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Water Scarcity

Ambondro's Low Agricultural Productivity Due To Water Scarcity

Ambondro: About the region in need

Ambondro is a commune found at the south of Madagascar that has been targeted as a community that is going through lots of complications regarding food production and water supplying. This commune is situated in a region which is characterized by arid and hot climates, making summers hot, wet, and often windy, with the temperatures usually reaching 30º Celsius. The area is also considered to be very susceptible to suffer from cyclones and droughts, contributing to its dry and erosion-prone lands. Focusing on some more geological features of the region, south Madagascar is covered by a quaternary sedimentary formation, which is based on a crystalline basement (limestone sandstone, marine sand and dunes, clayey sandstone, marls and clayey sand). These kinds of materials that make up the malagasy land usually create salinity problems and have really poor water retention capacity, making harvesting very demanding and, when possible, crops tend to dry out easily and can hardly find the nutrients they require to grow, making yields low and unreliable. (Nampionona, Andrifaliana, et al., 2019)

The accumulation of soil over these lands is the one thing malagasies seize the most in order to start harvesting, although we have to consider that soil in that region is very poor in nutrients, is sandy, and is thin. Also, the land erosion and winds remove some of the soil. All of these factors make the crops struggle when trying to grow in shallow soils that lack nutrients and barely retain any water. (International Organization for Migration, 2017)

In 2018, it was estimated that Ambondro's population was around 20,709 malagasies; 58% of them are dedicated to the agricultural sector, meaning they are farmers; and some other 40% of the population lives from raising livestock. Meanwhile, service-provide employment takes care of the missing 2%. A census targeting most communes, 1,385 out of 1,395, in Madagascar was proposed and executed by the Ilo program (Improved Policy Analysis for Economic Decision-Making and Improved Public Information Dialogue) from Cornell University by the end of 2001. They surveyed inhabitants of the different communes in groups of two, making it possible to construct a dataset of the whole nation for the first time in Madagascar. (Cornell University, 2002)

From the many data that is found in this census, it can be deduced that, in a remoteness index, Ambondro is considered to be at the third level, which means they have very limited access to services and goods that may come from outside of the

commune. It is also specified that children in the region only have access to study elementary school and middle school.

Regarding the agricultural sector, it is reported that what the population produces the most are cassava, cowpeas, lentils, sweet potato, peanuts, and maize. It is also notable that 17% of the population is considered to live in poverty, and 1% have no goods at all.

Regarding infrastructure, records indicate that, by 2001, there were no hospitals, private clinics, banks, post offices, high schools, courtrooms, landline phones, nor any airport in the commune.

A very interesting fact that is really important to emphasize, out of all the data from this census, is that by 2001 Ambondro was not supplied with water by JIRAMA, which is a state-owned company, founded in 1975, that is expected to provide electricity and water to the whole country. Although, in 2006, two drinking water pumps were installed in the region because of a project funded by the European Commission in collaboration with the Malagasy Ministry of Energy. These pumps are photovoltaic (solar-powered), taking advantage of renewable energy and making them sustainable for a region in such need. (Cornell University, 2002)

Ambondro's Major Problem: Water scarcity and other important considerations

Ambondro's population has been significantly affected by water scarcity for decades, and certain factors such as the arid climate, the droughts, and the poor harvesting conditions, are the ones that limit agricultural production and threaten food security. The little aid this commune has received from both great organizations, and its own government, is actually mediocre. It could even be perceived as if its population had been practically forsaken by the world to survive and sustain on its own. Many associations have tried to provide help to all of these small communities in Madagascar, conducting analysis on them and proposing strategies to save water, but nothing further has been done besides the research studies alone.

Under many of these communes, there tend to exist underground water reserves, known as aquifers, created by the infiltration of water through the porous and fractured rocky surfaces, during rainfall or cyclones. An option would be to increase the water supplies in Ambondro by taking advantage of these water reservoirs with pumping systems. Nevertheless, there is one major problem: most of this water is saline. (Nampionona, Andrifaliana, et al., 2019)

Salinity in groundwater is caused because of many environmental factors, beginning with the geological materials that make up the surface, because since these sediments have always existed in a marine environment, they naturally contain great amounts of salts and minerals. It is due to this that when natural water, rainwater for example, runs through these rocks and dissolves some of its many minerals, making the water in aquifers not an option that can be easily accessed. Additionally, the

eroded ground and droughts lower the freshwater levels underground, making seawater prone to intrude and reach aquifers, contributing to this salinity problem. (Nampionona, Andrifaliana, et al., 2019)

Finally, some of the crops harvested in Ambondro are really dependent on great amounts of water, crops grown in rain-fed fields that, if the rainy season happened to be delayed for any reason, won't be able to sustain the whole harvest that is expected to keep the region's population fed.

It should also be taken into consideration that one of the most important crops that malagasies in Ambondro harvest is maize, which needs great amounts of water. Many communities in Africa report that during drought stress, maize yields can lower between 25% and 50%, meaning that half of the harvest can be lost because of these droughts that have become more and more frequent every year, especially in regions like south Madagascar. (Platform for Agricultural Risk Management, 2023)

A Definitive Solution: Water pumping and nanofiltration complex–additionally, silvopastoral systems and alternative crops

There are many problems that have made Ambondro's situation critical for decades, and there has been little action taken by organizations or the very government to help this commune's population, who fight daily to accomplish their expected nutritional consumption.

The main problems that affect Ambondro's population and that decrease their agricultural productivity, making it inefficient and unsustainable in some cases have been explained. Now, it is important to explore what the best way to address these problems would be, so that insufficient agricultural production is no longer a constant fear, and making sure that the commune's population has the opportunity to improve their daily lifestyle. In order to achieve this goal, I have thought of one main "must", as well as two complementary long-term proposals which will help to improve Ambondro's current situation:

Nanofilters implementation

A great start would be addressing water scarcity. Whereas we cannot directly control climate change and prevent droughts, there are some other water sources we can focus on, as are the aquifers previously mentioned. Although these aquifers contain water that has been salinated within the decades, a study made by a research team strongly affiliated to the University of Antananarivo (a Malagasy university) proposed to use nanofiltration systems to desalinate the groundwater so that it can be effectively used, not only to cover the population's hydrating needs, but also to moderately irrigate harvests. Nanofiltration is a pressure-driven membrane separation process in which water passes through pores sized between 1 and 10 nanometers, making sure that most organic molecules, viruses, natural organic matter, and multivalent ions get removed, this by using semi-permeable thin-film membranes that selectively filter solutes. This way we can get rid of calcium,

magnesium, sulfates, hardness, and part of the dissolved salts from the water, so that it will be completely drinkable.

The same research team that proposed to use this nanofiltration systems also calculated the daily amount of water that some highly populated regions would need to generate, so it was through this same calculation that; considering 20,709 malagasies in Ambondro in 2018, and a population growth of 2.54% per year, estimated in the same study; it is calculated that by 2030, Ambondro's population should be approximately of 27,980 people. Taking this into account, and a really humble consideration of 30 daily liters of water per person, it would be needed to produce 850,000 liters of water every day, 850 cubic meters of water.

Now, nanofiltration usually requires 1.3 kilowatts-hour (kWh) per cubic meter of treated water, meaning that we would need 1,100 kWh per day to treat this much water. Adding to this, the energy needed for the water pumping, which I'll set to be of about 500 Watts (W) or 0.5 kWh per cubic meter of water that gets pumped from underground to surface. Adding all this up, daily, we would need about 1,530 kWh in total. (Nampionona, Andrifaliana, et al., 2019)

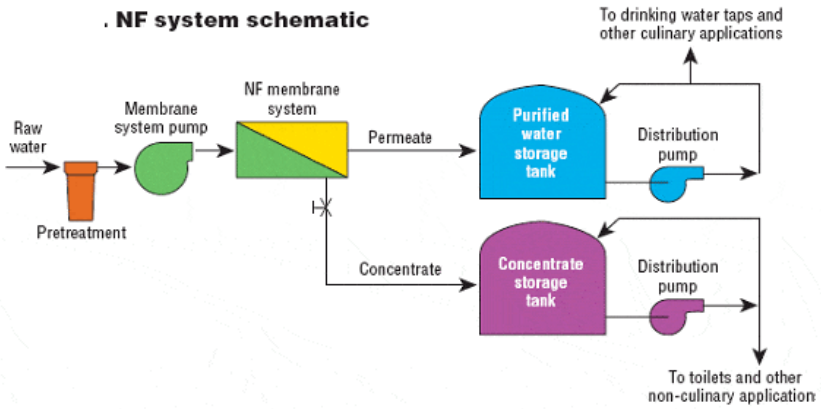

Figure 1. "Diagram of how nanofiltration works". AWC. "Advantages of Nanofiltration", American Water Chemicals, (2026), https://www.membranechemicals.com/water-treatment/advantages-of-nanofiltration/. [May 13th, 2026]

The most sustainable way to produce the energy needed for the nanofiltration and pumping is solar energy. The installation of solar panels would assure that the filters and pumps are constantly working but, in order to know how many solar panels will be needed, it is important to consider that southern Madagascar has strong solar irradiation, making it possible to estimate that a region like Ambondro tends to receive about five or six hours of daily efficient sunlight. This would mean that about 280 kilowatts (kW) of solar panels will be necessary; and considering 20% of safety margin for possible inefficiencies, cloudy periods, and some other complications, it would add up to 350 kW. Most modern solar panels have a capacity of 400-500 Watts per panel, meaning that about 700 solar panels will be just enough to satisfy the amount of treated water that malagasies in Ambondro are going to need.

With all of this information in mind, it is time to consider costs and start to set a budget for the project: large solar installations tend to cost 800-1,500 USD per kilowatt, the average would be 1,150 USD, times 350 kW that are to be satisfied, that would be 420,000 USD on solar panels; rural boreholes can cost 50,000 USD each, for multiple boreholes, we can estimate a total of 250,000 USD; then for the nanofiltration system, a filter with a capacity of 200 gallons per day costs around 600 USD, 200 gallons are 0.76 cubic meters, meaning 850 cubic meters would cost about 680,000 USD; finally, storage and distribution would cost some extra 150,000 USD; and everything would add up to 1.5 million USD.

This calculation was made trying to supply Ambondro from zero, but, considering that nearby areas are provided with some daily 230 cubic meters of water by JIRAMA, and expecting that Ambondro might as well receive about 190 cubic meters daily, that would lower the costs a bit. Only 540 solar panels would be needed, with them costing 310,500 USD; plus 520,000 USD on nanofilters; and probably about the same amounts on boreholes, storage, and distribution; this would reduce the cost to 1.2 million USD. All of what was proposed in this section is summarized in the next table:

Table 1. Calculations and costs according to the proposal, (Ramírez Solares Emiliano, 2026)

Population in 2018	Population growth	Population by 2030	Daily liters of water per person	Total L / m3
20,709 malagasies	2.54%	27,980 malagasies	30 liters	850,000 L / 850 m^3
kWh per m^3 treated	Total kWh so far	kWh per m^3 pumped	Total daily kWh	Daily efficient sunlight
1.3 kWh	1,100 kWh	0.5 kWh	1,530 kWh	5.5 hours
kW on solar panels	20% safety margin	500 W per panel	1,150 USD per kW on solar panels & pumping	
280 kW	350 kW	700 solar panels	420,000 USD	
850 m^3 into gallons	600 USD per 200 gallons	50,000 USD per borehole	Storage and distribution	Total
224,546 gallons	680,000 USD	250,000 USD	150,000 USD	1.5 million USD

It is really important to take into account that the amount of groundwater stuck in these aquifers is unknown, meaning that although they might provide with enough water, they might also not do it. Because of this, it would be important to carry out some studies that will let us make sure that there exist enough groundwater reserves. Also, most of those aquifers are replenished through rainwater, thus, if we start to take water out of these reservoirs during droughts without the correct management, it will eventually run out and won't be able to supply for as long as we would like it to.

In order to conduct the proper studies there are certain techniques that will make it possible to analyze how reliable the aquifers in Ambondro can be for this proposal to be carried further. First of all, it would be necessary to perform non-invasive geophysical explorations, such as:

- Electromagnetic Surveys: Pulsed electrical currents are sent into the earth, creating a magnetic field that travels through the different ground materials, and whenever the electricity changes the medium it is spreading on, it produces both eddy currents (circular electric currents) and a second magnetic field that travels back to the surface. It is important to focus on electrical conductivity and electrical resistivity: hard-rock or clean sand and gravel layers have high resistivity and low conductivity, while wet clay and saline water have, on the other hand, low resistivity and low conductivity. This method allows fast runs over large areas;
- Electrical Resistivity Tomographies (ERT): Once more specific areas can be taken into account, the ERT is implemented, which follows pretty much the same principles but, instead of general electromagnetic fields, it uses electrodes that are placed all along the determined surface, making it way more accurate to start getting to know highly conductive fluid pathways. (Plastow, Geoff, 2019)

Once certain areas are specifically chosen, some test wells can be drilled so as to take actual measurements and conduct direct observations as looking for how deep the aquifers sit, whether water flows freely or it is just tightly stuck between clay. Most importantly, it would be needed to calculate transmissivity and storativity, which refer to how easily water can move horizontally through the entire bore of the aquifer, and the amount of water it can take into storage according to the area of the aquifer, respectively.

Finally, hydrochemical analysis should be performed on water samples to determine the water's recharge source and flow rate, as well as whether the aquifer is actively replenished by rainfall or is it mostly still water. (Carrière, S. D. et al., 2018)

As can be inferred, for these various crucial studies there is a cost, much lower, but still needed to be taken into account: for the non-invasive tests we could estimate a cost of 15,000 USD; about 75,000 USD on the drilling of the test wells, whose cost is much lower since they are smaller and do not imply setting up a pumping system, and a final 5,000 to 10,000 USD on the extracting of water samples and the hydrochemical analyses. This will add up to an initial investment of 97,500 USD to make sure that the rest of the project is reliable and can be carried out properly, without having the 1.5 million USD that is being calculated wasted in vain. This estimations are shown in the next table:

Table 2. Estimations and costs to carry out the necessary studies, (Ramírez Solares Emiliano, 2026)

Geophysical surveys (about 10 candidate sites)	Exploratory boreholes	Little pumping and chemical analyses	Total initial investment
15,000 USD	75,000 USD	7,500 USD	97,500 USD

A project of around 1 to 2 million USD can be funded with the help of different organizations focused on rural water-development programs, especially if we are targeting an African region so prone to droughts as is South Madagascar. The strongest organizations we could rely on are:

- The World Bank Group, which has already funded several water projects regarding droughts and infrastructure in Madagascar;
- The African Development Bank, being heavily involved in water-security projects, supporting groundwater projects, solar infrastructure, drought adaptation, and climate resilience;
- UNICEF, which often finances drinking-water access and WASH (Water, Sanitation and Hygiene) programs, already supporting some of these programs in Madagascar; and
- The European Commission, which, as was referred to earlier, has already funded certain projects such as the installation of photovoltaic pumps in Southern Madagascar regions, and frequently finances renewable energies, climate adaptation, and water infrastructure projects in Africa.

It can be with the support of these organizations, through both money and specialists, that Ambondro and its population have the opportunity to improve their life dignity. They would be provided with as many basic needs as possible, completely changing the life of many Malagasies who will live in the best conditions they have ever had the opportunity to enjoy.

Besides the proposed actions, two complementary long-term strategies that will slowly improve Ambondro's field quality for harvesting can be implemented, significantly increasing agricultural productivity, which, added to the newly increased water supplies, will definitely take Ambondro's agriculture and life quality to the next level:

Silvopastoral Systems

Several communes in Madagascar have started to try agroforestry to convert the landscape into sustainable "foodland and woodland"; agroforestry is a system in which trees, crops, and sometimes livestock (silvopastoral systems) are integrated intentionally, creating a more productive, diverse, and resilient ecosystem. Trees drop leaves, their branches decompose, and the roots process and add organic matter to the soil, improving its water retention, which is really important. Also, whereas roots stabilize the eroded soil, the trunks reduce wind speed, helping to preserve the fragile soil that is accumulated and that is essential for farming. In such arid climates,

trees provide shade and lower temperatures that reduce water stress, as well as helping with nitrogen fixation which improves crops growth. Trees like acacia, moringa, and tamarind trees are really great options that can help with all that I just mentioned. Plus, they also provide fruits, fuelwood, and even medicine. Although we have to consider that this a very slow process, since trees take years to mature completely; it is still a great option that, in the long run, will benefit Ambondro's fields. (PubMed Central, 2021)

It is known that 48% of Ambondro's population is dedicated to livestock, nonetheless it is also important to point out that zebu (a bovine with prominent fatty hump on its shoulders, loose skin, and large ears) is a cornerstone in malagasy culture and economy. The well managed use of this kind of cattle in the fields can strongly help with natural fertilization, through their manure the soil acquires nitrogen, phosphorus, organic matter, and microorganisms. In addition, it should also be considered that cattle usually wander around the land; they trample leaves and plant residues, mixing organic materials into the soil surface as well. (Nishi, Maiko, et al., 2021)

Alternative Crops

It would be great to think of implementing certain crops such as millet (which is tolerant to harsh climates and easily grows in extremely dry soils, and is at the same time highly nutritious since it contains carbohydrates, fiber, B vitamins, iron, magnesium, phosphorus, and moderate protein levels); sorghum (being high-temperature resistant, surviving with low rainfall, and growing in sandy and nutrient-poor soils); and some drought-tolerant maize varieties, which have been strongly studied and developed by CIMMYT and DTMA in the last decades.

These options would improve the yielding of harvests despite the rough climates, and would as well provide the population with nutritious options and abundant food that will transform Ambondro, from having been a commune suffering from insufficient agricultural production and water supplies, into a renewed and relatively modern community with well established mechanisms to overcome food insecurity and water shortages, which were once a great deal that pulled back Ambondro from developing.

Pushing the Proposal for Long-Term Durability: Service providing and infrastructure maintenance

All of these different strategies are to be carried out by someone, it is important to have working hands that will help to change the way of living of every Malagasy in Ambondro. It is not enough to just help them, but to provide them with the tools and knowledge needed so that they can improve their lifestyles by themselves. If they are able to take care of the infrastructure they would receive from this project, and to fulfill the strategies needed to improve their agriculture, then it would be for sure that Ambondro will prosper, which is the main goal of this project.

In order to take care of the maintenance of water supply facilities implemented in various regions of Africa, on several attempts of carrying out water supplying projects, a Community Based Management (CBM) approach was proposed, which consists of local committees trained to sustain the infrastructure built in these projects. The problem is that these CBMs are expected to fund themselves and repair the systems on their own, and thus, as can be inferred, they have a documented and important failure ratio. Their unavailability to properly sustain infrastructures as they are intended to mostly relies on the fact that they can barely sustain themselves, and on the factor of time because the shipping of spare parts from the capital tends to take longer than it takes for the water system to fail. (Kativhu, T., 2018)

A clear example is a reform of the rural water supply sector that took place in the 1990s throughout several African countries. However, this proposal focuses on Malawi's case, which despite the facilities built during the reform, as of 2009 almost half of the systems and infrastructure had already been taken down because of failures and breakdowns, due to lacking the resources to take care of the repairing, the little commitment of the existing CBMs (which can also be attributed to several difficulties that the people in these committees have to go through), and the fact that most inhabitants have neither training or any sort of knowledge regarding the maintenance and sustainability of all the water supply infrastructure. (Chowns, Eleanor, 2015)

It would be important to start with the presence of different specialists that work in any of the mentioned organizations, who may be able to help with the technical development of the project. They could assist with the installation of infrastructure and teaching malagasies to give maintenance to pumps, filters, solar panels, fields, and cattle. Another way in which this support could be provided is by teaching the population to take care of the cleansing and basic maintenance of the infrastructure. Additionally, there are different universities in Malagasy regions which are more urbanized, such as Cornell University and the University in Antananarivo. These universities could start promoting information about this community and encourage their students to do social services dedicated to supporting Ambondro's population through helping with infrastructure implementation, helping out in the fields, and teaching the community about the effects of these strategies to improve their lifestyles. It would be important to have a group of Malagasies from Ambondro taking a more focused and detailed program, a sort of intensive training on how to replace parts of the nanofilters, recognize failure signals in order to prevent the mechanisms from stop working, and provide proper servicing to pumping systems and solar panels.

Finally, considering the CBM failures just mentioned, I suggest to destine a small part of the initial budget to the payment of a local technician, who visits the commune frequently to make sure that everything is working properly, and in case that there exist any damage or wearing, the technician can get spare parts in time to keep the infrastructure ongoing for a long time. Another option on how to pay the

technician's wage could be the implementation of a minuscule water-user fee that, because of the many thousands of inhabitants in Ambondro, will be just enough to cover the technician's funding.

Conclusion: Why does this matter?

Ambondro is a community that created a unique interest in me because of the little help it has ever received. It is a spot in Madagascar that has been ignored for decades and its population is in more and more need every year. They barely have access to any services and they have to work all day with no rest in order to make sure they will finish the day and have a "decent" meal.

If this community was to receive the help I have proposed, the life of every single of its inhabitants would change and improve drastically. Every Malagasy in Ambondro would have the opportunity to enjoy a fraction of the privileges that many of us consider basic and are not grateful for, though we should. The possibility of improving the Malagasies' lifestyle is an opportunity that has made me ponder deeply about how strong the people from many communities that suffer conditions similar to the ones in Ambondro are. I know they deserve better opportunities and great support from many of us, which can be carried out directly or indirectly by just getting to know about their existence and through the development of projects, such as this one, dedicated to try and improve the lives of many. Although I might not know the place personally, I am aware that they should have just as many opportunities and privileges as I do.

Through all the research that was carried out to design this project, I got to care for people that are so far away and that I have never seen. I understood that every single person in the world has a great responsibility to contribute in the making of a new world.

For us, young generations, it is important to open our eyes and be aware of the world we live in, understand its many complexities, and start to think about how we are going to make a change in it. We should guarantee that as many people as possible have access to a complete meal thrice a day, to drinking water, to having free time to enjoy with family, well-paid jobs, dignity, health, and lots of things which are indispensable for everyone.

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