Heinrich Barth who set the standard for reconnaissance diaries.¹¹ Prepared and endorsed, Duveyrier began a journey upon which he built a career, his book praised as an attempt "to conquer with science that which has not been conquered by politics and by military for the French flag."¹² He gathered details from personal observation, and he used second-hand reports to fill the blanks on French maps of the Sahara.¹³

Duveyrier was a keen observer of people and of hydrography and he included information on African hydrology. His informants described a Saharan region called Tasili with its forty deep lakes that never dried. In fact, they told him, crocodiles lived at these lakes. Duveyrier surmised that the sources of water were likely underground springs from an aquifer of considerable size. The significance of the crocodiles would come from another scholar many years after Duveyrier's book was published. Lysander Dickerman postulated that Ancient Egyptians used crocodiles in the time of Amenemhat III, ca. 1850 BCE, who built a massive reservoir, stocked with fish, at Lake Moeris/Birkut Qarun where some of the Nile's floodwaters were channeled for redistribution during the dry season. The crocodiles were sacred, according to Herodotus, and Dickerman believes that the animals may have acted as a gauge of water quality. Where crocodiles thrived, so could humans and the fish that humans consume.¹⁴ This African system of monitoring water quality was a sustainable and sustained hydrological technique.

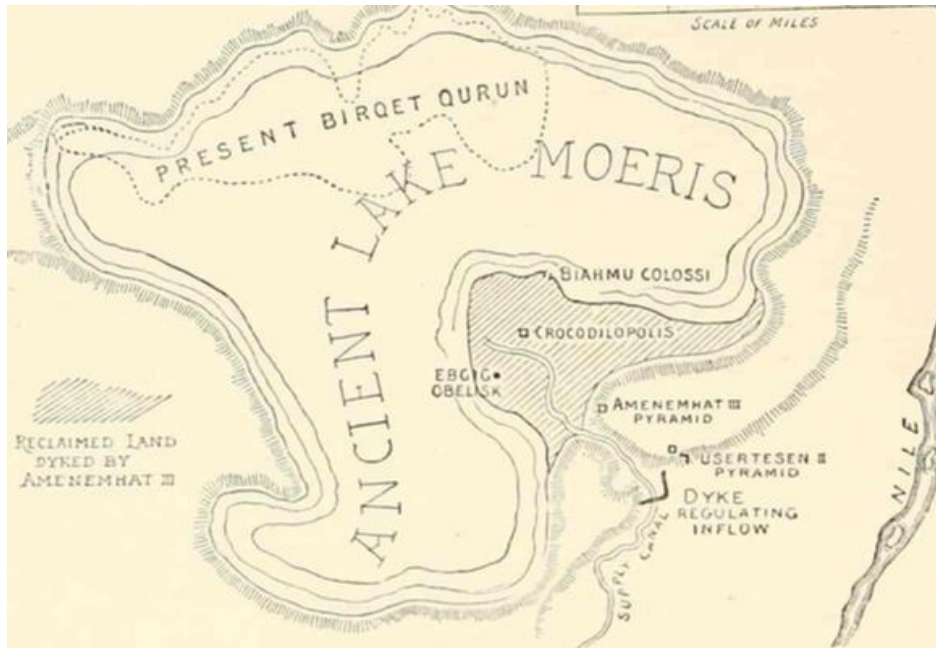


Image 2: Map of Ancient Lake Moeris reservoir constructed during time of Pharaoh Amenemhat III, ca. 1850 BCE. Source: "Lake Moeris," by John Ward and Francis Llewellyn Griffith, 1902, used with permission from the [Internet Archive Book Images at Flickr Commons](https://en.wikipedia.org/wiki/Lake_Moeris), at https://en.wikipedia.org/wiki/Lake_Moeris.

Duveyrier recommended that some regions of France adopt a subterranean *foggara* irrigation system. His description was quite accurate. Vertical artesian wells were drilled at intervals from an aquifer. These wells and the aquifer were then connected by a submerged horizontal gallery carefully inclined to provide water to the vertical wells for irrigating land with a continuous flow of water. Duveyrier counted more than 300 of these artesian wells in Ouâd-Rîgh alone. "This ingenious process," wrote Duveyrier, has more than one application in Algeria and even in certain areas of France.¹⁵ Other European scholars have since discovered that these *foggaras* or *qanats* appear across the Sahara, Arabia and parts of western Asia. Some of these systems worked for a thousand years.

Wilson and Mattingly studied one of these massive irrigation systems and learned that they work as long as there is water in the aquifer. The one at Ouadi al-Ajal in southern Libya irrigated 300 square miles of land in the middle of a desert for over a thousand years. That land fed as many as 50,000 people. Wilson and Mattingly found that this stable, engineered source of water raised food security to such a height that there was a "shift from fortified sites (Tinda, In Tafarat, Tuwash. It is very clear that water security had a peace dividend and that certainly had a positive effect on the profitability of trade until the Zinkekra) to undefended ouâdi-floor settlements" until the withdrawal rate exceeded the recharge rate.¹⁶

Duveyrier's explorations were sponsored by the French government and the French government wanted knowledge about the local economies. Duveyrier wrote that his goal for the trip was to increase "nos connaissances" of the district between Algeria and Central Africa.¹⁷ He sought increased familiarity but not factual mastery, not "savoir," of the region. "Connaître" is a verb associated with knowing people. "Savoir" is associated with facts, things, and processes. So, for Duveyrier, this was a mission of contacting people who had not been conquered by, nor committed to a trade agreement with, France. They were neither subjects of France nor its labor units. This was not an inventory assessment on the orders of William the Conqueror's *Domesday Book*. Those stages would follow. At this point, Duveyrier was somewhat of a guest and not a colonizer. There are signs, though, that the information he gathered about water had strategic value for those planning to colonize the area as part of a greater French security scheme for the nobility obligated to secure food in order to avoid another French Revolution.

Duveyrier defined a "ouâdi" as a riverbed without water, one that had been filled by sand and sediment until the water was submerged.¹⁸ Some riverbeds extended over 1000 kilometers into the interior. He noticed a curious pattern. Wells in the riverbeds were deeper than wells in the inner plateaus. These wells were also capable of producing more water than they currently did. This was key information for moving an army of merchants or soldiers.¹⁹ It was key information for extracting water to develop agricultural schemes on the order of Western Hemisphere sugar, cotton or rice plantations. There was water in the desert, some nearly saturated with salt but other water was sweet.

He noted that one needed to wait a week or so after the seasonal rains recharged the river to see an area turn green with fresh plant life.²⁰ He chose the word "rempli" (replenish) rather than *arroser* (to water).²¹ In another place, he suggested that the water table dropped due to some significant subterranean change that opened spaces into which the river water dropped and from which it can be drawn. If the fertility of the land along the riverbed returns when seasonal rains temporarily refill the basin, could that fertility be restored with water from an aquifer? This "rempli" of the rivers, something known as recharging, will trigger ideas in the mind of a later soldier, Victor Levasseur. Duveyrier should be classified with hydrographers who mapped the location of water.

A Transition from Hydrography to Hydrology: *Projet de Construction de 3 Barrages dan les Marigots de Gorum et de Lampsar, Senegal 1865*

An 1865 proposal to construct three dams on tributaries of the Senegal River indicates a change in France's approach to water and waterways in its commercial dealings with the peoples and economies of West Africa. It marks a step from hydrography, the mapping to water and waterways, to hydrology or using science to manage water. It marks a plan to subject the Senegal River and some of its tributaries to the industrial system of Europe. It

marks the ability to turn acres of land toward cash-crop production for the benefit of another nation. It marks the ability to supply water to growing urban areas. It means securing the export market by stabilizing water against the vagaries of natural weather cycles through hydro-engineering over several decades.

Acacia gum, or gum-arabic, was a primary commodity traded on the Senegal River according to the archival documents studied. In Europe, acacia gum was used to emulsify solids in liquids and to make adhesives. Demand for a steady, secure supply of acacia gum also came from the medical community because the gum was a key ingredient in the manufacture of medical pills.²² French citizens hungered for pharmaceuticals.

In 1836, the trade in acacia gum and other items was contracted with the Emirate of Trarza and the Emirate of Trarza seems to have coordinated the interior trade with the Kingdom of Oualo. These African states placed very specific limitations on the activities of French merchants as seen in a series of treaties.²³ For example, in 1836, the trading season was announced by cannon-shot on the first of January and the season closed the first of August. All transactions had to take place on ship and no warehouses or buildings could be constructed by Europeans on riverbanks. Curiously, the French commandant was ordered by treaty to shake hands with any “King, Prince, minister or chief sent to oversee the trade” in gum. This was a trade between equal powers, although the terms of trade suggest the French were less equal to the Maures of Trarza. Should any merchant wish to by-pass this official trading station to deal directly with the kingdoms of Oualo, that merchant’s ship’s cargo would be seized, and the action would suspend the gum trade for the remainder of

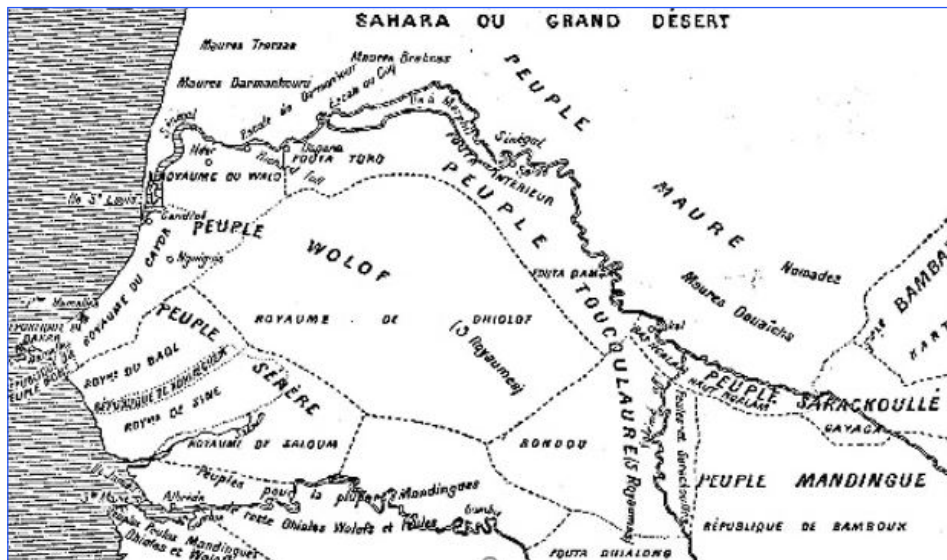


Image 3: Map of the Senegal River area, ca. 1853. Notice the Sahara Desert to the north of the river. Source: In the Public Domain at https://en.wikipedia.org/wiki/French_conquest_of_Senegal#/media/File:EthniesS%C3%A9n%C3%A9gal.jpg.

the season.²⁴ In the 1836 season, the waterway was a gate or even a doormat from which the French were not allowed to stray.

Economic demand can drive curious hydrographers. By 1843, France secured more favorable terms for use of the river. The first article allowed merchants to deal directly with suppliers whether they were Idaw al-Hajj Maures (also known as Darmankoures), Maures from Trarza or merchants from Oualo. The twenty-fifth article opened the way for expeditions to survey the interior lands.²⁵ Hydrography began.

The hydrographers were followed by the colonizers. The *exploitateurs* consisted of work-parties organized by contractors or *engagés*. These *exploitateurs* appear in a clause in a subsequent treaty that forbade the *engagés* from meeting their gum quotas through forced labor.²⁶ Additional signs of violence in the trade appeared in a change in the balance of power as shown in the first article of an 1847 document. This time, the French dictated the limits on trade, a far cry from the 1836 treaty. In this document, the Darmankoure Maures were banned from trade with the French until they recognized the authority of the French colonial governor.²⁷ The political power of the French flag began covering the Senegal River and Duveyrier's writings may have inspired somewhat the shift.²⁸

Why was there a shift from hydrography to hydrology? To answer this question in the space of an article, the reader should consult other sources about the age of revolution and civil wars in industrializing Europe between 1848 and 1871. Sometimes, it seems that political violence in some Western nations created such dire and lethal economic desperation therein that the people cried out, "Help!" or "*Au secours!*" and expatriates in the colonies replied by *secur*-ing alternative sources of basic goods along river routes.

Somehow, those subterranean rivers and aquifers had to be tapped. Monsoon waters had to be trapped. Alluvial plains needed discipline. A cadre of *exploitateurs* needed the best minds available to work on extracting more and diverse goods on lands identified by hydrographers like Duveyrier. Science had to do what politics did not inside Western nations: provide the means of life to those in European nations who envied the resources available in the African countries where, at the least, hydrology and European domestic security were tandem agendas challenging local African sovereignty.

If one thing was learned from African hydrologists, whether they were the enslaved rice cultivators of the American South or the *foggara* builders of the Sahara and West Asia, that lesson is that scientific knowledge about water has exponential returns on the capital invested. If there was one thing learned from the civil unrest of the Napoleonic Wars and the Revolution of 1848, it was that France could not afford to let this unrealized produce go spilling into the Atlantic Ocean.

This story of the change from hydrography to hydrology to resolve French domestic insecurity advanced in 1865 when the French colonial administration moved from *exploitateur* to *conservateur*.²⁹ It was a matter of French internal civil security for French nobles at this point who feared losing their jobs or worse if the French population was not fed.

Competition with the English was increasing. African interior kingdoms fought for sovereignty. War and potential warfare were matters for the military. In 1865, Gov. Faidherbe set into motion a mechanism for declaring the Atlantic Ocean itself to be an enemy of France. The battle would take place in Oualo.

One year after the publication of Duveyrier's report on the ouâdis and subterranean waters of the northwestern Sahara, four men met on 29 June 1865: "MM. Vallon, Capitaine du frigate, président, Maritz, Chef de Bataillon du Génies (Engineers), Peuchot, Capitaine du Génie, Rocomaure, Lieutenant du Vaisseau." ³⁰ They were commissioned by the colonial governor to consider solutions to a problem. Some of the tributaries of the Senegal River, inland from St. Louis, had varying degrees of ocean water for several days or more each year. In order to construct a dam between St. Louis and the Atlantic, the Commission called for a study of the salinity and force of flow in the area beyond St. Louis. ³¹ Blocking the ocean would leave water levels at St. Louis too low to function for business purposes unless fresh water for recharging the St. Louis area of the Senegal River could be stored by building three or four dams on the Lampsar, Djeuss, and Diaoudoun tributaries. A channel could be constructed to link these swelling rivers to the Tiaouey River that fed into Lake Guier. At some points, artesian wells would be needed to assure proper water levels. This system to block the invasion of Atlantic Ocean water into the Senegal River would coincidentally create a reservoir system that could be used to irrigate nearly 300 square kilometers of land. A corps of military engineers planned to use science to extend French *culture* (farming) in Oualo:

L'eau se précieuse au Sénégal. Au point du vue de l'agressent des fermes, des maisons de campagne, des jardins pleins de fruits inconnue sur une terre stérile courirent des rives des marigot voisins de Saint Louis: nos relations avec des peuplades reconnaissent deviendrait chaque jours plus faciles. ³²

The committee notes in the preceding quote that this part of Senegal is covered with tributaries of the Senegal River but farms, manor houses, and orchards are unknown in a land that seems sterile. This could be a result of salt residues from the seasonal influx of Atlantic Ocean water. It could also be a symptom of population depletion due to wars and the slave trade. The author used an archaic phrase "L'eau se précieuse." Larousse Dictionary defines "précieuse" as the name given to a group of aristocratic French women who undertook the refinement of manners and language in the early seventeenth century. It is likely a subtle insult to the royal women of Oualo, the *lingeers*, who once ruled with the *Brak* from the town of Ndeer on Lake Guier. These French gentlemen intended to use hydrology to dominate the land of the semi-matriarchal Oualo kingdoms where women and men fought Maures and French to maintain their sovereignty. By attempting an irrigation scheme on the scale of the *foggara* systems that Duveyrier discussed, this Commission planned to use hydrology to exploit this land and secure agricultural products for France.

Currently, there is a dam to the north and south of Lake Guier, now one of Senegal's larger surface sources of fresh water.

Levasseur's Mutinous Dreams of Water in the Desert

Victor Levasseur was a French military officer who watched too many people die while establishing a gathering network for France on the Saharan frontier. He did not disagree with the mission to help French citizens by securing goods from other nations. He disagreed with the dehumanizing conditions under which so many young French men died before they secured enough wealth to become fathers. He himself suffered on the frontier from water-borne disease. During that illness, he must have pondered the seemingly impossible nature of his mission. Victor Levasseur was a military officer. As a retired officer, he mutinied against the status quo by proposing something almost impossible. He rebelled by demanding a more life-sustaining investment of French capital.

L'eau est la premier l'élément dans la nature animale, minérale et végétale, car là où il n'y a pas d'eau, il n'y a pas rien. (Water is the first element in the animal, mineral and vegetable worlds, for there is nothing unless there is water.) ~ Victor Levasseur, retired officer of the French Cavalry, 1895.³³

Victor Levasseur discovered the limits of hydrography when he proposed creating an inland sea near Timbuktu that would be fed by water from the Atlantic. He was fully aware that water existed at various depths in the desert, whether because of his own travels or from Duveyrier's work. He knew that canals could be constructed. He convinced venture capitalists to commit to the idea, but they wanted the security of a fifty-year colonial concession on the lands to be developed. Levasseur may have styled himself as a French Cecil Rhodes for he wanted to create an inter-modal hub on this artificial sea.³⁴ What he did not seem to know is that such projects do not advance without hydrologists.

France conquered Timbuktu in 1894. Timbuktu was a commercial hub developed by Touareg merchants in the eleventh century. Situated near the Niger bend, Timbuktu straddled the intersection of the east-west sub-Saharan route that connected Atlantic communities to the Red Sea and Arabia, to the long-established routes that linked the gold and salt regions of the Sahel, and to trans-Saharan trade entrepôts in Morocco, Algiers and Tunis. At its peak, Timbuktu rivaled Cairo, Fez, Paris, Baghdad and Oxford as an intellectual center. If France could develop modern transport in Timbuktu, France could rival Cecil Rhodes' Cape-to-Cairo Railroad idea that threatened to give England a monopoly on trade from South Africa to Cairo and the Suez Canal. With England's position in Nigeria becoming more secure, France faced possible eviction from the Sahel. France needed to secure its position in the Sahara in order to feed French citizens. Levasseur, a loyal soldier, saw a way of doing this with man-made water infrastructure at Timbuktu. It was all so clear on a map.

So, in 1894, Levasseur celebrated the conquest of Timbuktu. He organized a group of venture capitalists called the Society for Artesian Wells and Canals in the Sahara Desert and Elsewhere. Then, he drafted a proposal entitled “Le Canal de Tombouctou à la Mer (Cap Blanc) Projet.” This canal could send ocean water into an interior reservoir. “Ce projet est réalisable.” It was only a matter of constructing a channel just over 1300 kilometers in length.³⁵ By comparison, the canal to connect Lac Guier to the reservoir system in Oualo was insignificant as was the nearly 200-kilometer Suez Canal. The Erie Canal in the United States was almost 600 kilometers. Surely, French engineers could double the American accomplishment! All that Levasseur asked was permission to construct this canal to Timbuktu using private capital.

Levasseur researched the project. He used topographical information from studies commissioned by General Faidherbe.³⁶ His selling points linked the technology of the ancient African hydrologists with the strength of their empires. Carthaginians and Numidians constructed rectangular canals and square basins to water their desert refuges to which they retreated when Romans invaded. He summarized Duveyrier’s descriptions of the *foggara*, the *ouâdis*, the water-tables submerged beneath sand and silt, and the stable, fresh-water lakes in the desert.⁴³⁷⁰ Massive irrigation schemes based on hydrology worked for the ancients and there was no reason, Levasseur thought, that an enlightened, modern France with its corps of engineers could not exceed the irrigation accomplishments of the ancients. Levasseur balanced patriotism with the practical matter of financing the project with private venture capital.

Levasseur must have been aware that the French colonial administration might be more interested in creating a railroad from the Mediterranean to Timbuktu for he proposed two lesser projects. One was a smaller canal (he estimated 15 kilometers) linking Timbuktu to the Niger River. From there, it was only a matter of negotiating with the British for access to the Niger Delta and the Atlantic Ocean. The second of these smaller projects involved constructing a score of artesian wells, at least twenty wells needed at Timbuktu to serve a future railroad community. This point was reasonable given France’s experience with the development of the railroad from Dakar to St. Louis only a decade earlier. He, or the scholars in his society, even understood that water pressure from these wells might be unreliable due to drought, so his proposal included hydraulic engines to maintain water pressure of 40 hp to assure that potable water would be in steady supply. Levasseur could very rationally assume that the French colonial administration would bring Timbuktu’s water infrastructure at least to the technological level of St. Louis and Oualo as planned in 1865.

Levasseur was a soldier before he was a *conservateur*.³⁸ He may have been writing from a sore place in the heart of a soldier. He himself had become ill from drinking poor quality water in French West Africa. In those moments of confronting his own mortality and that of those who would follow him, he found another equally important part of the mission:

protecting those made weak by poor water infrastructure in order to predict life for the strong. He was probably not surprised when word of a particularly disastrous expedition reached the public. In 1881, only thirteen of Lieutenant Colonel Paul-François Flatters' expedition of 92 men returned from exploring a possible route proposed by Duveyrier for the trans-Saharan railroad. Peter J. Bloom's 2008 book records that the disaster resulted from massacres and poisoning.³⁹ Levasseur reported that the majority of foreign businessmen who travel in the environs of the proposed trans-Saharan railroad became ill, often mortally ill, from diseases and fevers contracted from germs in the available drinking water. He believed that water from deep artesian wells, pumped by the hydraulic engines, would secure a healthier water source.⁴⁰ He knew that French troops were not secure without alternative sources of drinking water.

Water and hydrography took on a different security aspect in this case. The Oualo case concerned irrigation to secure food and agricultural products after two eras of internal civil strife in France that resulted in hunger and death for many citizens in the metropole. West African products secured the lives of French citizens. Levasseur presented his privately funded Timbuktu project as a military asset. Without healthy water for soldiers and railroad administrators, a trans-Saharan railroad was not "réalisable." The Minister of the Colonies consulted with the Director of Colonial Public Works in Paris. They concluded that the merits of the proposed project should be determined by the local colonial administrations. Perhaps the French were merely waiting for enough rains to recharge the pre-colonial canals that African hydrologists had constructed many, many years earlier rather than spend money on building a new one.

Conclusion and Going Forward

There is no trans-Saharan canal to the Atlantic. At the time, it may have seemed as unrealizable as Jules Verne's trip to the moon. However, France did construct a series of dams in Senegal, Morocco, Algeria, Mali and Tunisia—all places of agricultural interest to the French economy.⁴¹ France deployed hydrologists to create large-scale irrigation projects for the purpose of increasing the volume of agricultural products to be secured for the citizens in the metropole. In the Senegal River basin, they accomplished this by declaring war against kingdoms like Oualo.

Victor Levasseur, a French soldier, was a visionary whose idea is only now attainable. In 1894 he proposed creating near Timbuktu an artificial lake filled with ocean water channeled from Cap Blanc.⁴² At the time, a 1300 kilometer canal was "réalisable" but not practical.⁴³ Now, in the age of transcontinental petroleum pipelines from Chad to the Atlantic and desalination plants that supply fresh water for two million people a day in Algeria, hydrologists, venture capitalists, and national governments can partner to prevent water wars and create more consumers with disposable income. Before dismissing *Projet*

Levasseur, one must remember that Jules Verne's 1865 idea of a trip to the moon was once just a fantasy.

We can create lakes of water in the desert so that families can eat today and sleep securely through the night because of the peace dividends of massive irrigation projects. It takes the will to require that pipelines of semi-desalinated water from the ocean be constructed next to pipelines bringing petrocarbons to port. The water can be semi-desalinated or not at all. It is old knowledge that sand filters make water potable.⁴⁴ Imagine what the Sahara can do! Unfortunately, the World Bank's 2010 report on Africa's resources seems to encourage strife by prolonging water insecurity, leading to continued and more conflict in areas where water is scarcer than it ought to be. When looking at this situation with a view from children's graves, one sees a manufactured crisis in an artificial less-than-zero-sum game. When looking at this with a view from 30,000 feet, one sees rising oceans with water that can be desalinated and pumped inland to recharge areas with declining water tables. Levasseur shows us that a state can mindlessly diminish the amount of food available by interfering with water infrastructure development. It is a lesson repeated in Nigeria, Niger, Mali, Mauretania and Somalia where insufficient tax revenue and regulation result in poor infrastructure for the citizens. Between the Great Green Wall and a recharged Lake Chad, the insurgency flames of groups like Boko Haram and al-Shabaab can be doused. One wonders what the African Union will do to take this next step.

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NOTES

¹ “African Union Commission and FAO Step Up Support to Great Green Wall for the Sahara and Sahel Initiative (GGWSSI) Cooperation Agreement Signed on the Implementation of Action Against Desertification Project,” African Union, February 9, 2016, accessed March 16, 2021, <https://au.int/en/pressreleases/20160209>; Babalwa Bungane, “Partnership to Install Solar-Powered Desalination Plants in Kenya,” *ESI-Africa*, December 3, 2020, March 16, 2021, www.esi-africa.com; Taha Mebtoul, “Morocco Builds Largest Seawater Desalination Plant in Africa,” Morocco World News, November 10, 2020, March 16, 2021, <https://www.morocoworldnews.com/2020/11/325458/morocco-builds-largest-seawater-desalination-plant-in-africa/>; “Algeria to Undertake Construction of Three Seawater Desalination Plants,” May 19, 2021, www.constructionreviewonline.com; Horace G. Campbell, “Chad: Saving Lake Chad—a Pan-African Project,” Pambazuka News, March 16, 2018, accessed February 16, 2021, <https://allafrica.com/stories/201803200302.html>; accessed February 16, 2021, www.Greenbeltmovement.org; www.greatgreenwall.org; accessed February 16, 2021, www.unccd.int/actions/great-green-wall-initiative.

² Zombie economics is but one of the approaches that I developed to use in my scholarship. Over the last twenty years, I have developed alternative theories for examining world historical events that do not rely on patriarchy, racism, religious prejudice or zero-sum game political theory. Why? These approaches have not adequately explained why ordinary men and women followed generals and monarchs into wars far from home. One of my observations is that the frontiers between empires were often conflicts between societies that were more gender equal or matriarchal than the invading ones. Another observation is that much historiography from the European interlude of global colonization distracted many scholars from looking for older political theories, theories that are now in play in international politics. See Marsha R. Robinson, *Matriarchy, Patriarchy, and Imperial Security in Africa: Explaining Riots in Europe and Violence in Africa* (Lexington Books, 2012) and Marsha R. Robinson, *Disobedient Histories in Ancient and Modern Times: Regionalism, Governance War and Peace* (Cambridge Scholars Publishing, 2018).

³ Vivien Foster and Cecilia Briceño-Garmendia, eds., *Africa’s Infrastructure: A Time for Transformation* (Washington, DC: World Bank, 2010). There are five chapters devoted to water and water infrastructure.

⁴ The topic of American exports of cotton to the mills of Europe in the mid-nineteenth century was addressed by other scholars. Brian Schoen, *The Fragile Fabric of Union: Cotton, Federal Politics, and the Global Origins of the Civil War* (Baltimore, MD: Johns Hopkins University Press, 2009); Marc Engal, *Clash of Extremes: the Economic Origins of the Civil War* (New York: Hill and Wang, 2009); J. D. Bennett, *The London Confederates: the Officials, Clergy, Businessmen and Journalists Who Backed the American South During the Civil War* (Jefferson, NC: McFarland & Co, 2008); Thomas Boaz, *Guns for Cotton: England Arms the Confederacy* (Shippensburg, PA: Burd Street Press, 1996). Europe responded by enhancing alternative source markets of cotton. Allen Isaacman and Richard Roberts, eds., *Cotton, Colonialism, and Social History in Sub-Saharan Africa* (Portsmouth, NH: Heinemann, 1995); Richard L. Roberts, *Two Worlds of Cotton: Colonialism and the Regional Economy in the French Soudan, 1800-1946* (Stanford, CA: Stanford University Press, 1996); Arthur W. Silver, *Manchester Men and Indian Cotton, 1847-1872* (Manchester, UK: Manchester University Press, 1966); Sir Edward Baines, *History of the Cotton Manufacture in Great Britain: with a Notice of Its Early History in the East, and in All the Quarters of the Globe* (London: H. Fisher, R. Fisher, and P. Jackson (1835?)).

⁵ Frederick Jackson Turner, *The Frontier in American History* (New York: H. Holt and Company, 1920). The Turner thesis explains, in part, that the closing of frontiers affects national behavior and can lead to competitive, zero-sum game thinking. Globalization represents, for others, an opportunity to redefine some frontiers and the loss of other frontiers. The idea manifests in a variety of thoughtful communities. Thomas P. M. Barnett, *The Pentagon's New Map: War and Peace in the Twenty-first Century*, (New York: G.P. Putnam's Sons, 2004); Jamie Peck and Henry Wai-Chung Yeung, *Remaking the Global Economy: Economic-Geographical Perspectives* (London: SAGE, 2003); George Ritzer, *McDonaldization: The Reader* (Thousand Oaks, CA: Pine Forge Press, 2002).

⁶ French, like Arabic, is a language in which many words have gendered forms. The ending of a French noun -eur indicates that the person is male. In English and in languages like Wolof, such nouns are gender-inclusive and it is social custom that conveys any assumptions about the gender of the person who is described by that noun.

It has been known for a long time that more than 70 per cent of the agricultural labor in Africa is provided by women. While I acknowledge that this reality suggests that the proper word to use is *cultivatrice*, linguistic conventions and grammatical rules in several languages led me to use the -eur form of the word.

⁷ An *exploitateur* is a person who could join a labor union (*faire partie d'un syndicat*), or who could become (*enregistre comme*) a Freemason or a Rotarian. This is not about social caste. It is about one's preference for the type of products to be pulled from the land. The switch to cash-cropping and the consequent purchase of basic food is a marker of this stage. Specialization of production is not necessarily bad and often enhances the overall quality of life of a community. Intentional famine, though, is a slow form of warfare.

⁸ Raphael Danziger, *Abd al-Qadir and the Algerians: Resistance to the French and Internal Consolidation* (New York: Homes & Meier Publishers, 1977); Louis Lataillade, *Abd el-Kader, L'Europe et L'Islam au XIXe Siècle* (Paris: J. B. Janin, 1947); Mohamed Chérif Sahli, *Abdelkader: Chevalier de la Foi* (Alger: Éditions ANEP, 2007).

⁹ Public and scholarly curiosity about Mr. Champollion continues from the era of Napoleon Bonaparte through the present century. J-G Greppo, *Essay on the Hieroglyphic System of M. Champollion, Jun.; and on the Advantages Which It Offers to Sacred Criticism*, Isaac Stuart, trans., 2nd ed. (New York: Saxton and Mills, 1842); Daniel Meyerson, *The Linguist and the Emperor: Napoleon and Champollion's Quest to Decipher the Rosetta Stone* (New York: Ballantine Books, 2004); R. B. Parkinson, *Cracking Codes: the Rosetta Stone and Decipherment* (Berkeley: University of California Press, 1999). One of the more interesting recent publications on the invasion and colonization of Egypt is Shmuel Moreh, ed., *Napoleon in Egypt: Al-Jabarti's Chronicle of the French Occupation, 1798*, Shmuel Moreh, trans. (Princeton, NJ: Markus Wiener Publishers, 1993).

¹⁰ Duveyrier's influence on French imperialism was not limited to his initial trip. His work was cited in diplomatic contests between Spain and France over African territory. Thomas J. Bassett, "Cartography and Empire Building in Nineteenth-Century West Africa," *Geographical Review* 84, no. 1 (1977): 21–36. How much influence Henri de Saint-Simon had on Duveyrier as a French technocrat should be considered but is beyond the immediate scope of this essay. Robert B. Carlisle, "The Birth of Technocracy: Science, Society, and Saint-Simonians," *Journal of the History of Ideas* 35, no. 3 (July–September, 1974): 445–464.

¹¹ Henri Duveyrier, *Les Touareg du Nord* (Paris: Challemaïné, libraire-éditeur, 1864), ii–iii. Duveyrier was created a chevalier of the Imperial Order of the Legion of Honor and a foreign member

of the Royal Geographic Society of Berlin. The book was published in French and translations are my own. Heinrich Barth was a noted geographer who was the first European explorer to complete the sub-Saharan trade road connecting Lake Chad to Timbuktu. His notes, *Travels and Discoveries in North and Central Africa* (1857), are an encyclopedia of information about the geography, peoples, economies, essential glossaries for the various languages, brief histories and customs of societies. In sum, Barth provided information needed by financier, merchant, missionary and military officer. His work was a major leap forward from the travel narrative style of Mungo Park. The style of Duveyrier's book is closer to that used by Barth than by Park.

¹² I reprint the description here for I fear that I may not have captured the poetry of the last clause of the original sentence. "Une série d'observations physiques et astronomiques ces plaines du Sahara algérien et leurs nombreuses Oasis aux position extrêmes où s'arrêtait alors l'action politique et militaire de l'autorité française; il voulait étendre par les conquêtes de la science les conquêtes du drapeau." Written by the reporting editors MM. D'Avezac, J. Duval, V. Malte-Brun, Quatrepages, et Vivien de Saint-Martin to the Geographic Society of Paris. Duveyrier, *Les Touareg*, xvii.

¹³ Duveyrier can be viewed as heir to a tradition of the traveler/narrator that includes Ibn Khaldun, Ibn Battuta, Marco Polo, Alexis de Tocqueville, Frances M. Trollope, and Heinrich Barth. The realities that they described to their audiences at home were so different and relatively exotic that they may have seemed like tall-tales and fantastic fictions.

¹⁴ Duveyrier, *Les Touareg*, 29; Lysander Dickerman, "The Fayûm. With Brief References to Recent Discoveries in Other Parts of Egypt," *Journal of the American Geographical Society of New York* 24 (1892), 177–8.

¹⁵ Duveyrier, *Les Touareg*, 28. Andrew Wilson and David Mattingly, "Irrigation Technologies: Foggaras, Wells & Field Systems," in *The Archaeology of Fazzan*, David Mattingly, ed. (London: Society for Libyan Studies, 2003), 235–278; E. Klitzsch and D.W. Baird, "Stratigraphy and Paleohydrology of the Germa (Jarma) Area, Southwest Libya," in *Geology, Archaeology and Prehistory of the Southwestern Fezzan, Libya*, William Kanès, ed. (Castelfranco Veneto, Italy: Petroleum Exploration Society of Libya, 1969), 73.

¹⁶ Wilson and Mattingly, 275.

¹⁷ Duveyrier, *Les Touareg*, 1.

¹⁸ Duveyrier, *Les Touareg*, 27, 22.

¹⁹ Hydrography was a weapon in the Sahara. For millennia, the desert protected Amazigh nations from invasion from the north by decimating those troops with thirst and water-borne illnesses. In 1591, Ahmad al-Mansur sent a mercenary army that included European renegades to secure the gold trade on the Niger River by capturing Gao and Timbuktu, meaning his European soldiers arrived in Timbuktu long before the explorers referred to earlier. "The Moroccan troops were badly affected by the exhaustion which they endured, the lack of food, the destitution in which they lived, and the diseases which the insalubrity of the land caused. Water killed many beyond [the number of] those who perished in the battles." Lansiné Kaba, "Archers, Musketeers, and Mosquitoes: the Moroccan Invasion of the Sudan and the Songhay Resistance (1591–1612)," *Journal of African History* 22, no. 4 (1981): 469.

²⁰ Duveyrier, *Les Touareg*, 22, 27, 29.

²¹ *Ibid*, xxii.

²² "Critical Digest of the British and Foreign Medical Journals," *London Journal of Medicine* 1, no. 1 (January 1849): 90. J.T. Danson, "Some Particulars of the Commercial Progress of the Colonial

Dependencies of the United Kingdom, during the Twenty Years, 1827–1846,” *Journal of the Statistical Society of London* 12, no. 4 (November 1849): 349–439.

²³ Mercantile society on the Senegal River was very complex and often dominated by women. More insight about the role of women as brokers in the gum and slave trades during the nineteenth century is available. Hilary Jones, “From *Mariage À La Mode* to Weddings at Town Hall: Marriage, Colonialism, and Mixed-Race Society in Nineteenth-Century Senegal,” *International Journal of African Historical Studies* 38, 1 (2005); Lucie Gallistel Colvin, “Islam and the State of Kajoor: A Case of Successful Resistance to Jihad,” *The Journal of African History* 15, no. 4 (1974): 587–606. Their research adds new dimensions to that of a leading scholar of economic and imperial history in this region. See Boubacar Barry’s *Senegambia and the Atlantic Slave Trade* (Cambridge: Cambridge University Press, 1998); *Muslim Revolutions and the Atlantic Slave Trade: Senegambia Before the Colonial Conquest* (Cambridge: Cambridge University Press, 1997).

²⁴ “Traite de la Gomme: Instructions pour le Commandant de l’Escale de Darmankoure,” Q1, fol. 36, National Archives of Senegal, Dakar.

²⁵ ²⁸ “Arrête du 10 Fevrier 1843,” Q1, fol. 40, National Archives of Senegal, Dakar. The documents identify a group as Darmankoures. These Maures traded in a geographic space between the Trarza Emirate, and Oualo and Kajoor, all of whom traded along the Senegal River. James L. A. Webb, Jr., “The Evolution of the Idaw al-Hajj Commercial Diaspora (L’évolution de la diaspora marchande Idaw al-Hajj),” *Cahiers d’Études Africaines* 35, no. 138/9 (1995): 455–475.

²⁶ “Arrête du 10 Janvier 1844,” Q1, fol. 43, National Archives of Senegal, Dakar.

²⁷ “Extrait de l’arrête du 13 Fevrier 1847,” Q1, fol. 46, National Archives of Senegal, Dakar. A topic not addressed in this essay is the development of the groundnut industry in Senegal and the Senegambia region.

²⁸ This is one of those moments in history when an unwritten rule about history appears. There is a convention among some scholars that history began in this region in 1850 but that is a Western European bias. To follow the story of this region, see Barry, Jones and Colvin in note 23 and consult Andrew Francis Clark, *Economy and Society in the Upper Senegal Valley, West Africa, 1850–1920* (Lanham: University Press of America, 1999); Julian W. Witherell, “The Response of the Peoples of Cayor to French Penetration, 1850-1900,” thesis, University of Wisconsin-Madison, 1964; David Robinson, *The Holy War of Umar Tal: The Western Sudan in the Mid-Nineteenth Century* (Oxford: Clarendon Press, 1985). Of course, there are histories written using Arabic script that are far older than this.

²⁹ The *exploiteur* phase was clear under the governorship of Louis Faidherbe who was not above a scorched-earth policy to impose French dominion. Boubacar Barry details the “Machiavellian guile” displayed by Faidherbe against Kajoor to secure groundnut oil to lubricate France’s industrial machines. Barry, *Senegambia and the Atlantic Slave Trade*, 191. Another topic that is not presented here is the development of brutal, forced labor that eventually rivaled or exceeded the cruelties of slave labor in the Americas. Forms of this labor system still exist and are discussed under the topics of human trafficking, child-soldiers, etc.

³⁰ Captain Aristide Vallon was appointed president of this commission by Governor Louis Faidherbe who was reassigned soon thereafter to Algiers. For more on the activities of M. Captain Vallon and Hyacinthe Aube (possibly the Aube of these documents), consult David Robinson, “‘French Africans’—Faidherbe, Archinard, and Coppolani: The ‘Creators’ of Senegal, Soudan, and Mauritania,” in R. James Bingen, David Robinson and John M. Staatz, eds. *Democracy and Development in Mali* (East Lansing: Michigan State University Press, 2000), 25–27.

³¹ Boubacar Barry studied the impact and effectiveness of such a dam in another region of Senegal. See “Groundwater Flow and Quality behind an Anti-Salt Dam in Lower Casamance, Senegal,” thesis. Michigan State University, 1991.

³² “Addition d’eau de St. Louis, No. 1 Sénégal et Dépendances” No. 1, P415, fol.3. National Archives of Senegal, Dakar. The original French wording is in the essay in order to create a teachable moment about the experience that some of our students have when English is their second or fourth language. The interpretation presented in the next paragraph of the essay is my own, factoring in local culture rather than direct translation.

³³ Lettre de Victor Levasseur à son Excellence Monsieur le Ministre des Colonies, Paris, 15 Octobre 1895, P412, fol. 5, National Archives of Senegal, Dakar. Translation mine.

³⁴ Possible French envy of Cecil Rhodes’ efforts in the British colonization of Southern Africa has been noted by other scholars such as Douglas Porch, *The Conquest of the Sahara* (New York: Farrar, Straus and Girous, 2005), 130.

³⁵ “Projet Levasseur de Puits et Canaux artésiens au Sahara, 1894–1896,” P412, fol. 3, National Archives of Senegal, Dakar.

³⁶ Ibid.

³⁷ Lettre de Victor Levasseur à son Excellence Monsieur le Ministre des Colonies, Paris, 15 Octobre 1895, P412, fol. 5, National Archives of Senegal, Dakar.

³⁸ There is a Victor Levasseur who was a famous cartographer (1838–1854), publishing his maps in French and Spanish and another Victor Levasseur (1772–1809) who served Napoleon I. His son, Victor Jules Levasseur became a Colonel. Guillaume Levasseur d. 1643 was a cartographer (*Carte de l’Ocean Atlantique* / *A Dieppe Par Guilleme Levasseur, le 12 de Juillet 1601*, accessed February 16, 2021, www.trove.nla.gov.au/work/). A definitive study of the Levasseur family as soldiers and cartographers may include the Victor Levasseur who made this proposal. This Levasseur may be the author of “Le petit catéchisme du soldat des bataillons scolaires de la France” (Paris, L. Baudoin, 1889) as listed in the *Catalogs Général de la Librairie Française* (Otto Lorenz, ed., Paris: Librairie Nils-son, 1896), 412.

³⁹ Peter J. Bloom, *French Colonial Documentary: Mythologies of Humanitarianism*, (Minneapolis: University of Minnesota Press, 2008), 67–8.

⁴⁰ “La plupart des étrangers voyageurs commerçant qui traversent ces localités en y constrantent des maladies souvent mortelle à cause de ces fait, une partie des postes militaires du haut Soudan et du frontieres de Sénégal ne sont mieux approvisionés dela des cas nombreux de fièvres, dont moi-même j’ai constaté les effets pernicieux quand j’y était.” Lettre de Victor Levasseur à Son Excellence, Monsieur l’Inspector Général des Colonies, 28 Janvier 1896, P412 fol.2, National Archives of Senegal, Dakar.

⁴¹ George Spitz, *Sansanding: Les Irrigations du Niger* (Paris: Société d’Éditions Géographiques, Maritimes & Colonial, 1949).

⁴² The correspondence about Levasseur’s project does not mention desalination of ocean water. At that time, it was common to use slow sand filters to clean water. The Sahara Desert near Timbuktu has plenty of sand. For a concise historical overview of water filtration systems used in the British Empire, one might consult Philip D. Curtin, *Death by Migration: Europe’s Encounter with the Tropical World in the Nineteenth Century* (Cambridge: Cambridge University Press, 1990). Curtin’s fifth chapter contains information about the military’s efforts to secure potable water.

Many hydrologists research the issue of salinity and recharging African ground water. C. S. Swezey, "The Lifespan of the Complexe Terminal Aquifer, Algerian-Tunisian Sahara," *Journal of African Earth Sciences* 28, no. 3 (April 1999): 751–756; S. Bouri and H. B. Dhia, "Une Experience Trentenaire de Recharge Artificielle d'Une Nappe Côtière en Zone Aride: le Système Aquifere de Teboulba (Sahel Tunisien)," *Compte Rendus-Géoscience* 342, no. 1 (January 2010): 60–74; Bill Wallin, Cheikh Gaye, et al., "Isotope Methods for Management of Shared Aquifers in Northern Africa," *Ground Water* 43, no. 5 (September 2005): 744–749; Madan K. Jha et al., "Cost-effective Approaches for Sustainable Groundwater Management in Alluvial Aquifer Systems," *Water Resources Management* 23, no. 2 (January 2009): 219–233; J.J. de Vries, et al., "Groundwater Recharge in the Kalahari, with Reference to Paleo-hydrologic Conditions," in *Journal of Hydrology* 238, no. 1–2 (November 20, 2000): 110–123; A. Wright and I. Du Toit, "Artificial Recharge of Urban Wastewater, the Key Component in the Development of an Industrial Town on the Arid West Coast of South Africa," *Hydrogeology Journal* 4, no. 1 (1996): 118–129; etc.

⁴³ The word "réalisable" is an example of the necessity of clarifying the connotations of a word to multi-lingual audiences. In English, the word means that an idea can become something material, as in the situation of moving from script to performance or from a blueprint to an edifice. In French, it means feasible and shares the English meaning. In Spanish, however, there is a connotation of the State because the root word, real, means "royal." An example is "Real Cédula of 1802 issued by Charles IV of Spain. Projet Levasseur de puits et canaux artésians au Sahara, 1894–1896" P. 412, fol. 3, National Archives of Senegal, Dakar.

⁴⁴ Philip D. Curtin presented this in *Death by Migration: Europe's Encounter with the Tropical World in the Nineteenth Century* (New York: Cambridge University Press, 1989). Biosand water filtration is a modern version.