Feasibility Report

Small-Scale Spirulina Farms in Djibouti

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Executive Summary

Bilisso Abdi, a Mandela fellow from Djibouti, is working to address the issues of food insecurity and nutrient deficiencies in urban and rural communities within her country. Partnered with Sounah Al Haya and supported by the Djiboutian Ministry of Agriculture, Bilisso has identified small-scale spirulina farms as a potential solution for preventing nutrient deficiencies. As Engineering and Agricultural Development students at the University of California, Davis, we collaborated with our client to construct a feasibility study comparing the proposed solution to other malnutrition approaches and then identifying the technical, economic and social inputs necessary for such a project. Through the analysis of prior art and communication with Ms. Abdi, our team worked for ten weeks to development a study that may assist our client in the potential implementation of small-scale spirulina farms. Through the construction of needs assessments, SWOT analysis, and alternative analysis for the purpose of exploring different nutritional methods of addressing malnutrition, our team has identified that there must be specific social, technical and economic components put into place before implementing small-scale spirulina farms in rural or urban communities within Djibouti. This feasibility study contains our team's analysis of prior art, methodology used to identify essential inputs for development, results of our research and complementary information provided by our client, and recommendations regarding the future development of this project.

Introduction & Background

This project focuses on determining the feasibility of developing small-scale spirulina farms in Djibouti, Africa to address malnutrition and food insecurity. The client is Bilisso Abdi, an agri-food biotechnology engineer who works on laboratory projects within the Djiboutian Ministry of Agriculture. She also works with Sounah Al Haya, which is a non-governmental organization working against hunger and malnutrition in the city of Djibouti. Currently, they distribute various food and goods donations on a weekly basis. Our client is interested in determining whether it is possible to use small-scale spirulina farms as a way to decrease malnutrition and for households income generation.

Malnutrition and Food Scarcity in Djibouti

One reason for Djibouti's malnutrition is its arid climate that has extreme temperatures and low, unreliable rainfall. Recurrent droughts and scarce water resources, combined with poor soils make irrigation-based agriculture very difficult. Djibouti's high population of nomadic pastoralists have struggled under the recurrent droughts and have lost up to 70% of their livestock herds due to insufficient grazing regeneration [8]. Djibouti's terrain is mostly high plateau and desert with some mountains, with less than 1% of land considered arable. Very little food is grown in country and there has been a downward trend in availability of food supplies since 1974 [7].

Why small-scale spirulina farms?

We performed an alternatives analysis of different malnutrition interventions that included approaches from public health, aid, and agriculture perspectives. We then eliminated approaches based on whether or not they were conducive with the climate and growing conditions and the project's context. A description of alternatives that were considered but eliminated before the decision matrix can be found in Table 2 in the Appendix. After that initial elimination, we created a decision matrix ranking the four possible approaches based on criteria. A simplified version of the matrix can be found below as Table 1. A more detailed version of the decision matrix can be found in the Appendix as Table 3. We compared spirulina to other protein sources and crops common to the area and found that spirulina ranked superior in nutritional content shown in figure 1 in the Appendix.

	Criteria							
	Ease for Community	Culturally Acceptable	Improve Food Security	Promote Fair Access to Nutrition	Potential to be self sustaining	Proximity to Sounah Al Haya's current work	Evidence of Success	
Criteria Weight	**3**	**3**	**5**	**5**	**5**	**4**	**3**	**Final Score**
Micronutrient Fortification	5	5	0	4	2	0	3	69
Biofortified-Crops	1	2	2	2	3	3	2	62
Small Scale Spirulina Aquaculture	1	1	5	5	3	3	1	**86**
Increase Fishing	1	3	3	3	5	0	1	70

Table 1. Simplified decision matrix for malnutrition approaches.

Small-scale spirulina farms have the capacity to decrease household's dependency on expensive imported food and provide them with reliable source of protein, vitamins, and minerals. It could help make them more resilient to shocks since they would have a reliable food source well adapted to the hot climate. Small scale spirulina aquaculture ranked the highest on the decision matrix and was further investigated in the following sections. The next highest ranking option was fishing, which is a potential approach if the client decides to not pursue spirulina aquaculture.

Prior Art: Case studies

The production and consumption of spirulina has yet to be explored in Djibouti. However, there are multiple institutions introducing spirulina production into Kenyan and Indian markets that guided our project scope and potential.

1.1 IIMSAM

The Intergovernmental Institution for the use of Spirulina Micro-Algae Against Malnutrition (IIMSAM) is a well-established organization based in Kisumu, Kenya conducting a diverse range of activities. IIMSAM organizes courses on spirulina business ventures, produces and sells spirulina cultures and its consumable forms, and distributes it to over 200 malnourished children and HIV/AIDS patients in the region. It's production division produces approximately three kilograms of spirulina per day (IIMSAM, 2008). However, the operation has not been operating at its full potential due to water limitations. 10 ponds are available for production, but due to increased evaporation during the summer months only one pond is fully functioning. Each 3 x 15 meter basin requires 12,000 litres of water with continuous top-up [5]. Water limitations could pose serious feasibility constraints in Djibouti as water is very limited and thus expensive in the region. Therefore, water efficiency was an important factor to consider for our project. Overall, IIMSAM has the potential to offer support to the project in the design and implementation of Djiboutian small-scale spirulina farms.

1.2 Dunga Spirulina

Also located in Kenya, Dunga Spirulina is a privately owned Spirulina farm in Dunga, Kenya. With 4,500 square meter ponds, it has a production potential of 20kg of dry spirulina per day [5]. However, due to resource and financial constraints, the farm is currently producing about 5kg per day [5]. Although Dunga Spirulina caters their market to higher income households than our project, its production methods can serve as another reference of successful regional spirulina production and cultivation. Additionally, through connecting with the owners, there is potential for useful feedback on overcoming production constraints.

1.3 Galaxy

Galaxy, a youth-based organization located in Western Kenya, is composed of various spirulina production units yielding over 2 kilograms of powdered spirulina daily [5]. Unique from its Kenyan counterparts is the use of greenhouses for spirulina production, which increases algae reproduction, decreases water evaporation, and decreases contamination and cross-breeding.isdec. The organization mainly uses spirulina to combat malnutrition [5]. Greenhouses could be potentially used to improve water efficiency for spirulina production.

1.4 Potential Costs and Revenues

The SmartFish Programme, an eastern-southern Africa development initiative funded by the European Union, has estimated the costs of a small-scale spirulina start up. 10 grams of spirulina can be produced in 1 square meter of water on average. To establish the recommended pilot farm size of 6 meters by 80 meters (approximately 500 square meters), they estimated that it would cost 60,000 euros variable depending on local land costs, labor and materials [5]. With maximum production of 5kg per day and the wholesale Kenyan price of 50 euros per kilogram, total revenue is 4,500 per month. Calculations estimate that payback would take about 20 months, therefore total revenue would be 60,000 to cover the initial investment cost [5]. Such calculations are useful when proposing the implementation of small-scale spirulina farms in Djibouti.

1.5 Regional Exports in Kenya

There is high potential for exporting Kenyon spirulina regionally; purchasing cultures from these organizations would be particularly useful for our project. However, with all of the above organizations, production fails to meet market demand due to financial and resource constraints [6]. Kenan producers have failed to find reliable distributors in their own country, so finding ones to distribute regionally would pose even more difficulties. Additionally, since spirulina is a food supplement, food safety regulations must be considered. Djibouti has its own unique rules and regulations on food imports that may

not comply with Kenya's standards. Meeting such standards could impose higher production costs that would raise the price of importing spirulina [6]. Given that Kenya has greater access to resources than Djibouti, exporting constraints could be even more severe in Djibouti.

1.6 Integration of Spirulina into Rural Indian Household's Diets

A whole-village study in rural south India was conducted in 1984 assessing the nutritional costs and benefits and social acceptance of algal food supplements like spirulina [1]. The results indicated that algal food supplements were highly cost-effective method of fulfilling nutrient deficiencies to rural communities. However, the adoption of consuming spirulina was rather slow due to its taste but improved with better algal recipes [1]. Although this study focused on the consumption of spirulina, it provided a useful framework on how to better integrate spirulina into communities.

1.7 Murugappa Chettiar Research Centre

Small-scale development projects in other developing countries are using organic nutrient sources like waste effluents to tackle the market constraint of cost and availability of inorganic nutrients. For example, in India, the Murugappa Chettiar Research Centre has developed the use of digesters that produce biogas slurry and then treat the water, leaving the organic nutrients for spirulina production [2]. Spirulina is grown in mud pots using the waste effluent medium and stirred by hand by local producers. Bangladesh, spirulina is being cultured in a variety of different agro-industrial wastes such as urban waste, organic matter, and fertilizer factory waste [2]. Both countries have produced successful results in both yield and profitability thus far, serving as "a low-cost alternative and highly productive input" [2]. Therefore, if there are constraints around attaining inorganic nutrients, the use of waste effluents serves as a potential nutrient alternative to inorganic fertilizer in Djiboutian spirulina production to reduce dependence on outside markets.

Methodology

Needs Assessment

Our client interviewed ten people in the targeted communities during Sounah Al Haya's weekly food distributions. During these interviews Ms. Abdi asked about their eating habits and sources of income. This provided information that directed us to focus the project on rural areas rather than urban areas since the urban poor have greater resource

access. Resources include family help, begging, organizational support, and unskilled work opportunities.

Alternatives Analysis

After an initial brainstorm and research on different methods of addressing malnutrition in developing communities, we narrowed down the list to options that had the possibility of feasibility within our criteria framework. Some approaches that were considered but eliminated are shown in Table 2 in the Appendix along with their reasons for being eliminated. Once the list of approaches were narrowed down, we used a decision matrix to help us evaluate which approaches were superior; the detailed results can be found in Table 3 of the Appendix.

SWOT Strategic Project Planning Tool

We used a SWOT analysis to understand the strengths, weaknesses, opportunities, and threats involved in the project to help us strategically plan our approach. Strengths were aspects of our team and the resources we had that were advantageous to have. Weaknesses were internal aspects that could hinder our effectiveness as a team to work on the project. Opportunities were external aspects such as the market and public opinion that promoted our project . Threats were external aspects beyond our control that could harm the project. An assessment of the SWOT analysis can be found in the results section below while the SWOT table can be found in the Appendix as Table 4. We gathered information through conversations with our client and supplemented through online research.

Results and Discussion

Results: Needs Assessment

Over the course of the quarter, the client interviewed 10 households regarding how people generate income and their eating habits.

When the client inquired about standard sources of income for households, she received the following answers:

- Financial help from other family members
- Begging in the street

- Financial help from government agencies and/or organizations
- Financial support from work opportunities which require no qualifications

The client also gathered information on people's eating habits from these interviews, but further details were not enclosed.

Results: SWOT Strategic Project Planning Tool

The SWOT analysis our team conducted can be found in the appendix as Table 4 and is further detailed below.

<u>Strengths</u>

- International Agricultural Development and Engineering Students
    - Our team consists of two international agricultural development majors and two engineering majors (civil and biosystems engineering). Our team offers a diverse set of skills, with members who are well-versed in community needs assessments and community mapping, as well as other team members who are well-versed in the technical aspects of building such a small-scale spirulina farm, as well as its necessary inputs.
- Participatory Planning/ Project Experience
    - The members of our team have planned and conducted programs within various countries with similar economic and community-level limitations. Additionally, our team is comprised of members who study global development and specialize in addressing agricultural and environmental issues that arise as development practices are put into place. Our team's project experience complements our client's vision and allows for a wholesome approach to identifying appropriate participatory planning methods for such a project.
- Connection with urban/ rural communities
    - The client has connections to both urban and rural communities through the Building Life Organization that she works for. On weekends, the client, along with a team, goes to impoverished, malnourished communities to hand out meals. This pre-existing connection to community members is serves as a useful entry-point for the implementation our project tackling food insecurity in such areas.

Weaknesses

- Out of country, limited communication
    - The client lives and works in Djibouti, on the east coast of the African continent. There is a 10-hour time difference between Davis, CA and Djibouti City, Djibouti, making communication complicated and limited as a result of this distance. Our team had only a handful of meetings with the client due to many scheduling difficulties, making it challenging to progress quickly with the project's needs.
- Lack of funding
    - The proposed project is not currently financially backed by any institutions.
        - For reference, projects only slightly larger in scope (IIMSAM) cost 60,000 Euro to produce 3 kg a day on average, which would roughly supply spirulina to 300 people per day.
        - However, the client has expressed interest in applying for various grants that could assist in funding the project. The client has connections to various organizations that could assist in the acquisition of funds.
    - It is evident that startup capital is necessary for the success of the project because of the various inputs that are required. Most notably, these include concrete, chemical inputs, and the spirulina culture.
- Lack of construction/ implementation experience
    - Our team has only a small amount of construction/ building experience. One team member (Lauren) has poured concrete and built basic structures out of wood and has experience with water and soil testing, but other than that, our team has limited experience with traditional building materials and methods.
- Low ability to make effective programs
    - Our team currently has limited knowledge about community-level norms and the presence of local liaisons who are invested in the project and plan to support the implementation of such a project. With limited knowledge concerning how the client and the association will directly engage with various sub-groups within the communities, it is difficult to construct any type of informative program material that will be essential to introduce a concept as small-scale spirulina farms. Some type of curriculum or

educational programming will be in high demand for such a project, as most people are unaware of the nutrient and its value. However, with little information of the exact communities being served and how the project management team will directly engage with target communities, creating and conducting appropriate programs poses as a team weakness.

Opportunities

- Connection to Djiboutian Dept of Agriculture
    - Our client has connections to the Djiboutian Ministry of Agriculture and has been working in the clonal propagation and mass production of Date Palm vitro plants for four years. These connections to agricultural projects could assist with the spirulina project, another agricultural-based project.
- Possible funding source from World Bank "Zero Stunting" Project
    - The World Bank is currently funding a USD $15 million dollar project called "Towards Zero Stunting in Djibouti". The objective of the project is to reduce stunting among children under five. There are many components to the project, all of which center around health of children.
    - A small-scale spirulina farm could be in-line with the goals of the Zero Stunting Project, and Ms. Abdi could attempt to receive some funding from them to start a smaller operation to ultimately better the health of the general community.
- Climate is conducive to spirulina growth
    - The hot, arid climate makes traditional agricultural methods nearly impossible. However, spirulina thrives in arid, dry environments like Djibouti. As long as there is a consistent supply of water and covering to reduce evaporation, Djibouti would be a great place to grow spirulina.
- Spirulina fills health requirement
    - Spirulina is nutrient-dense, containing high amounts of iron and vitamin A, which are two of the most defining nutrient densities in malnutrition.

Threats

- Lack of local inputs
    - According to our client and online sources, Djibouti imports the majority of its chemical inputs from France [8]. As a result, acquiring all necessary chemicals in their proper proportions has the potential to impose very high project costs. The list of required chemicals is extensive. To successfully

grow spirulina, the following chemical inputs should be considered: sodium bicarbonate, magnesium sulfate, potassium nitrate, citric acid, common salt, urea, calcium chloride, iron sulfate, and ammonium sulfate.
    - It is not feasible to depend on importing various chemicals with no secure and sustained funding planned for the foreseeable future.
    - Additionally, there is no local vendor for spirulina in the area - it would need to be imported. The client suggested sourcing the spirulina from a nearby lake, but upon further investigation, there is a high risk for contamination if spirulina was sourced in this way and poor infrastructure makes the lake hard to access.
- Lack of local contractors
    - As the client stated, there are little to no people in these semi-rural communities that know how to use and manage concrete. Therefore, the community would depend on outside help for building and maintaining the concrete structures to house the spirulina in.
- Extreme climate, water scarcity
    - Djibouti's arid climate makes it difficult to engage in traditional modes of agriculture. Water scarcity and poor soil has created a chronic food deficit in Djibouti, and the country imports 90% of its food needs.
    - Djibouti has unreliable rainfall, which results in recurrent droughts and scarce water resources. The soils are very poor, which makes traditional agriculture nearly impossible.
    - Water is very scarce, and it would be a challenge to source and pay for the used for filling and topping off the spirulina basins.
- Lack of community knowledge on malnutrition
    - When the client conducted interviews of 10 households, no households were aware that malnutrition was a problem. The lack of awareness poses a threat to the project because if people are not aware of the fundamental issue, they are much less likely to adopt a solution to a problem they do not realize they have in the first place.
- Lack of community interest
    - Upon interviewing 10 households within the targeted community, none had heard of spirulina. The client, after meeting with different members of her association to discuss the project, thought that a small-scale spirulina farm

pilot project would be better received by rural communities by first educating the community; stakeholders may become more invested once they understood its' value. Now, our client would like to try to first start an awareness campaign to get people educated on its benefits which would hopefully spark community interest.

- Not initially income-generating
    - Small-scale spirulina farms have a time-intensive labor requirement in the production, maintenance and processing of spirulina. If people spend most of their time doing activities that generate necessary income (i.e. begging in the street, working), maintaining the farm could pose a threat to essential time devoted to income-generating activities.

Challenges

The primary challenge this project faces is the lack of market access to necessary initial capital investments like infrastructure, skilled labor, and other essential production inputs.

As can be seen in the SWOT Strategic Project Planning Tool (see Table 4 in the Appendix) , there is a lack of access to basic building materials for the project. The client stated that concrete can be sourced for $0.135 per kilogram, but the targeted community members lack experience working with cement so outside assistance would be necessary to install the spirulina farms. Hiring contracted, skilled employees to build concrete would require additional funding that would have to be factored into the overall startup cost of this project. Additionally, there is no local source for the chemical inputs or spirulina culture. The chemical inputs must be imported from France. The shipping schedule and costs were unavailable to our team, this cost must be acknowledged. Although there are regional spirulina producers that sell spirulina cultures, financial and resource constraints make these nearby markets inaccessible. Therefore, spirulina cultures would also need to be imported overseas, further increasing start-up costs.

According to household interviews, the community lacks knowledge about the impacts of malnutrition and spirulina in general. Without background on spirulina and its role in filling nutrient deficiencies, it will be difficult to incorporate spirulina into their diets, let alone implementing small-scale spirulina farms. Our targeted community consists of low-income households that must devote much of their time to informal

income-generating opportunities. There would be great difficulty in convincing community members to spend hours each day in maintaining spirulina production without a clear market for consumption and opportunity for income generation. As an already vulnerable population, their survival needs must be considered to understand their decision making around their interest in the project.

Recommendations for Next Steps

Based on our research, we believe that this project is not feasible under the current market, resource, and community constraints. However, if these constraints are properly addressed, there is potential for spirulina farms to be implemented in the long-run. Before implementing spirulina farms, the project should include an extensive community awareness campaign around malnutrition and spirulina.

Through identifying current feasibility setbacks of implementing small-scale spirulina farms through various methods, our team has identified a number of recommendations that we believe will be beneficial to future projects of this nature.

Stakeholder Engagement
As was communicated by the client, a small-scale spirulina pilot project focused on nutrient awareness and education would be better received by rural communities as they would be more likely to invest after understanding its nutritive value and understanding the income-generating aspect of the nutrient. However, with the initial steps of this project implementation providing little to no income for stakeholders, there must be a strong foundation for community engagement in order to prove that learning about this nutrient and its effects are worth the time of community members. Proving that the opportunity costs of spending time and energy learning about a new product are significant is essential in promoting community interest and consequential investment. In order to do this, we recommend the construction of a community assets map, a type of needs assessment used by John Kretzmann and John P. McKnight in a 1996 paper that illustrates how to effectively engage various sub-communities to guarantee autonomy and equal learning opportunities among stakeholder groups (Kretzmann & McKnight 1996). Using a model illustrated in the paper, our team has composed a sample community assets map (Figure 2) that may be used by our client and her association to identify relevant community institutions and groups to begin to determine how best to go about

introducing Spirulina within rural Djibouti. In order for this approach to gain traction, there must be credible local liaisons that are invested in the project goals as well as the prosperity and success of the individual stakeholders.

Startup Capital Acquisition

Another recommendation for our client would be to acquire some form of start-up capital to spearhead the project. There are many required upfront costs that cannot be avoided. This includes: the spirulina culture, chemical inputs to ensure integrity of the aqueous solution, concrete, contractors to build the structure, and other necessary construction tools. As mentioned in the SWOT analysis breakdown, the World Bank is funding a "Zero Stunting" project with 15 million dollars, and perhaps the client could apply for funding through the World Bank. Ultimately, the client's project goals align with the goals of the World Bank's "Zero Stunting" project, and this could be an effective way to acquire startup capital.

Spirulina Cultivation "Starter-kit"

If the client acquires funding and wants to carry the project forward, we recommend creating a "starter-kit" with all the necessary input chemicals and spirulina culture in their proper proportions. We believe this will allow for knowledge to pass more easily through communities if kits are already assembled with all necessary inputs. While there are many chemicals required to ensure a balanced and optimal growth medium for the spirulina, perhaps a pre-made mixture of the chemicals would be more beneficial to Djiboutian rural communities, so long as the mixture could be imported. As aforementioned, this would minimize the number of steps to learn to effectively grow spirulina and increase the likelihood that the technology would disperse.

Establishing Partnerships

Establishing multilateral partnerships could alleviate financial and organizational pressures of the project. Since the main constraints of small-scale spirulina farms revolve around initial investment capital and resource acquisition, using the support of financial institutions would be essential to the conception of the project. Additionally, there are specialists from a wide variety of backgrounds in each institution that could offer necessary feedback and support throughout the development of the project.

In Table 5 located in the appendix is a list of domestic, regional, and international institutions where partnerships can be potentially established in the design and implementation of small-scale spirulina farms in rural Djiboutian communities.

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Appendix

Malnutrition Approach	Reason for Elimination
Diversifying Diets	Though this is the most desirable approach for preventing malnutrition, this is not easily achieved when families are poor and when there is a lack of arable land for interventions like gardens.
Increasing Crop Yields, Developing Commercial Agriculture, or Horticulture Training	These approaches are not easily achieved due to the severe lack of arable land and water resources to irrigate. These environmental conditions make it difficult for traditional agricultural approaches.
Deworming	Worms can lead to chronic infection and hinder development, removing them promotes weight gain and absorption of nutrients. Though this can be valuable in areas, it requires medical staff and does not address hunger. It is a possible public health approach but is outside of our client's expertise and the NGO's scope of work.
Ready to Use Therapeutic Food and Complementary Food Supplements (These are specialty products designed to be sources of energy, protein, and essential fatty acids.)	Though they are easy to administer, this approach creates a dependency and requires a constant funding source to afford the specially produced item. It does not encourage self sufficiency since it is not locally produced and requires a distribution network. In addition it is not very different from the current work Sounah Al Haya does by distributing donations. We did not want to propose this as an approach because it would not improve upon the work Sounah Al Haya, it only alters it.
Food Based Approach: Soy	Soy crops use four times the amount of water as spirulina for same weight amount of protein. This makes it difficult to be produced locally in such a water scarce area.

Table 2. Malnutrition approaches considered but eliminated prior to decision matrix.

	Description	Notes	Ease for Community	Culturally Acceptable	Improve Food Security	Promote Fair Access to Nutrition	Potential to be self sustaining	Proximity to Sounah Al Haya's current work	Evidence of Success	
			Decision Criteria							
Guiding Questions			Do households need to change their behavior very much? How much time and training is required?	How much do people need to change their behavior? Is it easily integrated into their diet?	Does this approach increase the local availability/affordabili ty of food?	Does this approach provide better access to micronutrients for the malnourished populations that need them the most?	Are there reoccuring costs or complicated monitoring? Does the community have ownership over the project?	Does Sounah Al Haya have experience working in this area? Do they have the know-how?	Has this approach been successful in the past?	
Criteria Weight			3	3	5	5	5	4	3	**SCORE**
Micronutrient Fortification	Industrial process of, adding essential vitamins and minerals to foods (can incorp. iron, zinc and calcium. Sometimes vitamin A, B, & riboflavin.	Likely still imported.Already existing mandatory rice fortification program but could be expanded to other grains.	Communities would simply purchase or recieve fortified food. Households do not need to do very much.	Households do not need to change behavior or diet since many different foods, including cereals, can be fortified with micronutrients.	Does not increase access to calories, only nutrients. May slightly increase food prices.	Costs are low once network is established. Requires business model. Not available to those with strained financial resources.	Business model. Not very locally based since they have to rely on larger scale industrial processing of the food which will likely be out of the country. Distant from the communities.	Involves working with industrial processing of food and supply chain to get the food to the people who need it.	Well documented evidence of reducing morbidity and mortality. Common strategy of WHO.Used in Kenya [4].	
			5	5	0	4	2	0	3	69
Biofortified Crops for small scale farms	Obtained through breeding or transgressive segregation/heterosis Done to staple food crops. Breed food crops that are rich in bioavailable micronutrients	Not very easy since it needs to correspond with producers of the imported food or a local university involved in agriculture.	Would get communities involved in growing of the crops once the biofortified versions are developed.	Largely dependent on which crop is selected (e.g sorghum different than rice). Requires labor input to grow the biofortified crops once developed.	If crops are better developed for climate, it could allow for small-scale farms to increase local access to food. Otherwise it might be just a switch from current crops to crops that are more nutrient dense.	Ideally the biofortified crops have significantly increased amounts of micronutrients.	May require fertilizers or other farming inputs. Could sell crops for profit since they may be part of local diet already. Locally based.	Biotechnolgy/plant breeding approach. Once initial research/breeding phase is over, would be working with communties they are already working with to get them inovlved in growing the biofortified crops.	May have little impact due to mismanagement, underfunding, logistic problems and poor compliance like in india	
			1	2	2	2	3	3	2	62
Small Scale Spirulina Aquaculture	An aquaculture-based farming system cultivating blue-green algae as a nutrient source. Requires a pond, water, a culture/starting population, chemical inputs, and a cover to limit evaporation. Requires training and daily maintenance.	Client proposed this option. Smaller ponds are more expensive than one large pond.	Labor intensive. Communities would be required to learn how to work and manage the aquaculture farm.Fixed location so not easy for semi-nomadic populations.	No significant aquaculture or Spirulina knowledge. Small amount needed to get important micronutrients and protein, so can be addedd to existing diet. Green color may affect appearance of foods.	Provides a local source of protein and micronutrients that was not previously available.	Algae (especially Spirulina) is very nutrient dense and includes good amounts of iron and vitamin A.	Relies on chemical inputs that do not have existing supply chains we are aware of. Requires water testing.	Would work with communties they are already working with to get them involved in aquaculture.	There are mixed results. The spirulina has a strong positive effect on its consumers but the farms themselves are difficult to keep functional.	
			1	1	5	5	3	3	1	**86**
Increase Fishing	Provide training, loans for equipment, etc. Underutilized resources. Work is already being done by Djibouti Agriculture Integrated FIsheries Development Project	Currently small scale/subsistence fishing, no processing. Djibouti currently imports 5x as much fish as they export. Less than 0.001% of pop work in primary sector, Fisheries are considered underutilized.	Likely work with existing subsistenve fishers and expand production.Currently underutilized resource. Best for communities close to the ocean. Difficult for rural communities unless there is a dependable transportation network.	Though subsitence fishing does exist, most people do not consume fish. This is likely due to a lack of financial capital though local availability may also be a factor.	Increases local supply of fish which are good sources of protein. The fish may end up being exported since there are more attractive prices on international market.	Fish do not contain the high amounts of vitamin A or iron which are often two of the most deficient nutrients in malnutrition. Do contain riboflavin and B6.	Should work with government to prevent overfishing. Need necessary start up capital and equipment, but after there are not frequent inputs.	Would involve skills training, possibly loans for equipment, and transportation infrastructure (e.g. loading dock).	Recommended by the FAO.	
			1	3	3	3	5	0	1	70

Table 3. Detailed decision matrix of malnutrition approaches ranked based on criteria.

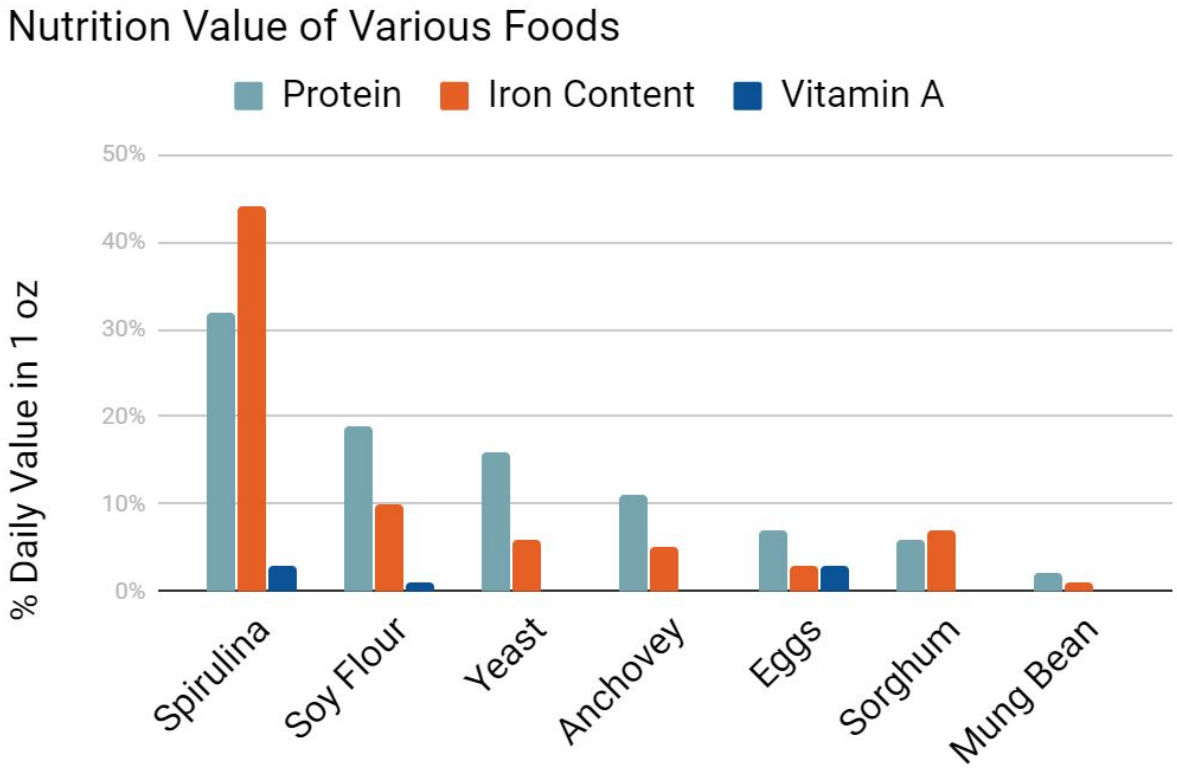

Figure 1. Bar chart of nutritional value of various foods.

SWOT ANALYSIS

Strengths - Agriculture & engineering experience - Participatory planning/ project experience - Connection with urban/ rural communities	**Weaknesses** - Out of country, limited communication - Lack of funding - Lack of construction/ implementation experience - Low ability to make effective programs (not having the right people, not team with the right skill-set, overactive project team rather than engaging community and what they want)
Opportunities - Connection to Djiboutian Dept. of Ag.	**Threats** - Extreme climate, water scarcity - International competition - Lack of local contractors

- No other spirulina farm competition in Djibouti - Climate conducive - Health need for spirulina	- Lack of local inputs (spirulina culture, chemical inputs) - Community members aren't aware of malnutrition - Community lack of interest - Possible pushback from community - Not income generating at the start

Table 4. Description of strengths, weaknesses, opportunities, and threats for the SWOT analysis.

Name of Institution	**Type of Institution**	**Domestic/ Regional/ International**	**How is it a community asset? How will it benefit your project?**
University of Djibouti	Academic Institution	Domestic	Hotspot for local experts in agriculture and education; offers a potential site for testing the design of the farms
Sounah Al Haya	Non-governmental Organization (NGO)	Domestic	Direct connection to the targeted community; connection to local networks of NGOs; shares vision statement
Djibouti Ministry of Agriculture	Public Institution	Domestic	Potential to receive government funding; More investment in the project if collaboration is possible; Local experts for consulting
Intergovernmental Institution for the Use of Spirulina Micro-Algae Against Malnutrition (IIMSAM)	Multilateral Institution	Regional	Direct experience with small-scale spirulina production; potential to partner with existing resources and knowledge networks; shared vision statement
Intergovernmental Authority on Development (IGAD)	Multilateral Institution	Regional	Strong connection to regional partnerships; potential to partner with existing resources and knowledge networks
Islamic Development Bank	Multilateral Institution	International	Funding opportunities via loans and grants

World Bank	Multilateral Institution	International	Funding opportunities via loans and grants (*see above for stunting grant available)
United States Agency for International Development	National Development Agency	International	Existing domestic presence with food insecurity aid (Food For Peace Program); strong professional network base
Food and Agriculture Organization of the United Nations (FAO)	Multilateral Institution	International	Strong professional network base; shared vision statement

Table 5 : Institutions identified as potential partners.

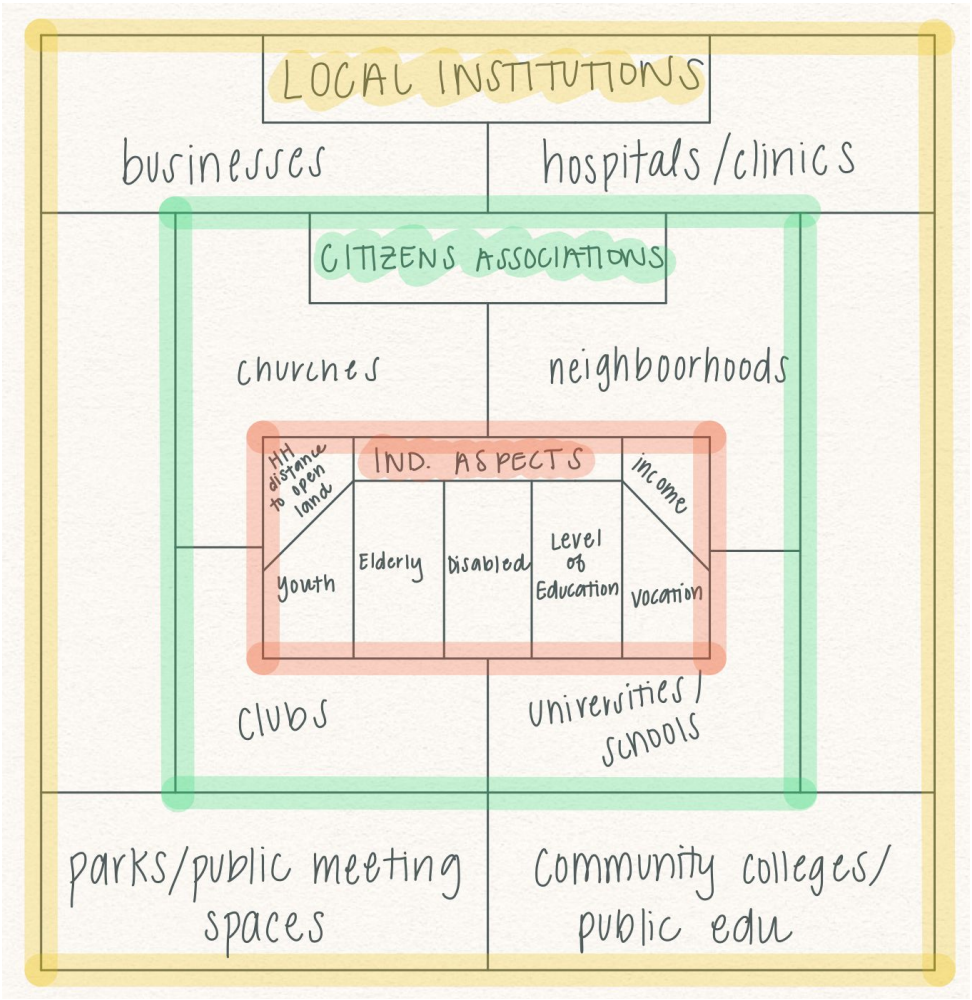

Figure 2: Stakeholder Analysis diagram.