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Madagascar, Climate Change

Madagascar: Microbial Desalination and Saline Agriculture

Madagascar faces many challenges today. Madagascar's challenges include the food and water crisis, deforestation, poverty, and government. Madagascar is the fourth largest island in the world. It also has one of the most diverse ecosystems. Being located on an island, Madagascar has a wide variety of food recently cut short due to the food and water crisis. Most families in Madagascar do not have clean or enough water to harvest their crops. Farmers have had to sell their land and livestock to have enough money for food, water, and a roof over their heads. People and climate change contribute to these challenges, but a possible solution exists.

Madagascar has a population of 28.92 million as of 2021; 39.21 percent of its land is urban, and 60.79 percent is rural. Only about five percent of their land is farmable. Their main crops include rice, coffee, and potatoes. One of their main exports is vanilla. Eighty percent of the world's supply of vanilla comes from Madagascar. The average farm size is about 1.3 hectares. Madagascar is the most environmentally diverse country in the world. Five different regions divide the island: the east coast, the central highlands, the Tsaratanana Massif, the west coast, and the southwest. The east coast is a narrow lowland. The east coast is a straight line that faces the Indian Ocean. This side of the island is straight due to erosion. Unlike the East Coast, the West Coast has a rigid coastline. This coastline consists of harbors, broad plains, and estuaries. The central highlands have multiple land masses, such as the Anjafy High Plateau and Antananarivo, Madagascar's Capital.

The Anjafy High Plateau, a volcanic crater, formed around Lake Itasy. High forests and hills make up this region. The Tsaratanana Massif, a mountain range in Madagascar, is located at the island's north end. This region is well known for the mountain Maromoktro. Maromokotro is the highest mountain in Madagascar. The last of the five regions is the southwest, the driest of the regions. The southwest is so dry that no crops can grow due to the arid, barren climate.

Madagascar's government is a semi-presidential democratic republic. The government consists of a President and a Prime minister, who work together. Although they work together, the President is the head of the state, and the Prime Minister is the head of the government. Their government is considered corrupt by the international community. The government overlooks their residents' conditions and is not helping with the food and water crisis and other problems Madagascar faces.

As of 2022, 8.8 million people face food insecurity, and 2.2 million people in the south face emergent food insecurity. One problem that contributes to the food crisis in Madagascar is the high fertility rate. Many families average five children per family in more rural areas and around three children in more urban areas. Most families consist of a father, mother, and children; they live with their aunts, uncles, nieces, and nephews, contributing to the malnutrition rates. Many children in Madagascar are malnourished and can't walk or do everyday tasks. Families living in rural areas have to move to more populated areas due to the drought in 2018-2022. This drought has caused significant climate change on the island. They must move to these urbanized areas to make enough money to buy food and feed their families.

Around 38.1 percent of the population's food is so scarce they can only eat one meal daily due to poverty and food insecurity. Most of their meals consist of rice and greens. Their food is either farmed or bought. Usually, families cook food over a wood or coal-burning stove. Typical job seekers find work in

the agricultural sector. Multiple activities support yearly incomes. Student prospects are offered an education, and while most make it through primary school, a majority drop out of school to help support their families. They help their families by working. Madagascar has been trying to improve its education system with increasing teacher preparation programs.

Although they have a healthcare system in place, it is only used for basic care and is free of cost. These healthcare facilities are more populated in Antananarivo, which is a lengthy trip for anyone not living near the capital. Madagascar does not have a good infrastructure set in place. A natural dirt path is a typical road found throughout the country. About fifteen percent of residents have access to electricity. Around half of the population has essential water and sanitation systems, but more than half don't have access to clean, safe drinking water. Additionally, they don't have access to clean water to irrigate crops, so their crops are not growing, and yields are low, causing financial strain.

Madagascar has recently had a drop in rainfall, causing a four-year drought. The drought has been growing for several years but has stayed at a constant rate in recent years. But most rivers have dried up, and people must dig for water, causing many issues in the southern region of Madagascar. It also leads to a problem of water scarcity. The prolonged drought tremendously affects the Malagasy people. Again, malnutrition has become a problem for most children. Because of malnourishment, their bodies can not grow properly, and tasks for children are a struggle. Groups have had to move to more urbanized areas to make enough money and support their families.

Another reason that has a significant impact on the food shortage is due to the recent and drastic climate change. As a result, there has been a water deficiency, so there is insufficient water to supplement the crops. These crops are how some families eat and make a profit. Since it is challenging to grow crops because of climate change, some have to eat plants that provide little to no nutrients. The effect then causes diseases, such as stomach issues. Diarrheal disease is one of the most common causes of death in Madagascar.

Another major problem that contributes to climate change is deforestation. After years of drought, the community cut down trees to clear out areas for farming. Since the island lacks electricity, burning down trees was a method for creating charcoal and using biomass, wood, for cooking fuel and other fuel needs, but is being consumed faster than the growth of the trees. Deforestation threatens Madagascar's ecosystem. Only ten percent of Madagascar's forests remain.
Around 80 percent of Madagascar is in poverty. This number is shocking because of the challenges discussed above on the people's primary sources of income, farming, and agriculture. Malagasy people have to sell their cattle and farmland for money. Not only does this affect the population, but it also affects the environment. The soil is becoming more and more infertile due to damage. Different types of animals have been recently distinct due to deforestation and climate change.

Madagascar's environment has changed significantly in recent years, affecting tourism revenue. Madagascar is a green island slowly turning into a red desert. The red sand blows into villages, roads, and Malagasy people's eyes. This also affects tourism. In 2019, Madagascar was at its peak in numbers concerning the amount of tourists. 2020, there was a drastic fall because of COVID-19, and it has decreased since then. The marine environment has also been affected by coral bleaching, seagrass and fisheries loss, and ocean acidification. The overall environment of Madagascar will keep decreasing because of the climate shocks.

With best efforts, few solutions have been identified to address these problems. But, a promising, energy-efficient, cost-effective, and ideal solution is a new and upcoming project involving microbial desalination. Water makes up 75 percent of the earth, but there is only 2.5 percent that is freshwater used for farming, making microbial desalination very important in converting seawater into clean drinking water

and irrigation. Also, the project provides many environmental benefits. It uses recycled plastics to run the cells used in the project. The project is called MIDES.

Microbial Desalination Cell (MDC) technology exists but has limitations. MDC has a low desalination rate, does not use energy efficiently, has high manufacturing costs, etc. Current MDC technology has become more common at an increasing rate, but these plants reach a capacity of 1,000,000 m^3/d and use 4 kwh/m^3 of electricity. To run the pumps for these plants, you need specific power stations. The founders created MIDES to overcome the limitations. MIDES started in a lab in Madrid, Spain. The first pilot plant was cultivated in Dénia, Spain. The second pilot plant is on Tenerife, a Spanish island. Other plants are being implemented in Tunisia and Chile.

One key detail in the MIDES project that differs from MDC technology is that one alternate MIDES project does not use electricity. Current MDC technology takes wastewater, treats it, and turns it into treated wastewater. On the other hand, MIDES is a multi-step process that can transfer seawater and convert it into safe, clean, low-energy water for drinking, farming, and running water for households. There are three major steps of the MIDES microbial desalination process. The first step is to put seawater with a salinity of 35 $g\ L^{-1}$ and put it through ceramic membrane pretreatment. The ceramic membrane pretreatment uses ceramic materials. The pores made from the ceramic materials separate particles and filter out any impurities. This process uses less than 0.1 $kWh\ m^{-3}$. This filtered seawater is put through the microbial desalination cells (MDCs). The MIDES built two of their own MDCs. Each cell has a stack of 15MDC units covering $0.4m^2$ per unit. These cells can process thousands of liters of brackish or seawater. The MDC is the process of a microbial fuel cell that works on an electrical current run by an electro-active bacteria called Geobacter. Geobacter alters the energy that is contained in organic matter found in filtered seawater or wastewater into electrical energy. It powers the desalination of the salt in the water between two membranes. Wastewater is put into a bioreactor containing microbes and produces an acetate to fuel the Geobacter. The microbial desalination cell also uses fewer chemicals than most desalination processes. Microbial desalination removes most of the salt in the seawater but not all of the dirt and bacteria. After these processes, reverse osmosis will completely clean the water to be used as clean drinking water. Reverse osmosis uses less energy, making the water low energy. The water that is produced can be used as clean drinking water for humans and livestock and for electricity production.

The pilot plant in Dénia, Spain, started using brackish water and wastewater pretreatments, then ran through microbial desalination cells (MDCs), put through a reverse osmosis process, and a post-treatment to guarantee clean drinking water. The Spanish island's second pilot plant in Tenerife, used the MDCs to desalinate saltwater, ran it through reverse osmosis, and used a post-treatment to convert it to viable drinking water. At this plant, the clean water produced was made without electricity. This project will enable low-cost, clean drinking water.

The MIDES technology can be facilitated in remote areas, which would be very helpful in south Madagascar; another benefit for the South is that this technology doesn't use much electricity suitable for the limited power supply. This will also provide treated wastewater that can be used in farming and agriculture. This will relieve pressure on the current resources used for farming and agriculture. Once the population's needs are met, the brackish water made through this process could be used for irrigation. This type of irrigation is called saline agriculture.

Madagascar's west coast is rigid and made up of many estuaries made up of brackish water. Establishing a plant next to brackish water or along the southern coast of Madagascar, the driest region of the island, would provide irrigation to a crop that could be harvested for an additional food supply and an exchangeable commodity on the open market.

Saline agriculture will help improve food security. Viable land and freshwater are becoming more and more scarce. Saline agriculture can help restore Madagascar's ecosystems. With suitable crops, fertilization, and irrigation, farming is possible on salt-affected soil using brackish water. Only salt-tolerant crops are able to grow in these soils and are irrigated with brackish water. However, some crops are more tolerant to saline agriculture: barley, cotton, wheat, and rice. These are good examples of crops that can handle high salt levels and produce a feasible yield. A few management practices can help improve the growth of the crops in salt-affected soils. Loosening the soil and improving the drainage by deep tillage, the rotation of different crops to reduce salt buildup, and using saline-tolerant fertilizers can help produce acceptable yields for these crops. But one disadvantage of saline agriculture is that to know how to manage your crops, you need a qualified agronomist to develop a plan to manage the crops specific to your land, climate, and crops being grown. However, this could aid in the growth of new jobs and job opportunities.

A plan has to incorporate multiple factors, including the amount of salt in the water, the pH of the soil, and the climate. Considering the type of crop being grown and the crop market, this would help boost Madagascar's economy. Overall, the best choice for selecting the right crop depends on the unique conditions of the area where the harvest is being grown.

I recommend the international community help lead this project. Assuming Madagascar's government will not help with this crisis, the United Nations must help as it is a humanitarian issue. The World Food Programme has also stated that Madagascar is at risk of "the world's first climate change famine." They have also helped Madagascar with a short-term solution of feeding them and are currently working on a long-term one.

I would also recommend implementing a testing facility, pilot plant, and demonstration facility to integrate a nearby estuary to use irrigation techniques for saline agriculture. International policies would hold the Madagascar government accountable if the funds are mismanaged. The World Justice Project ranks Madagascar 112 out of 139 counties on the rule of law, so the international community must be involved. Since the rule of law in Madagascar is weak in holding officials accountable, international sanctions and oversight by the World Bank would be necessary for the project's health. The idea I am suggesting would require a migration back towards the southern coast of Madagascar. This would be challenging because a lot of families sold their land for money and moved north to the urban areas, but seasonal migration is also a common occurrence in the region. The MIDES project meets National regulations for the water that is produced. The MIDES project and saline agriculture should be expected to meet the population's needs if properly implemented and managed.

Finally, implementing MIDES and saline agriculture together would benefit the island of Madagascar. MIDES is a versatile project. The MDES concept and technology pave the way to a more permanent solution to most of the country's climate-caused problems. This technology can be used as both a short and long-term solution.

The primary mission of my recommendation is to help the people of Madagascar using low energy, low costs, and with the most impact. MIDES uses less chemicals than other desalination processes. Overall, MIDES will positively impact the residents in Madagascar. Continuous funding, leadership cooperation, local population buy-in, and patience are essential in this endeavor. All projects of this nature take considerable capital to research and implement. Leadership must be dedicated to the long-term sustainability of the project. Successful implementation could lead to new industries providing jobs for the local community and further economic development. Finally, nothing of this magnitude happens overnight. An unwavering team would be necessary for the continued oversight of this project.

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