Planting Mangroves
In Non-Native Environments

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The world population of human beings reached six billion in 1999. By mid century ten to eleven billion humans will inhabit this earth. To predict the consequences, we need only look at present day problems and estimate how they will be worsened by the increased population. The poor countries of the world, about 80% of the world's population, will be even poorer. The desperate poverty will result in ever increasing chaos, disorder, crime and violence. Military dictators will emerge, and they will be corrupt. Their coterie of thugs will administer the corruption, share in the profits, and effectively suppress any disssension. The population problem will grow worse. Poor people do not have knowledge of contraception, are too poor to purchase the paraphernalia, and want more children to keep them from starving in their old age. The hope of ever emerging from this desperate situation will be small.

Six billion people are pretty effective in despoiling the earth's environment. How much more effective will ten or twenty billion people be? At the present time we add three and a half billion tons of CO2 to the atmosphere each year. Scientific opinion is divided as to what the consequences will be, but if global warming occurs, and the polar ice caps melt, countries like Holland and Japan will disappear, and all the great coastal cities of the world will be under the sea. Despite our uncertainty as to whether or not this catastrophe will result, we must pay close attention to this problem. We are growing mangrove trees where they do not naturally occur, and developing seawater agriculture and mariculture as one possible contribution to averting the problems we have mentioned. We are hopeful that with the passage of time more and more people will turn their attention to these urgent, practical problems.

Mangroves occur in nature in the intertidal zones of tropical countries. They provide nursery grounds for fishes, and shrimps. Their falling leaves, through a complex food chain, provide food for a multitude of marine animals. The leaves of Avicennia, the most common mangrove in Eritrea, are more nutritious than alfalfa, (their dry weight is fifteen percent protein). It is excellent fodder for camels, goats, and cattle. We can estimate their economic value from the observation that a hectare of Avicennia drops up to ten tons of litter per hectare per year. It is reasonable that a hectare of Avicennia produces about twenty tons, dry weight, of leaves per hectare per year, or three tons of protein. If converted directly into beef with 100% efficiency, we could produce ten tons of beef per hectare per year. Cattle are notoriously inefficient in food conversion so a hectare of trees would produce one ton of beef per year. This has a value of about 3000 USD, or equivalent to four times the annual salary of a fully employed Eritrean worker at this time. One worker could manage up to five hectares with a helper to manage the cattle. There are many ways to convert mangroves to valuable products, but this example

is sufficient to demonstrate the economic feasibility of growing mangroves. The cost of establishing, and maintaining a hectare of mangrove trees is presented in Table 1. The cost is a small fraction of the value produced. Depending on the density of planting, fodder cannot be harvested for two or three years after planting. This delay is a relatively small factor in assessing the cost/benefit value of planting mangroves.

Table 1.

Cost of planting one hectare of trees in the intertidal zone

Cost of establishing 1000 trees in the nursery 20 USD
Cost of planting seedlings in final site 20 USD
Cost of fertilizer 50 USD
Cost of Fences for one hectare 50 USD
Cost of guard per hectare per year 50USD

The cost of labor in Eritrea at the present time is 2.00 USD per man per day. We estimate it will require at most ten man days to gather 1000 seeds and plant them in plastic bags in the nursery. It will require no more than ten man days to plant 1000 trees in each hectare. At the initial planting each tree will be provided 500 grams of Diammonium phosphate, or 0.5 tons per hectare. This fertilizer should last two years when the trees are small. After the second year we will provide about one and a half tons of diammonium phosphate per year. Because of the layout of the plots, each hectare of plot will require about 100 meters of barbed wire fence. The duty of the guards who can care for about twenty hectares will be to prevent camels from breaking in and destroying trees, and at certain seasons to remove encircling wrasse from young trees.

Only fifteen percent of the coast of Eritrea contains mangroves. The mangroves typically grow in mersas where the seasonal rains are channeled to enter the sea. We reasoned that the rains must be bringing needed mineral nutrients from land. When we compared the composition of sea water to that of a complete algae medium, we found three elements in short supply in sea water-----nitrogen, phosphorus, and iron. To test our explanation for the occurrence of mangroves in mersas, we planted trees in intertidal areas where trees had never grown before, and provided them with a slow release fertilizer. We place five hundred grams of diammonium phosphate, DAP, and a few grams of iron oxide in a plastic bag. seal it shut, and punch two holes on one side of the bag with a small nail. The bag is buried next to the tree with the holes facing the tree. The fertilizer diffuses out through the nail holes over a period of years. ***Figure 1***, shows an Avicennia after two years of growth in an intertidal area where trees had never before grown, but can grow if provided with DAP and iron. The tree is approximately two meters tall. Many negative control experiments were inadverdently performed. Before we knew the importance of DAP and iron, hundreds of trees were planted and failed to become established. With the provision of DAP and iron the trees are routinely established.

Near the city of Massawa, the Italians built a jetty. Before the jetty was built mangrove trees grew on both sides of the jetty. After the jetty was built trees on one side of the jetty died out. We reasoned that the jetty prevented the flow of water carrying the nutrients in the seasonal floods from reaching the area. To test this hypothesis, we planted trees in the area where they had died out and provided them with DAP and iron. ***Figure 2*** shows trees growing in this area. After one year they are approximately one meter tall.

Where trees do grow in the intertidal zone in Eritrea, they typically form a narrow fringe no more than 100 meters wide. Often beyond this fringe mud flats extend as much a kilometer out to the low tide line. The reason for the restriction of trees to the first hundred meters from the high tide line is that as nutrients are brought by the seasonal rains they are too dilute after the first hundred meters to nourish the trees. To test this

idea, we have planted trees several hundred meters from the high tide line in areas where trees had never grown before, and they grow well if fertilized by our methods.
We conclude that the entire 1200 kilometer coast could be planted with mangrove trees with an average width of about 500 meters in the intertidal zone. This could increase the economic productivity of the country by about 50%.
We have also planted trees in the desert away from the sea. Here we dig a hole one meter deep and fill it with sand to provide drainage. The trees are planted in the sand, fertilized as described, and irrigated by a pump with sea water every few days. Drainage is important for preventing the accumulation of salt and providing air for the roots. Between the trees we have planted a grass, Distichlis spicata, which can grow with sea water irrigation, and is good fodder for ruminants. ***Figure 3*** shows mangroves growing in such a site along with the grass.
We conclude that large areas of the Eritrean desert could be converted into lawn covered forests, with trees and grasses that would provide food for cattle, goats and camels. If the area to be irrigated were only 10 kilometers wide, the economic production of Eritrea could be increased ten fold.
Planting mangroves in areas where they do no naturally occur can do much to alleviate the poverty of much of the developing world. It can also relieve much of the tensions that develop over competition for fresh water. In addition if large deserts such as the Sahara, the Arabian peninsula, and the Atacama were planted with mangroves and irrigated with sea water, these forests could fix all the CO2 produced by burning fossil fuels. The cost of such a program could seem daunting but is miniscule compared to the economic devastation caused by the melting of the polar ice caps.
At the present time (August, 2000), we have forty thousand mangroves established in our nursery (***Figure 4***), and these will all be planted by the end of the year in four hectares of the intertidal zone at one thousand trees per hectare. We calculate that this will provide a full canopy by the time the trees are mature. In the year 2001, we will plant one million trees to occupy one thousand hectares of intertidal zone near the village of Hargigo about ten kilometers from Massawa.
This work can be carried out in Eritrea because of the special conditions found in the country. The leaders of the country are men and women dedicated to the well being of the people. There is no corruption. The international business community knows that Eritrea is a country where business is conducted without payment of bribes to government officials. The government is enthusiastically supporting work to develop the work of the Manzanar project and the program of the Seaphire corporation to develop shrimp farming and Salicornia farming in Eritrea. Salicornia is a succulent shrub that can grow with sea water irrigation, produces seed oil of high quality, and its stems when dried can be used as cooking fuel. These unconventional approaches are encouraged by the government because the country is poor in known natural resources, and conventional agriculture is insufficient to feed the nation. In contrast to Eritrea, two neighboring countries, Ethiopia and Sudan, do not even develop their known resources for the benefit of their people. Eighty percent of the arable land of Ethiopia is not farmed, and the country suffers from famine. The Sudan has forty six million acres of potential farm land and the waters of the Blue and White Nile. If farmed, the Sudan could feed all of Africa. The Sudan suffers from famine. In Eritrea there are nine ethnic groups, and two main religions, Christianity and Islam. All live together in harmony, and share in the power of

governance. Eritrea has all the conditions favorable for development-----dedicated, and competent leadership, no corruption, and remarkable national unity in an ethnic and religiously diverse society.

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Figure 1: Tree planted as a small seedling in the intertidal zone where trees had never grown before with fertilization. After two years the tree is about two meters high. Many trees had been planted here without fertilization and uniformly failed to become established.

Figure 2: Trees growing with fertilization in an area where trees had died out after a jetty was built. The large tree in the center is one of the few trees that had survived after the jetty was built.

Figure 3: View of the nursery with seedlings growing in sand filled plastic bags. The nursery contains about forty thousand trees which will all be planted by the end of 2000.

Figure 4: Trees and grass growing with sea water irrigation in the desert away from the sea.

Planting Mangroves Where They Do Not Occur in Nature