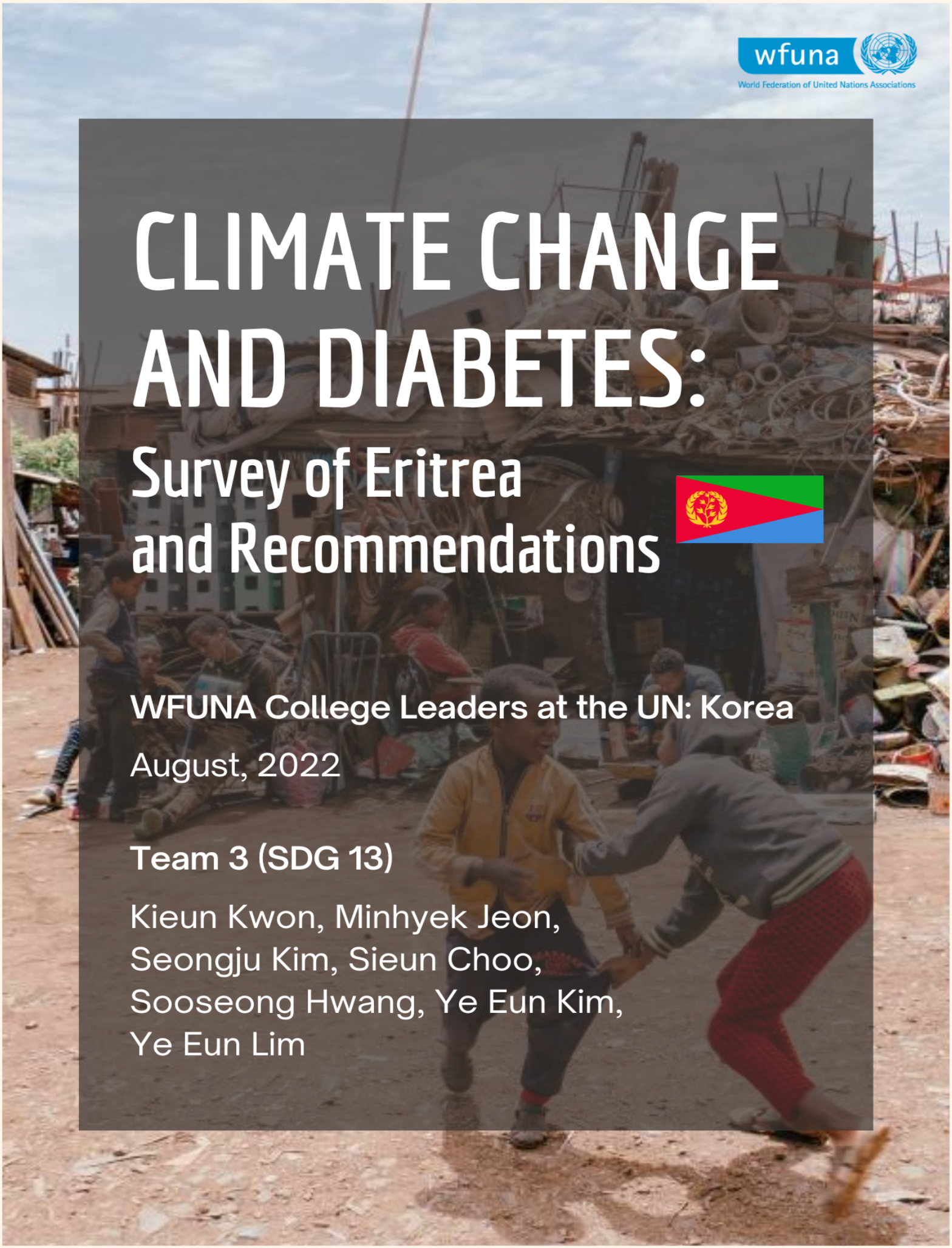

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World Federation of United Nations Associations

CLIMATE CHANGE AND DIABETES:

Survey of Eritrea and Recommendations

WFUNA College Leaders at the UN: Korea

August, 2022

Team 3 (SDG 13)

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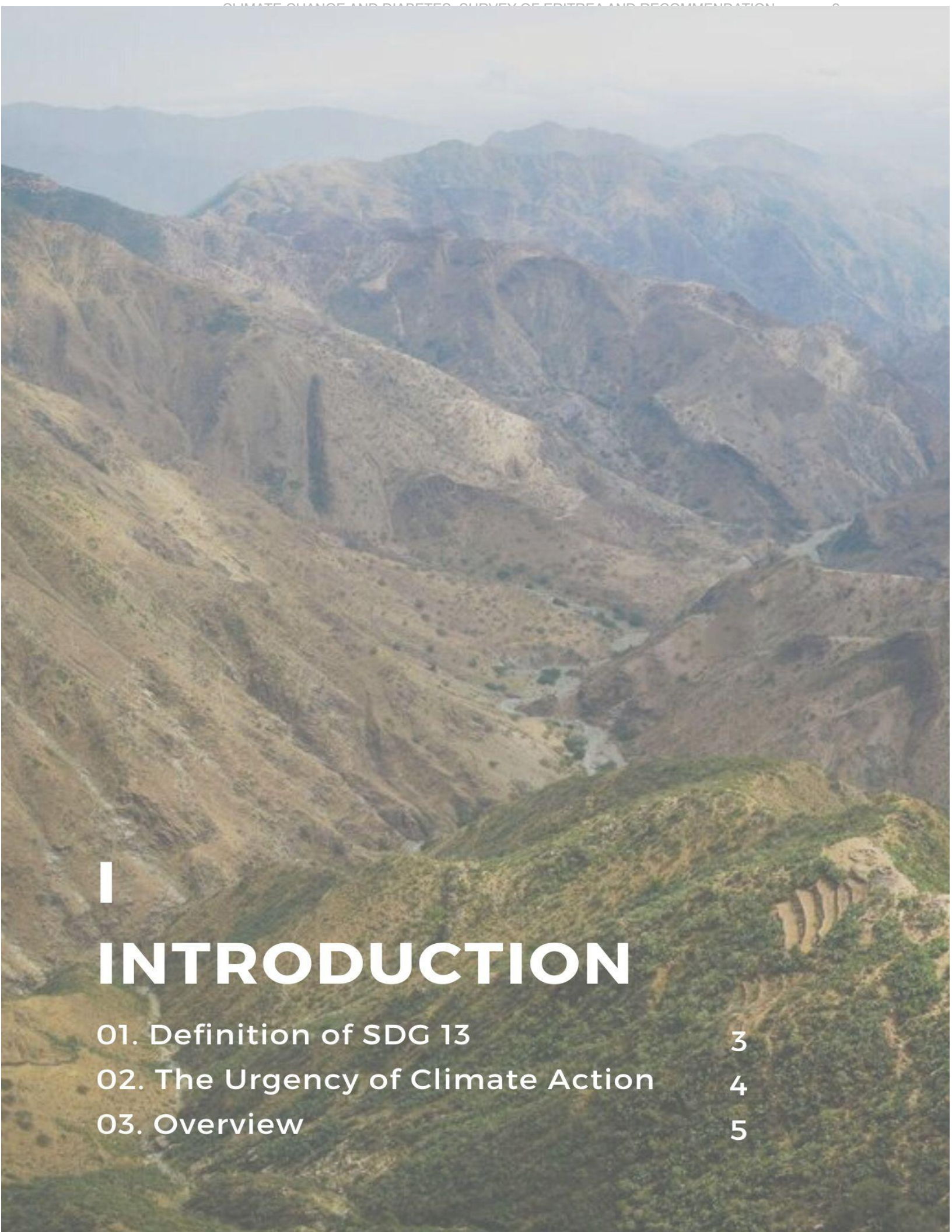


I INTRODUCTION

1.1 Definition of SDG 13: Climate Action

Goal 13

Take urgent action to combat climate change and its impacts.

Target

1.3.b

Promote mechanisms for raising capacity for effective climate change-related planning and management in least developed countries and small island developing States, including focusing on women, youth and local and marginalized communities.

1.3.b.1

Number of least developed countries and small island developing States with nationally determined contributions, long-term strategies, national adaptation plans and adaptation communications, as reported to the secretariat of the United Nations Framework Convention on Climate Change.

1.2 Why Climate Action?

“The climate crisis is our number one emergency.”

– Antonio Guterres (United Nations Secretary-General)

All of the 17 Sustainable Development Goals, designed to address fundamental human challenges through transformative measures, are simply indispensable. However, SDG 13 truly stands out as it forces us to face the ethereal nature of human existence, which depends on the maintenance of a healthy climate condition.

(mention Donald Lee after interview) The Earth has witnessed a total of five mass extintions thus far, the last and most recent occurrence being the extinction of dinosaurs around 65 millions years ago. Many scientists contend that human life may be facing a 6th mass extinction due to climate change.

In his remarks during a press conference, Mr. Guterres encapsulated this sense of urgency for SDG 13: “The headlines are naturally dominated by the escalation of tensions and conflicts, or high-level political events. But the truth is that the most systemic threat to humankind remains climate change” (Secretary-General, 2018). To put in plainly, our very lives depend on our ability sustain the diverse envrionment and climate that we live in.

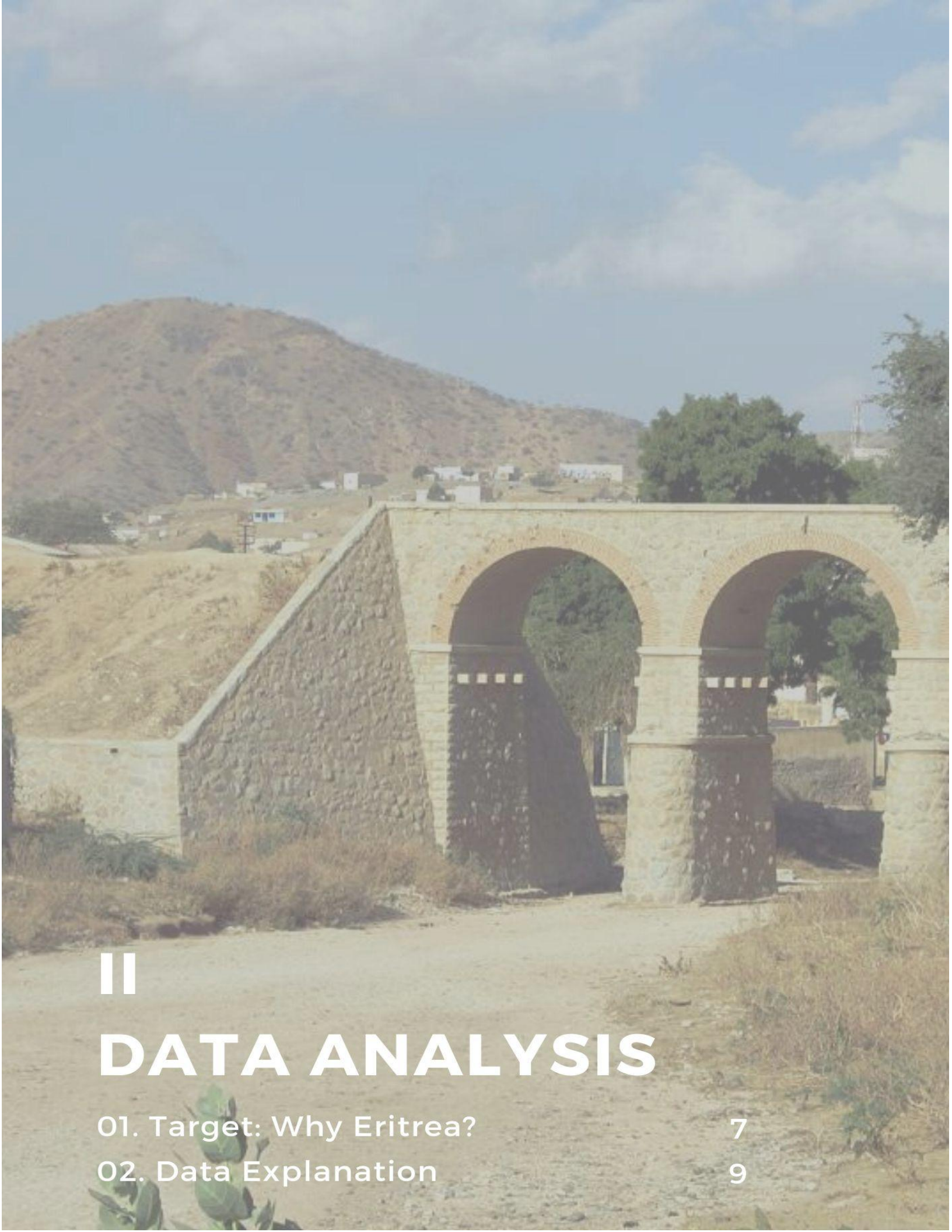
Furthermore, SDG 13 is also in direct accordance with one of the most basic human rights to pursue happiness. It is crucial that we take action to alleviate the impact of climate change. This way, we can not only continue to live happier and healthier ourselves, but also ensure that we provide a better future without an existential threat to the next generations to come.

1.3 Overview

Developing countries are most vulnerable to the negative effects of climate crises since they lack either the appropriate monitoring system or a reliable infrastructure for healthcare. In our effort to find the country that was most severely impacted by it, we investigated chages in temperature and percentage of forest area loss from 2009 to 2020 across 243 countries. Among them, we were able to determine that Eritrea experienced one of the most intense rates of temperature rise and forest area loss. Based on this observation, we hypothesized that the likelihood of certain diseases rises from such drastic change in its climate. Moreover, we discovered significant correlation between the number of patients suffering from diabetes-related diseases, and temperature change and forest area loss.

Upon further inspection on Eritrea’s social, environmental, and scientific conditions, it was clear that climate change not only was a serious issue but also one that increased the prevalence of diabetes in the African country.

In this comprehensive report, we propose an adaptive solution that can possibly mitigate climate change and advocate for the well-beling of the people in Eritrea.



II
DATA ANALYSIS

2.1 Target: Why Eritrea?

We utilized an algorithm model to analyze the climate impact in Eritrea. We employed three criterias in selecting the target country: temperature rise, deforestation, and GDP per capita.

First, temperature rise was an obvious choice as it is a representative phenomenon of climate change. Based on temperature data from the 1990s to the 2000s, we made a list of countries that reported drastic changes in temperature. As illustrated in Figure 2-1 and Table 2-1, Eritrea fell in the 90th percentile and ranked 12th for temperature variation, respectively. It shows that Eritrea observed significant climate change and, thus, in need of corrective measures.

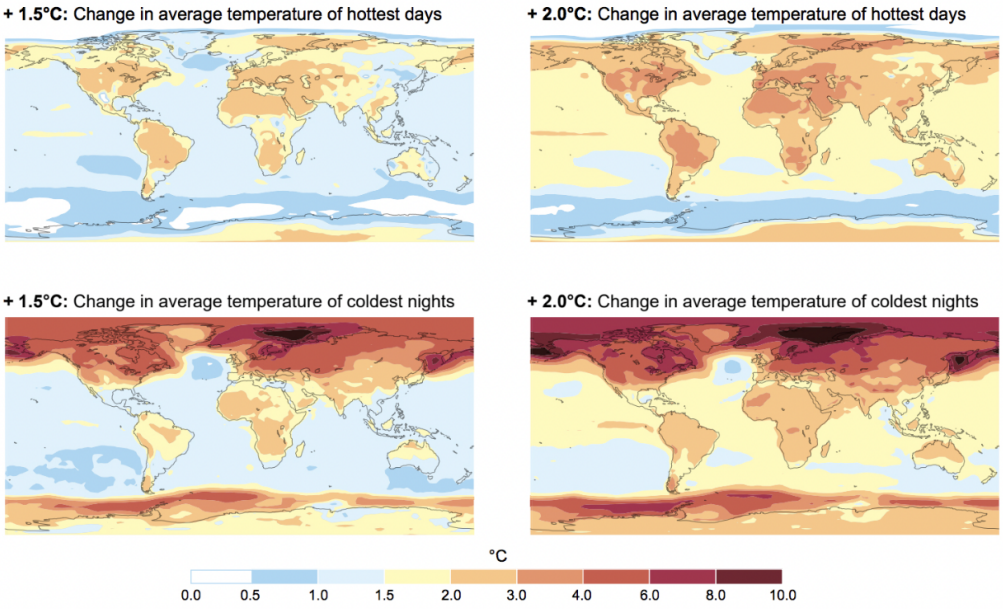


Figure 2-1. Corresponding Effect of Temperature Rise (Buis, 2019)

Deforestation is also seen as an important factor that covers a wide range of environmental phenomena such as drought, water pollution, and air pollution. Based on forest area loss data from 1990s to 2000s provided by KOICA, we made a list of countries that reported drastic changes in forest area.

Country	Ranking of Temperature Variation	Forest Area Under 60	GDP per capita
Greenland	1	46	16
Egypt	3	55	103
Armenia	7	43	107
Albania	9	56	97
Algeria	11	58	84
Eritrea	12	20	181

Table 2-1. Ranking of Temperature Variation

With two data sheets (temperature rise and deforestation), we compared countries that met both criterias and narrowed them down to a total of 12 countries. Among these countries, six countries (Greenland, Egypt, Armenia, Albania, Algeria, and Eritrea) with a forest area of 60 or less were selected. We then applied GDP per capita to select the poorest developing countries. As a result, Eritrea was chosen as it was the country with the lowest GDP per capita on the list. Through the selective process, we designated Eritrea as the target country.

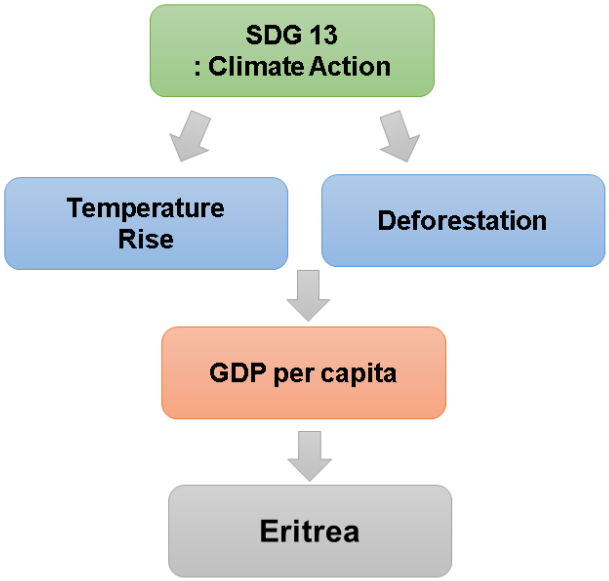


Figure 2-2. The process of selecting Eritrea as our research country

2.2 Data Explanation

As mentioned above, our team chose Eritrea among 243 countries because Eritrea has the highest increase in temperature and the most severe forest destruction. We aimed to find health-related issues regarding climate change and focus on population mortality. If we can prove that the mortality rate of a certain disease varies in proportion to the temperature or forest area, we can confirm that a particular disease is associated with two factors.

The data we analyzed are the GHO(The Global Health Observatory) Eritrea data set from WHO(World Health Organization) ranging from 2000 to 2019. We merged 20-year-ranging data to observe the changing tendency of 131 kinds of most important diseases and calculate the covariance coefficient of each disease with two significant Eritrea's nature indicator features, forest area, and temperature.

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Lower respiratory infections	3469.92	3414.08	3574.87	3547.31	3757.01	3807.15	3783.18	3862.25	3915.42	3813.93	3804.41	3790.83
Diarrhoeal diseases	3427.96	3268.48	3238.62	3037.00	3078.76	3023.96	2993.72	3040.45	3139.12	3077.92	3056.59	2993.14
Stroke	2039.72	2033.71	2066.66	2052.98	2126.36	2184.41	2264.41	2301.09	2372.92	2381.76	2388.39	2421.41
Neonatal conditions	1794.30	1838.30	1920.38	1993.28	2082.84	2133.61	2166.38	2202.93	2211.20	2178.41	2142.84	2079.15
Ischaemic heart disease	1360.33	1398.14	1455.71	1481.01	1556.60	1618.72	1699.34	1747.46	1815.91	1836.72	1851.84	1890.17
...	...	...	...	...	...	...	...	...	...	...	...	...

Figure 2-3. Part of Merged disease dataset

The covariance value can range from -1 to +1, with a negative value indicating a negative relationship and a positive value indicating a positive relationship. The greater this number, the more reliant the relationship. Positive covariance denotes a direct relationship and is represented by a positive number.

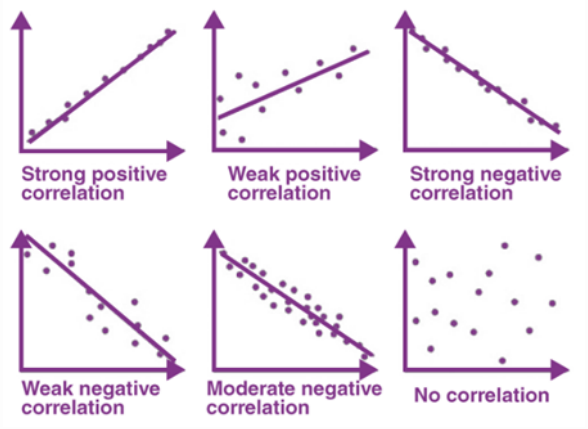


Figure 2-4. Covariance value ("Correlation")

Since forest area decreases and temperature increases as time goes by, we focused on diseases that showed a strong negative correlation to the forest area and a strong positive correlation to the temperature. In other words, we tried to find a disease that increases its mortality rate as the temperature goes up and the forest area decreases in size. In the covariance formula, the covariance between two random variables X and Y are denoted as Cov(X, Y). The population covariance Formula is defined as follows:

$$Cov(x, y) = \frac{\sum(X - \bar{X}) * (Y - \bar{Y})}{N}$$

Where X is the value of the X-variable, Y is the value of the Y-variable, $\overline{X}$ is the mean of the X-variable, $\overline{Y}$ is the mean of the Y-variable and N is the number of data points. To also analyze the correlation between diseases, we made a 133 x 133 correlation heatmap which is a graphical representation of a correlation matrix representing the correlation between different variables. Correlation between two random variables or bivariate data does not necessarily imply a causal relationship.

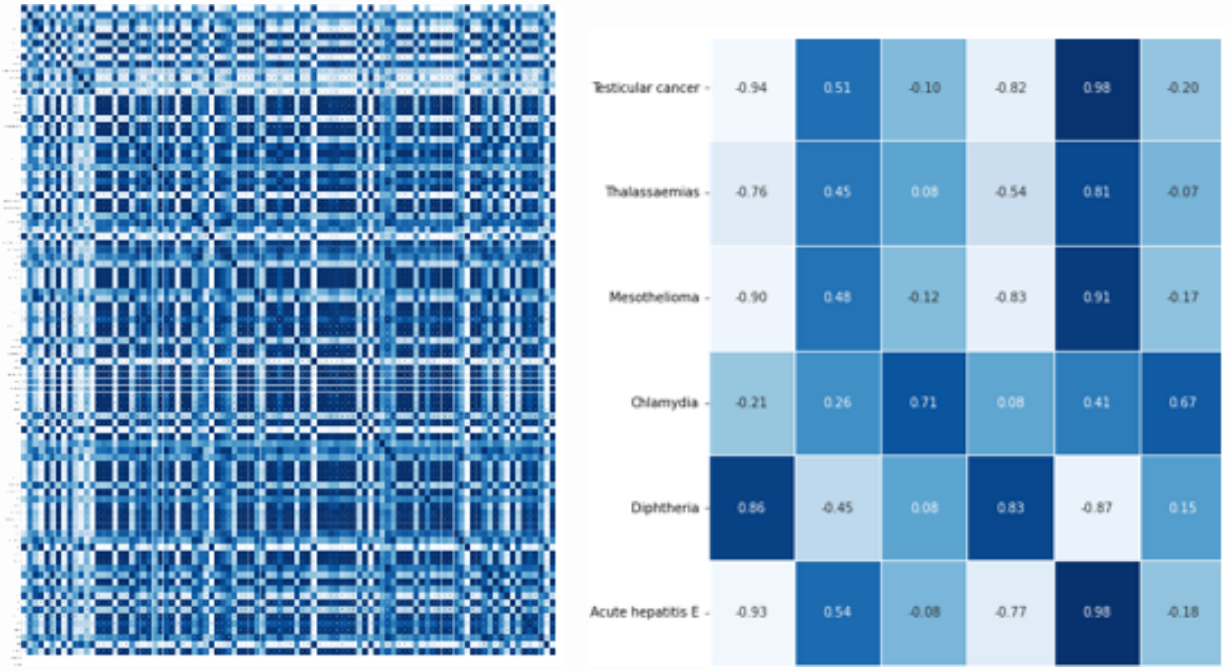
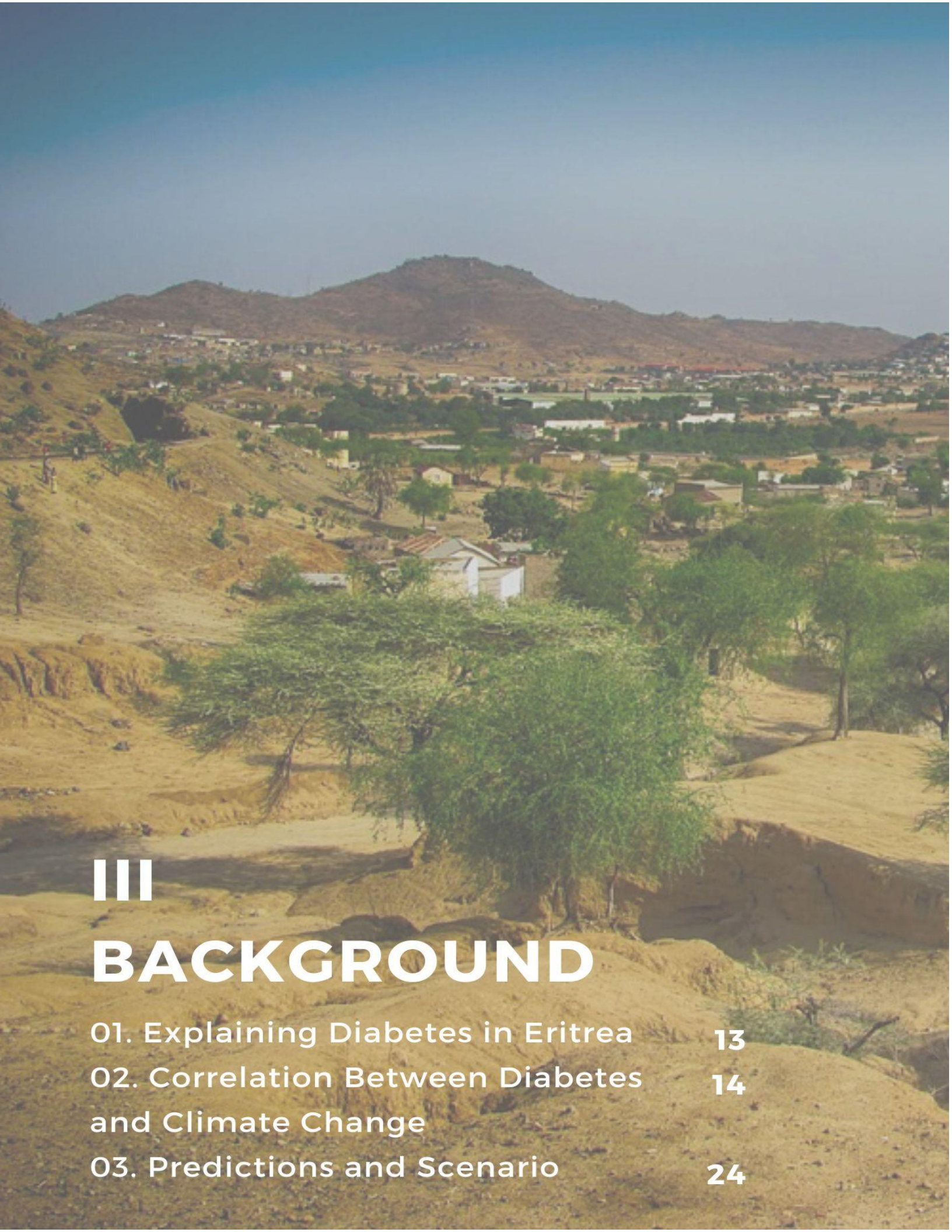


Figure 2-5. Correlation Heat map

Based on the heat map, our team filtered types of disease with a certain correlation value to select diseases that show the highest correlation with the two factors. Considering that the forest area feature showed a strong negative correlation with many diseases, it was filtered with values under -0.9. On the other hand, because the temperature feature showed a strong positive correlation with a few types of diseases, it was filtered with values over 0.65. 42 types of disease were selected among 131 disease–-Stroke, Ischaemic heart disease, Road injury, Hypertensive heart disease, Diabetes mellitus, Chronic obstructive pulmonary disease, Kidney diseases, Interpersonal violence, Breast cancer, Falls, Alzheimer's disease and other dementias, Paralytic ileus and intestinal obstruction, Cervix uteri cancer, Lymphomas, multiple myeloma, Leukaemia, Colon and rectum cancers, Oesophagus cancer, Gallbladder and biliary diseases, Liver cancer, Mouth and oropharynx cancers, Parkinson disease, Trachea, bronchus, lung cancers, Ovary cancer, Prostate cancer, Bladder cancer, Skin diseases, Pancreatitis, Kidney cancer, Melanoma and other skin cancers, Drug use disorders, Brain and nervous system cancers, Pancreas cancer, Inflammatory bowel disease, Gallbladder and biliary tract cancer, Corpus uteri cancer, Thyroid cancer, Rheumatoid arthritis, Multiple sclerosis, Urolithiasis, Testicular cancer, Mesothelioma, Acute hepatitis E.

Among 42 diseases, we then filtered it once more and selected the top 14 diseases that were proven to be most detrimental to Eritrea based on its cumulative population of mortality number for the past 20 years. Top 14 diseases are as follows: Chronic obstructive pulmonary disease, Trachea, bronchus, lung cancers, Acute hepatitis E, Skin diseases, Inflammatory bowel disease, Ischaemic heart disease, Hypertensive heart disease, Diabetes mellitus, Gallbladder and biliary diseases, Liver cancer, Kidney cancer, Pancreas cancer, Gallbladder and biliary tract cancer, Pancreatitis.

We classified 14 diseases into 3 groups as respiratory related diseases (Chronic obstructive pulmonary disease, Trachea, bronchus, lung cancers), waterborne diseases (Acute hepatitis E, Skin diseases, Inflammatory bowel disease) and diabetes related diseases (Ischaemic heart disease, Hypertensive heart disease, Diabetes mellitus, Gallbladder and biliary diseases, Liver cancer, Kidney cancer, Pancreas cancer, Gallbladder and biliary tract cancer, Pancreatitis). Until now, many are revealed on waterborne diseases, pulmonary diseases, and their relation to Eritrea's climate change. Even though diabetes-related diseases were the most frequent in Eritrea, the quantitative approach on diabetes and its relationship with Eritrea's climate change has not been conducted.



III
BACKGROUND

3.1 Explaning Diabetes in Eritrea

3.1.1 Diabetes

Diabetes mellitus is a metabolic disorder with high blood glucose either due to the inadequate amount of insulin production, the improper response rate of body cells to insulin, or both. As 90% of diabetes cases around the world is estimated to be Type 2, this report specifically focuses on Type 2 diabetes. Type 2 diabetes covers the body's malfunction without enough amount of insulin or body cells' resistance to insulin. Considered to be a metabolism disorder, diabetes has to do with how we manage digested food– Glucose. Glucose is a simple sugar in the blood which serves as a main fuel for running our body for enhancement of energy and growth. And the pancreas-produced hormone insulin enables glucose's entrance into a cell; As soon as the pancreas releases insulin to move the glucose present into a cell, our blood glucose rate drops. Therefore, diabetes indicates over the elevation of glucose in the blood with a hyperglycemia state.

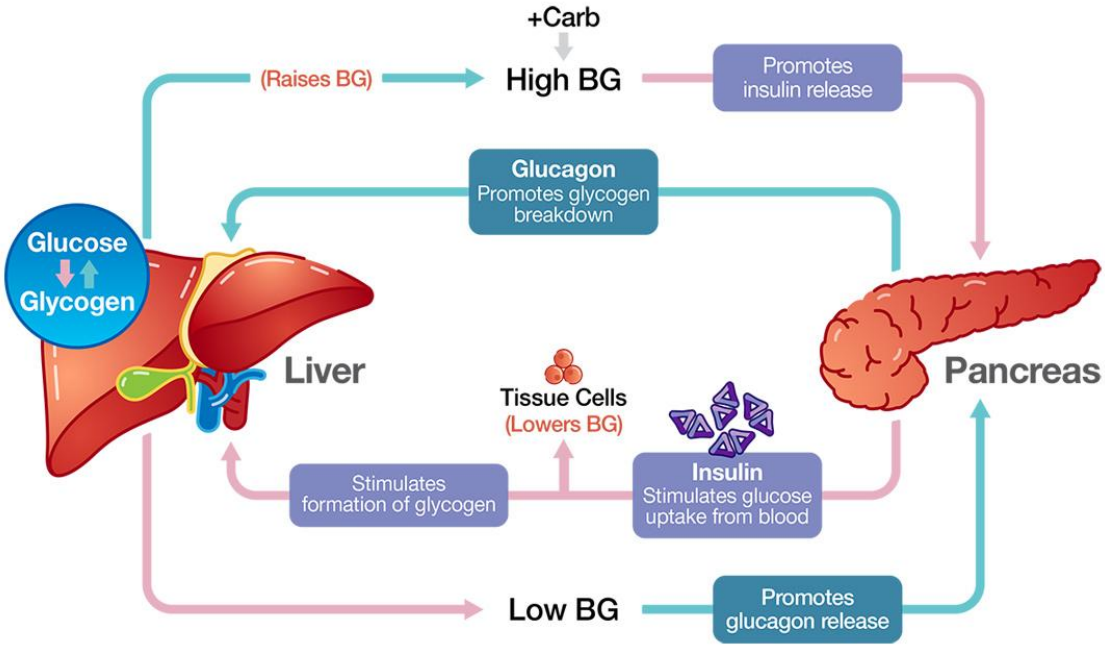


Figure 3-1. Diabetes and Glucose in Our Body("What is Diabetes")

3.1.2 Diabetes' Relevance to SDG

Covering the

- SDG 6: Clean Water and Sanitation

The water and sanitation system is the baseline indicator for diabetes. Rural regions with straggling infrastructure lead to a decline in water security. When people do not consume enough amount of water, not only does it increase the risk of infection but also it exacerbates the symptoms. Thus, an appropriate sanitary system and national security of water should be made in advance.

- SDG 3: Good health and Well-being

SDG 3 is the core of improving the disease with its agenda named health promotion. It especially emphasizes the need for well being and maintaining good health with targets and indicators.

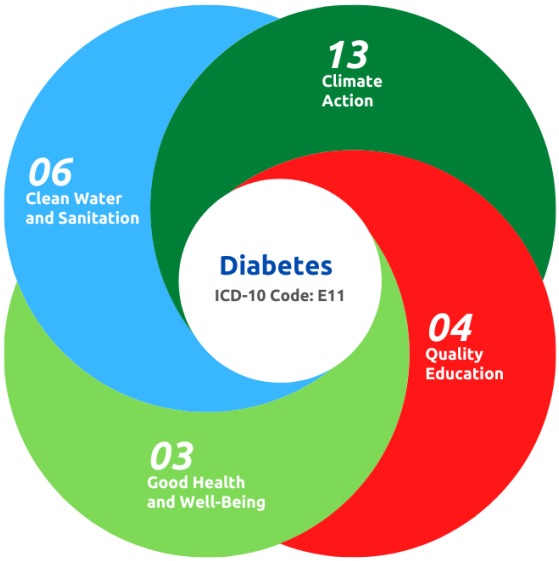


Figure 3-2. Relevance to SDG 3,4,6,13

3.2 Correlation Between Diabetes and Climate Change

We set temperature rise and deforestation as main environmental elements affected by climate change. We also considered these two factors as contributing to diabetes.

3.2.1 Temperature Rise

3.2.1.(a) Global

"1-degree Celsius rise in environmental temperature could account for more than 100,000 new diabetes cases per year in the USA alone" *(Howard, 2017)*

- *Lisanne Blauw,*

This paper will explain how temperature rise could affect the prevalence of diabetes from a social and environmental perspective.

Since the late 1950s, a global average temperature increases of 0.6°C has occurred. This rise in temperature caused different effects including declined productivity of agriculture, desertification, degradation of the ecosystem, soil degradation, acidification of oceans, reduction in fresh-water resources, loss of biodiversity as well as depletion of the ozone layer. Rise in global greenhouse gas emissions (GHGs) is one of the critical contributors to climate change. Such an increase would be a huge threat to the survival of our planet, its ecosystems, and therefore to humans and their health. A change in climate also worsens a number of health risks, morbidity, and mortality from common non-communicable diseases including type 2 diabetes. (Maalouf, 2021)

The research figures out what is the physiological relationship between temperature increase and diabetes.

Brown adipose tissue (BAT) is activated in a cold environment and forms part of the normal biological composition of human beings. This tissue is responsible for increasing the sympathetic nervous system as well as combusting a large amount of lipids in order to generate heat. The lipid usage by BAT will in turn increase the influx of glucose to skeletal muscles and therefore improve insulin sensitivity. It is known that type 2 diabetes patients who spend about 10 days in a moderate cold environment shows a meaningful improved insulin sensitivity. An inverse relationship is observed between interactive BAT activity rate and HbA1C levels as well as blood glucose following a cold exposure, independent of body fat. Hence, with global warming, the BAT physiological role in glucose homeostasis would be interfered and diabetes susceptibility increases among the population. For every incremental degree Celsius, the incidence rate of obesity-adjusted diabetes is found to increase by 0.29 per 100, while the diabetes prevalence increases by 0.17% for every degree Celsius increase (Agius, 2021, p.1).

There are some cases that have been researched around the world which can show the correlation between temperature increase and diabetes. Heart attack (acute myocardial infarction) is the most serious cause of death among patients with diabetes and was found to happen more frequently during times of extreme temperature. In a large study of 53,769 myocardial infarction admissions to public hospitals in Hong Kong from 2002 to 2011, scientists found an increased risk for admission during periods of both low and high temperatures. Hospitalized patients with diabetes may require more hospitalizations per year and may have a longer length of stay (Zilbermint, 2020).

3.2.1.(b) Regional

Eritrea's drought was highly related to a historic event, 30 years of war, and the situation degenerated as time passed. In 1991, Eritrea got its independence from Ethiopia, but the fight did not end there. Border wars continue to break out, and the government has no choice but to devote its efforts to soldiers and military resources. Many citizens were forced into compulsory military services, which led to the desertion of the arable land of Eritrea (image 3-1) (Sims, 2019). In the meantime, a drought began in 1999, and the government could not focus on the problem since it was too busy with border wars, which worsened drought conditions (Samson, 2021).

Image 3-1. Eritreans in the war

The drought in 1999, as shown in image 3-2, was fatal to many Eritreans since agriculture is one of the main economic activities in Eritrea. Agriculture accounts for 11.7 percent of GDP in Eritrea, and nearly 80 percent of Eritrean's workforce is engaged in agriculture (CIA, 2022). One of the most significant downsides to the drought is desertification. A tremendous adverse effect on people in agriculture and increased the level of poverty due to the lack of topsoil (Jordan, 2017). Drought is classified as a physical natural hazard due to the loss of animals and crops. The poverty rate increases, and the economy begins to collapse when many people's primary income source is affected. Drought can be a significant disaster for Eritrea due to high agricultural dependence and unpredictable rainfall. In addition, Drought would deepen the water shortage problem in Eritrea, broadly leading to water insecurity and food insecurity, as image 3-3.

Diabetes occupies a large part of the Diseases that have been occurring in this country. Malnutrition which is contributing to developing Diabetes is caused by food and water insecurity. Dr. Donald Lee, President of ATD(All Together in Dignity) Fourth World, has acknowledged that Food insecurity has correlated with Diabetes (Samson, 2021).

Image 3-2. Drought in Eritrea

Image 3-3. The water crisis in Eritrea

As mentioned above, temperature rise and drought are closely related. Climate change increases the factors of worsening drought in many parts of the world. The same situation occurred in Eritrea. Rising temperatures resulting from climate change would enhance evaporation, and it contributes to altering the timing of water availability. The following are analyses of temperature rise and drought patterns in Eritrea over time.

Earth's surface temperature continues to rise despite natural variability. Figure 3-4 shows Eritrea's historical record evolution. The climate of Eritrea ranges is varied: hot and arid areas adjacent to the Red Sea, the temperature in highlands, and sub-humid in isolated micro-catchment areas. In most parts of the country, nearly 70%, the mean annual temperature is more than 27°C, indicating a hot to the very hot range. As shown in Figure 3-5, about 25% of the areas experience warm to mild weather with a mean temperature of around 22°C. Overall, Eritrea experiences an arid climate; 70% of its land area has an average annual rainfall of less than 350 mm, identified as a hot and arid climate.

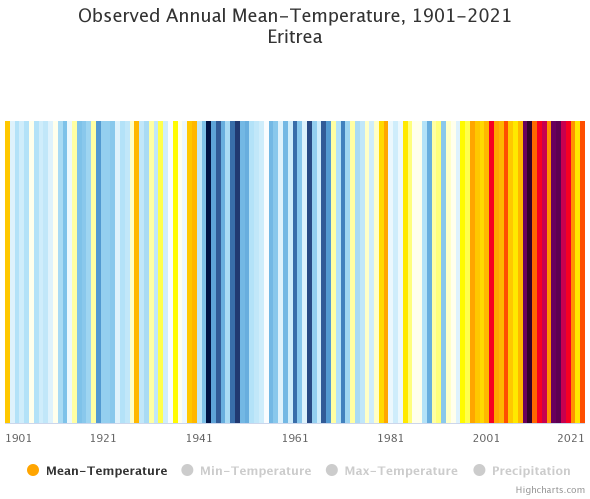


Figure 3-4. Observed Annual Mean-Temperature, 1901-2021 Eritrea

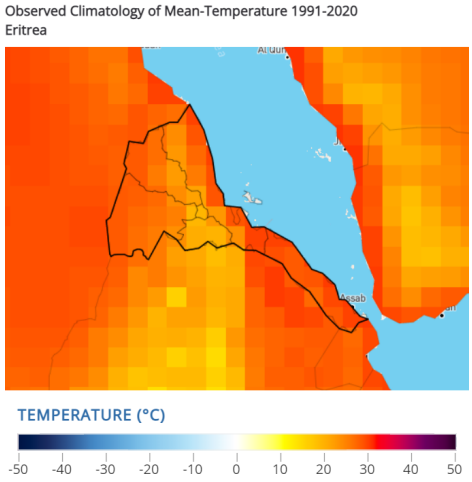


Figure 3-5. Observed Climatology of Mean-Temperature 1991-2020 Eritrea

Research investigated some of the features of Eritrea and found that this country is suffering from diabetes more severely than other countries around the world. And the research assumes that the prevalence of diabetes in Eritrea has correlation with temperature increase in Eritrea. Among the African countries, Eritrea is the most vulnerable to climate change, especially temperature increase. And the research argues a correlation between temperature increase in Eritrea and the prevalence of diabetes in this country.

According to the latest WHO data published in 2020 Diabetes Mellitus Deaths in Eritrea reached 944 or 3.71% of total deaths. The age adjusted Death Rate is 51.06 per 100,000 of population ranks Eritrea #37 in the world *(Diabetes mellitus in Eritrea, 2022).* The following shows how severe the prevalence of diabetes in Eritrea is:
Below, there are two diagrams.

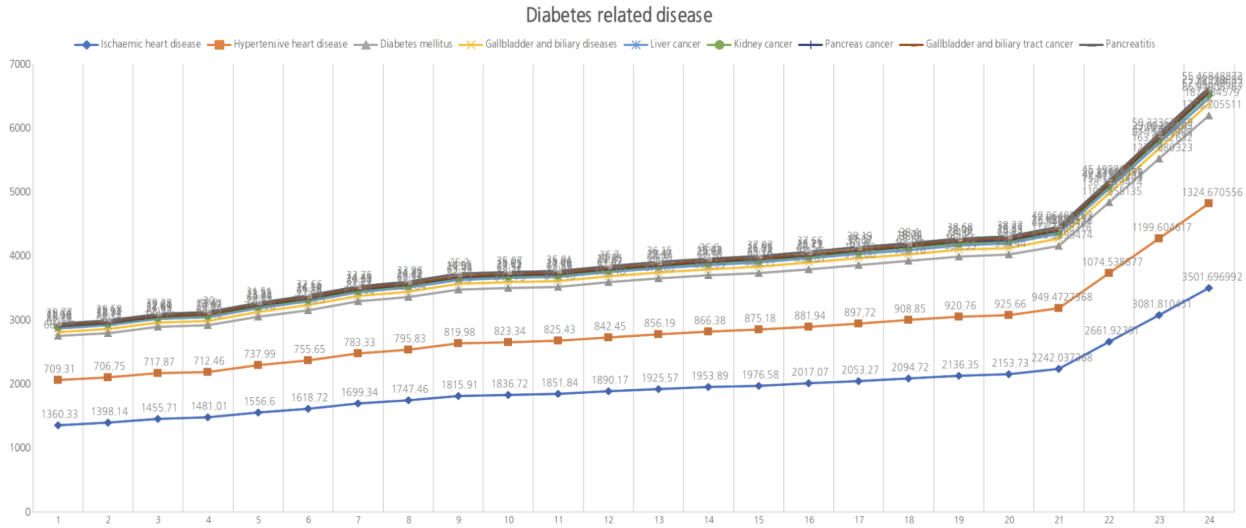


Figure 3-6. Patients in Eritrea who are suffering from Diabetes related diseases

Patients in Eritrea who are suffering from Diabetes related diseases as shown in figure 3-6 constantly increase as the Annual temperature of Eritrea increases. As a result of the research, there was a significant correlation between Patients in Eritrea who are suffering from Diabetes related diseases and temperature of Eritrea. This clearly shows that there is a correlation between these two figures.

3.2.2 Deforestation

One of the most serious environmental problems caused by Climate change in Eritrea is Deforestation (Ghebrezgabher, 2016). A century ago, 30% of Eritrea's land surface was covered by forest, which dwindled to less than 1% now as shown in Figure 3-7 (UNFCCC, 2021). The main contributing factor to Eritrea's deforestation is the Temperature Increase because it leads to a high rate of evaporation of moisture from the soil (Ghebrezgabher, 2016). The experts predicted that across Eritrea a large portion of the woodland will be shifted to dry forest("State of Eritrea", 2006)

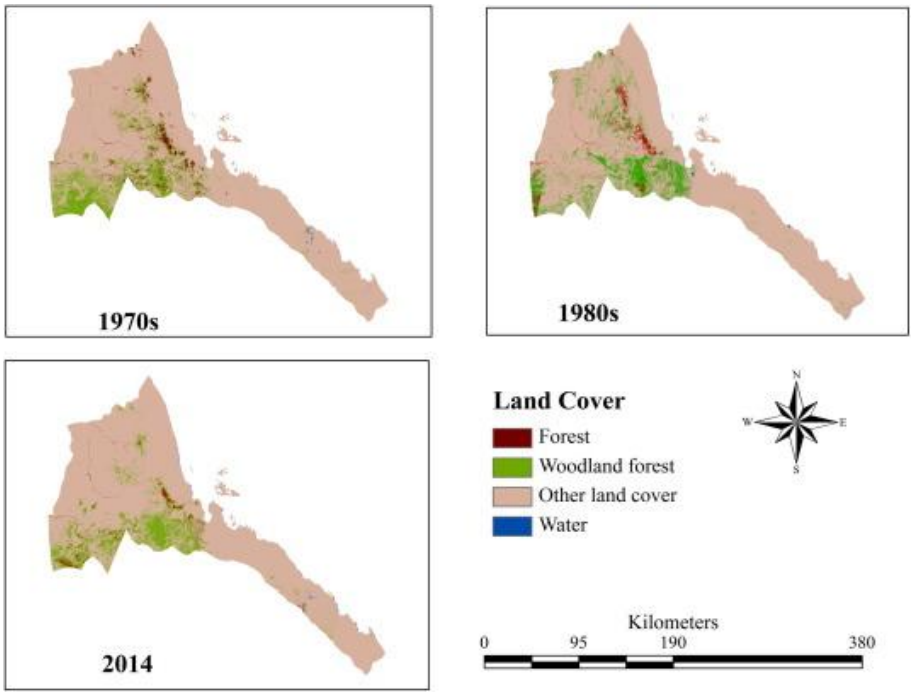


Figure 3-7. Deforestation in Eritrea

There is no doubt that the forest has a large impact from a public health perspective. Forests have the ability to purify water and air pollution which are connected to illnesses like diabetes. In this section, we will figure out the correlation between deforestation and diabetes by relating forest's ability.

3.2.2. (a) Rainfall

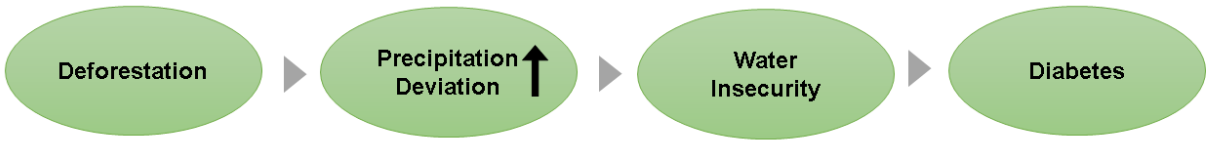


Figure 3-8. How Deforestation affects Diabetes

The recent study shows as deforestation progresses, rainy season onset has been increasingly delayed over time. In areas that are more heavily deforested, there is a higher probability of longer dry spell events which leads to a water deficit(Leite-Filho, 2019). It means dry spells which caused by deforestation can affect in a negative way on water security (Breinl, 2020). Nobre, an Earth System scientist from Brazil said “In areas with high deforestation, shown clearly, the beginning of the rainy season is delayed by one to two weeks compared to non-deforested areas, and the dry season is drawn out.”(Hanbury, 2020). In addition, severe precipitation deviation caused by deforestation. A wet spell that follows the dry season also has a negative impact on water security. The deforested watershed which is accompanied by land-cover change reinforced the impact of heavy rainfall on drinking water quality (Bastaraud, 2020).

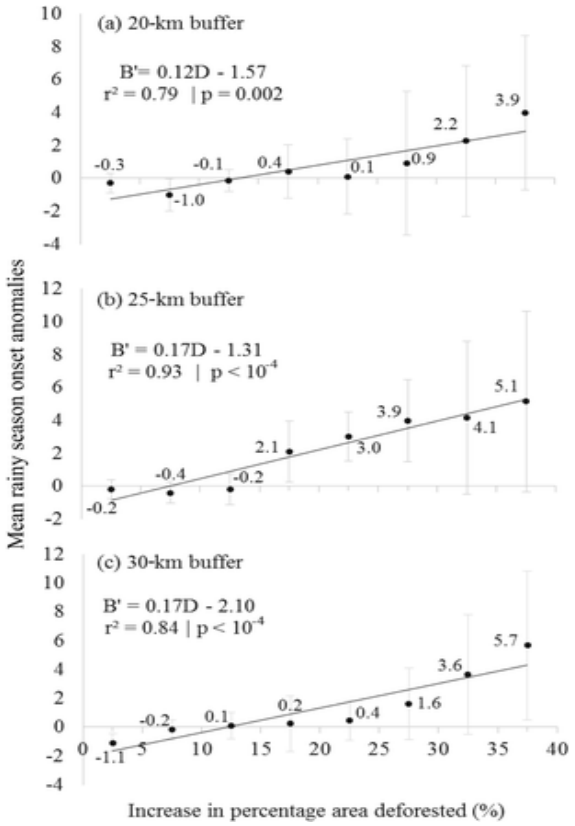


Figure 3-9. Correlation between Mean rainy season onset anomalies and Increase in percentage area deforested

From a global perspective, there is an extreme rainfall and it’s predicted to be intensified by climate change (Bastaraud, 2020). This regimes of extreme rainfall are likely to be associated with drinking water contaminations. This is the reason why they both are important for urban water management for example in the design of water storage components (Romps, 2022).

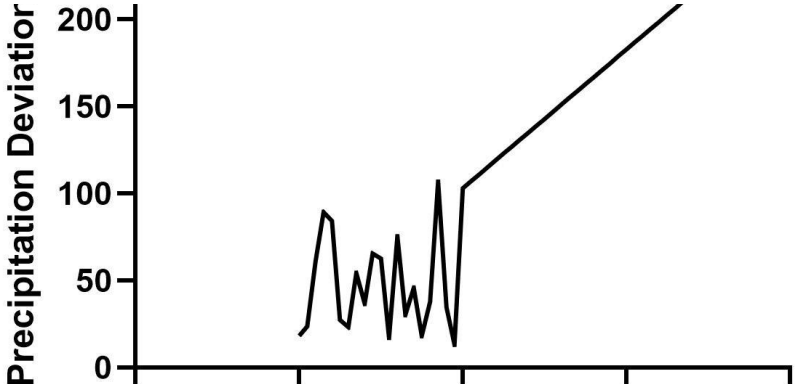


Figure 3-10. Precipitation Deviation in Eritrea

Eritrea is subject to harsh climatic conditions, including cyclical drought and flooding during rainy seasons (ACAPS, 2022). According to the results that we analyzed the Precipitation Deviation in Eritrea, there is a tendency that would escalate as time goes by. This means a threat to water resources would be increased in Eritrea.

As mentioned above, the freshwater source is much important when wanting to deal with Diabetes and Eritrea has a lot of people who are living with this disease. As much as it's almost impossible to address diabetes without water, we have to focus on climate change—deforestation and extreme rainfall—which is the bedrock risk factor for water insecurity.

Drinking water is important for everyone, but it's much more important for people who are living with diabetes because even a little dehydration can have a notable impact on them.("Drinking Water", 2020) Diabetes occurs when the body doesn't produce enough insulin, creating extra sugar in your blood, and your kidneys work overtime to filter and absorb the excess sugar. If your kidneys are overworked, the Mayo Clinic says, your body expels the excess sugar in your urine, which in turn drags fluids from your tissues. This makes you urinate more often, and that could leave you dehydrated. Drinking more fluids quenches your thirst, but it also makes you urinate even more, which could leave you even more dehydrated. This is why diabetes patients are more prone to dehydration ("Staying Hydrated", 2019) and why we have to mention the freshwater source when addressing this disease.

3.3.2. (b) Air Pollution

According to Eritrea's Air Quality Policies research (UNEP, 2015), there is no sufficient electricity and infrastructure. Instead, people in Eritrea usually use firewood for living which causes CO2 emission and leads to air pollution. Decrease in forest area also means that there are no trees to purify air quality. According to the report, Eritrea shows a limited number of regulations on air pollution. There are no incentives for energy efficiency, restriction on automobile emissions, and legal framework for waste combustion. Overall, the absence of such a legal system makes it difficult for Eritrea to control and manage air pollution (Frumkin, 2019).

Studies reveal an association between exposure to air pollution and diabetes risk although the evidence may not be conclusive. According to the 2016 survey, ambient PM 2.5[1] brought about 3.2 million cases of diabetes and 206,000 deaths from diabetes (Frumkin, 2019). The risk of diabetes increases with the chemical constituents of air pollutants. The mechanism of air pollution and diabetes development can be explained by increasing the risk of insulin resistance in the human body, which leads to type 2 diabetes. A study infers that the children who were more exposed to air pollution got greater level of insulin resistance.

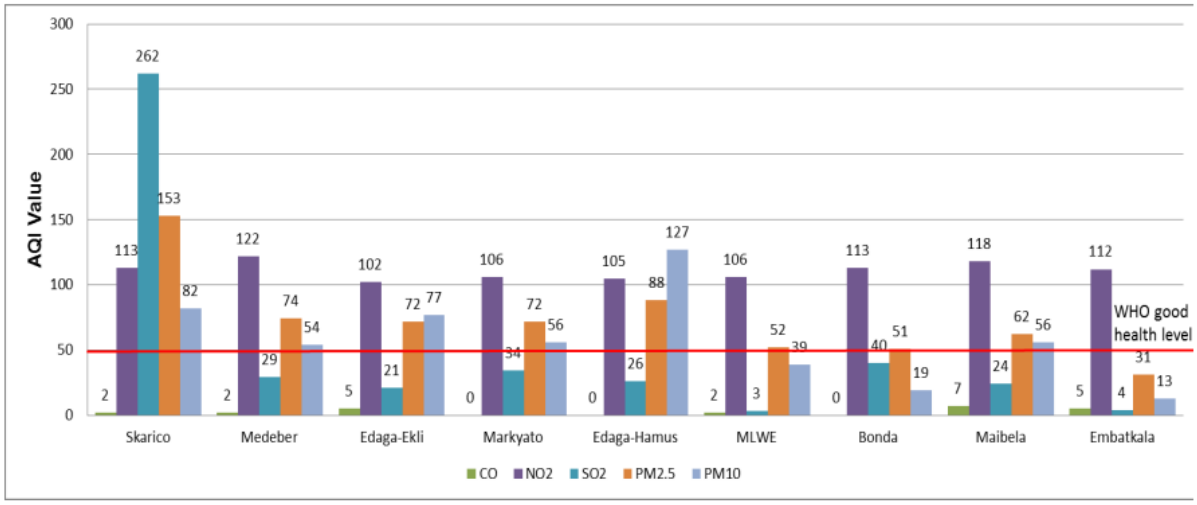


Figure 3-11. Comparison of Pollutants in Asmara with WHO AQI Standard (Eritrea, 2021)

The Ministry of Land, Water and Environment reported that air pollution concentration in Asmara, capital of Eritrea, is higher than the standard recommended by the WHO (Eritrea, 2021). Eritrea has high NO2– indicated with purple bar– levels (Figure 3-11). Higer NO2 level leads to greater insulin resistance. It means that the greater the risk of diabetes. CEIC reported the 2016 mean annual PM 2.5 data was higher(50.514 mcg/Cub m) than 2015 (50.17mcg/Cub m). The Statistical data proved that Eritrea's air pollution situation can be considered as one of the affecting factors in diabetes.

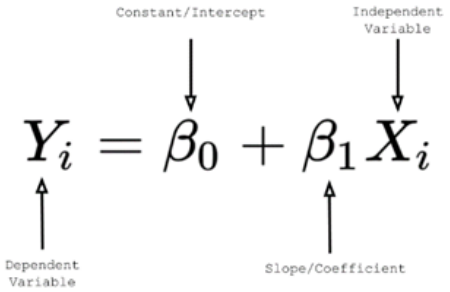
3.3 Predictions and Scenario

We used statistical methods to predict values of selected 11 –3 climate related and 8 diabetes related–features:

- Climate related: forest area, precipitation, temperature
- Diabtes related: ischaemic heart disease, hypertensive heart disease, diabetes mellitus, gallbladder and biliary disease, liver cancer, kidney cancer, pancreas cancer, gallbladder and biliary tract cancer, pancreatitis.

[1] PM 2.5 refers to fine dust under the particle size of 2.5 μm

Linear regression attempts to model the relationship between two variables by fitting a linear equation to observed data. Linear regression shows the linear relationship[2] between two variables, which is formulized as below:



For training data, we used data from 2000 to 2019 and set the learning rate as 0.01. To solve the problem of underfitting, we used monthly data to increase the data size and in the end, enhance overall prediction accuracy. For every iteration, we updated the regression coefficient until it converges to a certain value. We minimized cost value by trial and error, trying lots of values and visually inspecting the resulting graph.

Gradient Descent is a general function for minimizing a function. In our research, we used the Means Squared Error cost function. We start by initializing θ_0(=β_0) and θ_1 (=β_1) to any two values. Formally, the algorithm[3] updates value as follows:

$$\theta_j := \theta_j - \alpha \frac{\partial}{\partial \theta_j} J(\theta_0, \theta_1) \quad (\text{for } j = 0 \text{ and } j = 1)$$

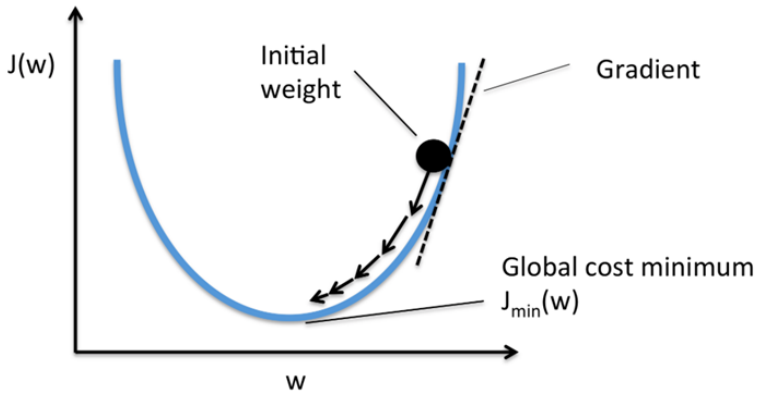


Figure 3-12. Gradient descent

[2] 0 is a constant, 1 is the regression coefficient

[3]

Using this concept our linear regression formula can be represented as follows.

$$\text{repeat until convergence } \{$$
$$\theta_0 := \theta_0 - \alpha \frac{1}{m} \sum_{i=1}^{m} \left(h_\theta(x^{(i)}) - y^{(i)}\right)$$
$$\theta_1 := \theta_1 - \alpha \frac{1}{m} \sum_{i=1}^{m} \left(h_\theta(x^{(i)}) - y^{(i)}\right) \cdot x^{(i)}$$
$$\}$$

Our regression coefficients converge to the point where J(w) is minimized which can be viewed from the graph above.Where h(x) is cost value and y(x) is expected value.

Using this equation we predicted the possible feature(Ischaemic heart disease, Hypertensive heart disease, Diabetes mellitus, Gallbladder and biliary diseases, Liver cancer, Kidney cancer, Pancreas cancer, Gallbladder, and biliary tract cancer, Pancreatitis) value for years 2022 to 2050 which are listed in below table.

	Forest area	Precipitation	Temperature	chaemic heart disea	ertensive heart dise	Diabetes mellitus
2020	10.44811881	103.0248947	27.02237237	2242.037368	949.4727368	973.2299474
2021	10.41683168	107.0105038	27.11756974	2284.026023	961.9793308	986.5624662
2022	10.38554455	110.9961128	27.21276711	2326.014677	974.4859248	999.894985
2023	10.35425743	114.9817218	27.30796447	2368.003331	986.9925188	1013.227504
2024	10.3229703	118.9673308	27.40316184	2409.991985	999.4991128	1026.560023
2025	10.29168317	122.9529398	27.49835921	2451.980639	1012.005707	1039.892541
2026	10.26039604	126.9385489	27.59355658	2493.969293	1024.512301	1053.22506
2027	10.22910891	130.9241579	27.68875395	2535.957947	1037.018895	1066.557579
2028	10.19782178	134.9097669	27.78395132	2577.946602	1049.525489	1079.890098
2029	10.16653465	138.8953759	27.87914868	2619.935256	1062.032083	1093.222617
2030	10.13524752	142.880985	27.97434605	2661.92391	1074.538677	1106.555135
2031	10.1039604	146.866594	28.06954342	2703.912564	1087.045271	1119.887654
2032	10.07267327	150.852203	28.16474079	2745.901218	1099.551865	1133.220173
2033	10.04138614	154.837812	28.25993816	2787.889872	1112.058459	1146.552692
2034	10.01009901	158.8234211	28.35513553	2829.878526	1124.565053	1159.885211
2035	9.978811881	162.8090301	28.45033289	2871.86718	1137.071647	1173.217729
2036	9.947524752	166.7946391	28.54553026	2913.855835	1149.578241	1186.550248
2037	9.916237623	170.7802481	28.64072763	2955.844489	1162.084835	1199.882767
2038	9.884950495	174.7658571	28.735925	2997.833143	1174.591429	1213.215286
2039	9.853663366	178.7514662	28.83112237	3039.821797	1187.098023	1226.547805
2040	9.822376237	182.7370752	28.92631974	3081.810451	1199.604617	1239.880323
2041	9.791089108	186.7226842	29.02151711	3123.799105	1212.111211	1253.212842
2042	9.75980198	190.7082932	29.11671447	3165.787759	1224.617805	1266.545361
2043	9.728514851	194.6939023	29.21191184	3207.776414	1237.124398	1279.87788
2044	9.697227722	198.6795113	29.30710921	3249.765068	1249.630992	1293.210398
2045	9.665940593	202.6651203	29.40230658	3291.753722	1262.137586	1306.542917
2046	9.634653465	206.6507293	29.49750395	3333.742376	1274.64418	1319.875436
2047	9.603366336	210.6363383	29.59270132	3375.73103	1287.150774	1333.207955
2048	9.572079207	214.6219474	29.68789868	3417.719684	1299.657368	1346.540474
2049	9.540792078	218.6075564	29.78309605	3459.708338	1312.163962	1359.872992
2050	9.50950495	222.5931654	29.87829342	3501.696992	1324.670556	1373.205511

Table 3-1. Possible feature value for years 2022 to 2050

	Gallbladder and bil	Liver cancer	Kidney cancer	Pancreas cancer	Gallbladder and bil	Pancreatitis
2020	113.7456316	69.59668421	35.63610526	18.688	17.69994737	40.06405263
2021	116.2102632	70.17479699	36.35978195	19.025	17.96760902	40.57753383
2022	118.6748947	70.75290977	37.08345865	19.362	18.23527068	41.09101504
2023	121.1395263	71.33102256	37.80713534	19.699	18.50293233	41.60449624
2024	123.6041579	71.90913534	38.53081203	20.036	18.77059398	42.11797744
2025	126.0687895	72.48724812	39.25448872	20.373	19.03825564	42.63145865
2026	128.5334211	73.0653609	39.97816541	20.71	19.30591729	43.14493985
2027	130.9980526	73.64347368	40.70184211	21.047	19.57357895	43.65842105
2028	133.4626842	74.22158647	41.4255188	21.384	19.8412406	44.17190226
2029	135.9273158	74.79969925	42.14919549	21.721	20.10890226	44.68538346
2030	138.3919474	75.37781203	42.87287218	22.058	20.37656391	45.19886466
2031	140.8565789	75.95592481	43.59654887	22.395	20.64422556	45.71234586
2032	143.3212105	76.53403759	44.32022556	22.732	20.91188722	46.22582707
2033	145.7858421	77.11215038	45.04390226	23.069	21.17954887	46.73930827
2034	148.2504737	77.69026316	45.76757895	23.406	21.44721053	47.25278947
2035	150.7151053	78.26837594	46.49125564	23.743	21.71487218	47.76627068
2036	153.1797368	78.84648872	47.21493233	24.08	21.98253383	48.27975188
2037	155.6443684	79.4246015	47.93860902	24.417	22.25019549	48.79323308
2038	158.109	80.00271429	48.66228571	24.754	22.51785714	49.30671429
2039	160.5736316	80.58082707	49.38596241	25.091	22.7855188	49.82019549
2040	163.0382632	81.15893985	50.1096391	25.428	23.05318045	50.33367669
2041	165.5028947	81.73705263	50.83331579	25.765	23.32084211	50.84715789
2042	167.9675263	82.31516541	51.55699248	26.102	23.58850376	51.3606391
2043	170.4321579	82.8932782	52.28066917	26.439	23.85616541	51.8741203
2044	172.8967895	83.47139098	53.00434586	26.776	24.12382707	52.3876015
2045	175.3614211	84.04950376	53.72802256	27.113	24.39148872	52.90108271
2046	177.8260526	84.62761654	54.45169925	27.45	24.65915038	53.41456391
2047	180.2906842	85.20572932	55.17537594	27.787	24.92681203	53.92804511
2048	182.7553158	85.78384211	55.89905263	28.124	25.19447368	54.44152632
2049	185.2199474	86.36195489	56.62272932	28.461	25.46213534	54.95500752
2050	187.6845789	86.94006767	57.34640602	28.798	25.72979699	55.46848872

Table 3-2. Possible feature value for years 2022 to 2050

Based on this table, following graph represents overall predicted value of each feature.

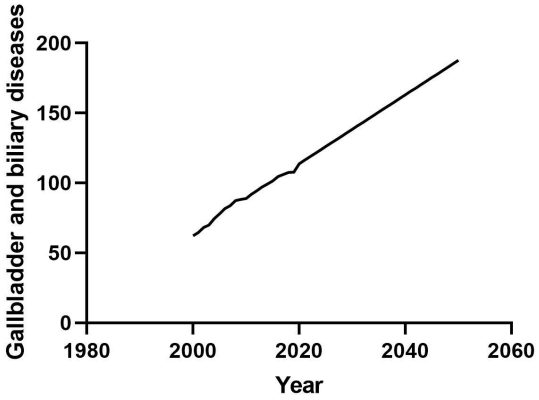


Figure 3-13. Incidence frequency of Gallbladder and biliary diseases per 20 years

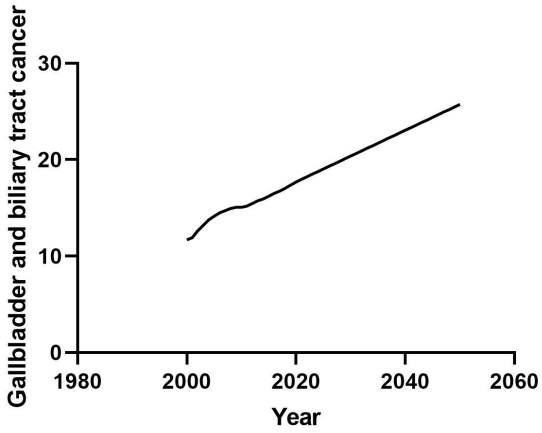


Figure 3-14. Incidence frequency of Gallbladder and biliary tract cancer

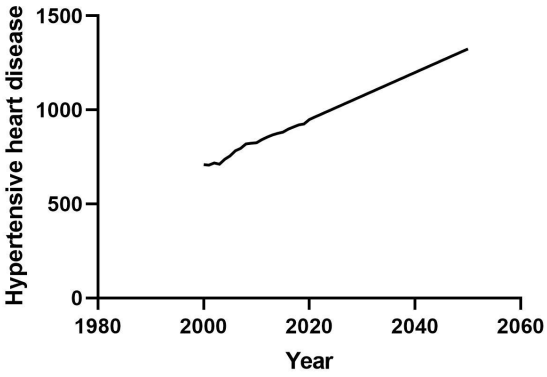


Figure 3-15. Incidence frequency of Hypertensive heart disease per 20 years

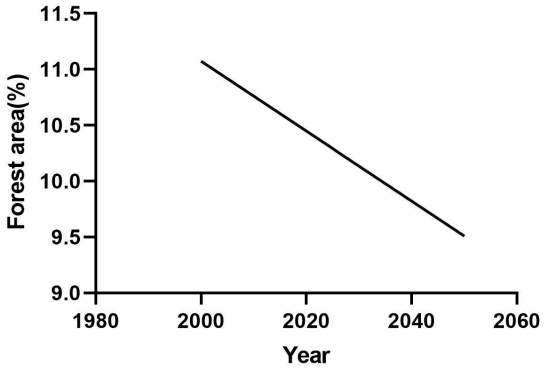


Figure 3-16. Proportion of forest area per 20 years

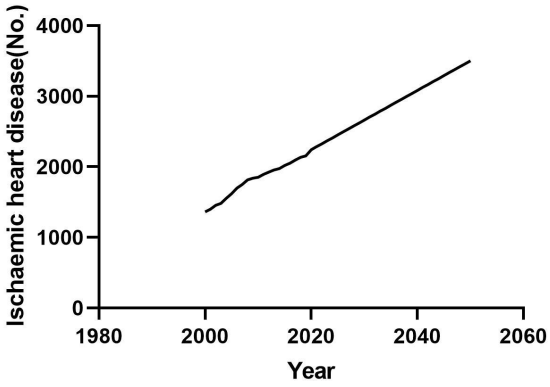


Figure 3-17. Number of Ischaerric heart disease per 20 years

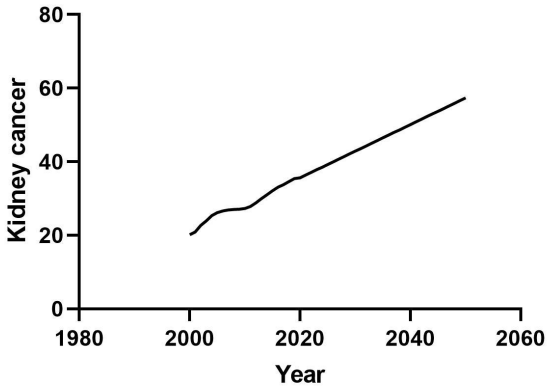


Figure 3-18. Incidence frequency of Kidney cancer per 20 years

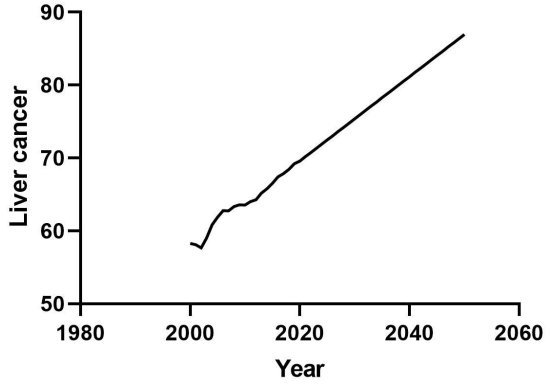


Figure 3-19. Incidence frequency of Liver cancer per 20 years

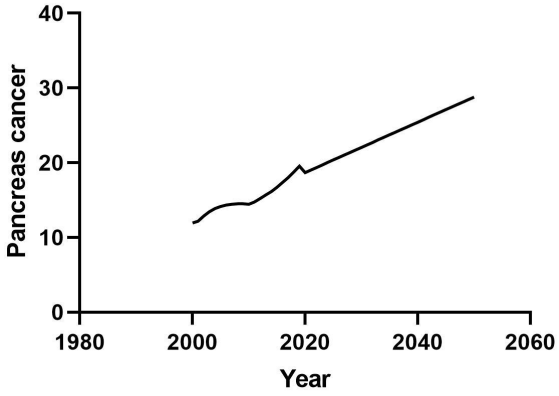


Figure 3-20. Incidence frequency of Pancreas cancer per 20 years

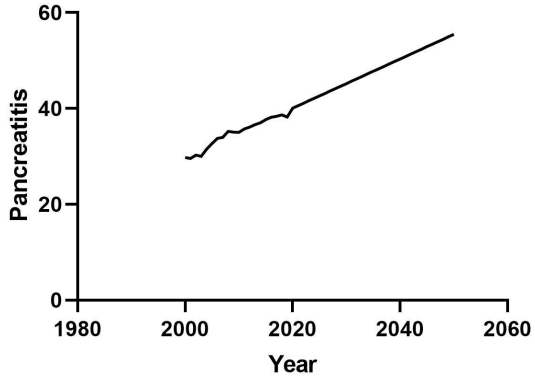


Figure 3-21. Incidence frequency of Pancreatitis per 20 years

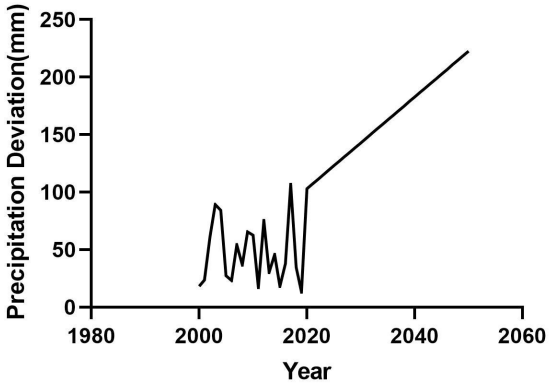


Figure 3-22. Precipitation deviation per 20 years

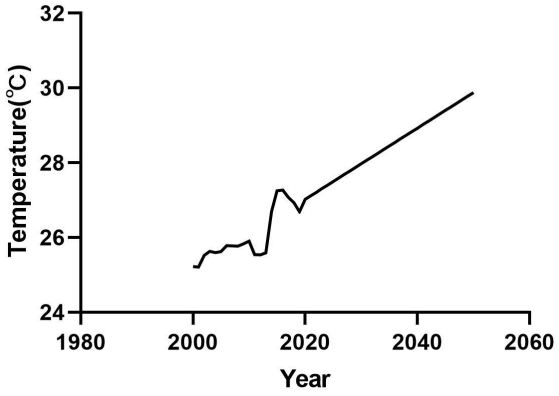
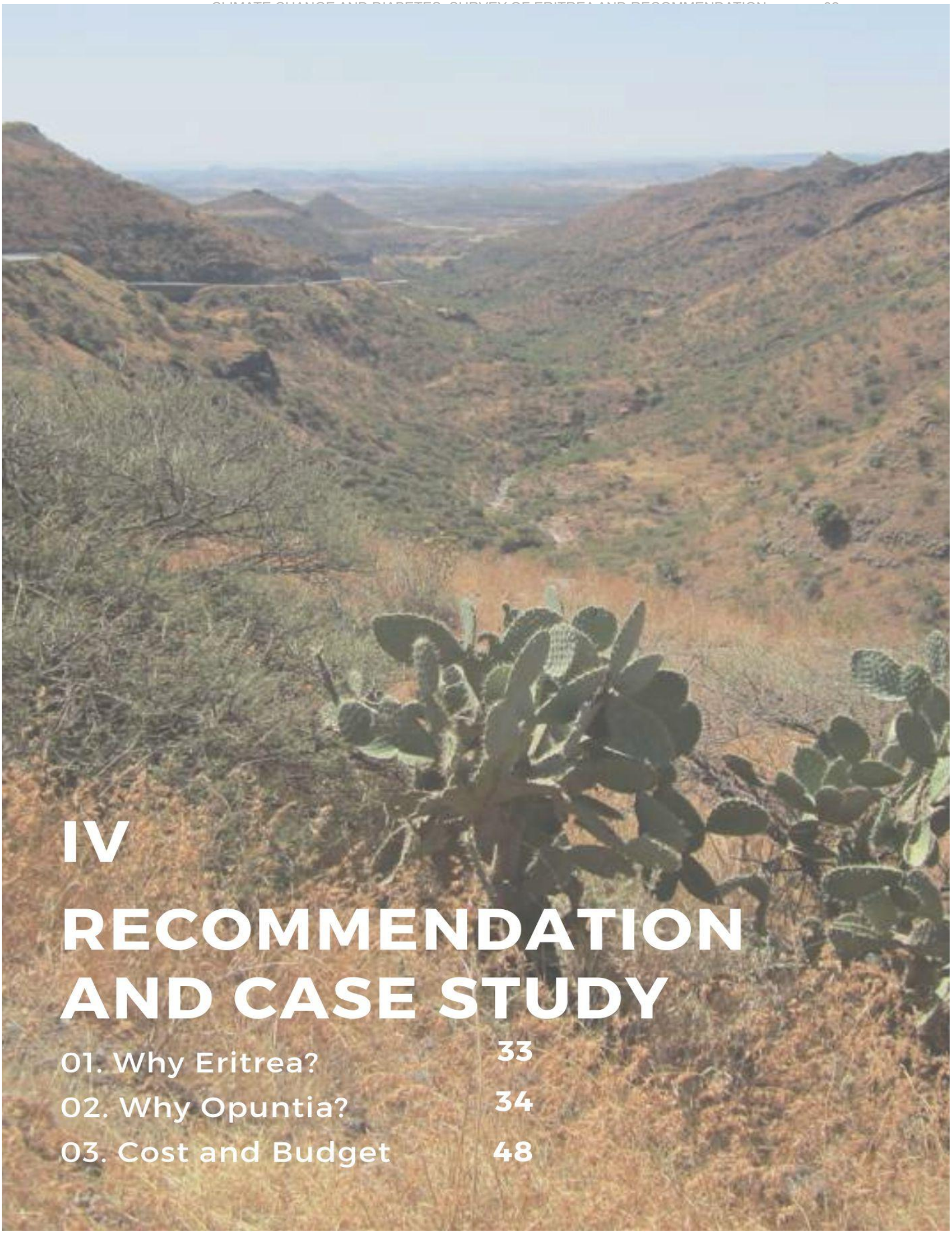


Figure 3-23. Temperature per 20 years



IV RECOMMENDATION AND CASE STUDY

Dear policymakers in Eritrea,

4.1 Why Eritrea?

4.1.1 Type 2 Diabetes & Environmental Condition

As discussed above, diabetes is one of the most common diseases in Eritrea. This disease specifically correlated with deforestation and the temperature rise, ended up arousing the climate crisis. Yet, due to its coarse atmosphere– lack of infrastructure and low GDP–, Eritrea has not been able to adopt an appropriate policy so far. To address a solution that can be applied on a local scale in Eritrea, demographic labor force is taken into consideration. About 80 percent of the poor in rural areas depend on agriculture for their daily income (IFAD). In accordance with the workforce dominance in agriculture, we suggest an alternative crop where Eritreans can resolve the food security problem while finding a decent job opportunity.

Image 4-1. Eritrean Agriculture

4.1.2 What Eritrean Government Wants (Estimation)

According to the article from the ministry of agriculture in Eritrea (MoA) published in August 2021, the government is looking for alternative crops and plants that are resilient to the extreme weather changes in Eritrea. Unpredictable weather conditions are the significant causes of crop failures in Eritrea. The paper mentioned that the succulent prickly pear is suitable for Eritrea as an alternative crop since it is less likely to be affected by Eritrea's erratic and torrential rainfall patterns. Finding new crops, such as cactus, is essential for Eritrea to ensure the country's food security. The article mentioned the people and Government of Eritrea increasingly recognized the economic benefits of prickly pears.

Nonetheless, there is still a lack of means to mass-produce and commercialize available resources. According to the Ministry of Agriculture, less than 25% of wild cactus plants are currently used, although cacti covers 18000 hectares of land. Therefore, Eritrea needs to fully exploit its resource of cactus and develop its capacities to produce prickly pears by adding values. It is time to get support from other countries or organizations with well-developed cactus plants. Technologies and knowledge of growing methods, value addition systems, and marketing strategies will be greeted in Eritrea (Asmelash, 2021).

4.2 Why Opuntia?

4.2.1 What is Opuntia?

Opuntia or more commonly known as prickly pear cactus originated from North and South America. It is found in arid to semi-arid locations with well-drained soil and high level of sunshine. It is resistant to damage by animals and highly salt-tolerant, making it very resilient against natural changes in its surrounding. They have flat paddle-shaped stem and grow round fruit, which is edible. The stems and spines contain low level of toxins and could irritate one's skin when on contact. However, its poison is not fatal and the irritation usually goes out of one's system quickly in a matter of a few days. Additionally, while opuntia has various health benefits, those interested in cultivating them should be mindful of its invasive characteristic.

4.2.2 Diabetes (Nutrition, Benefit)

4.2.2. (a) Types of Diabetes

Although type 1 and type 2 diabetes may sound similar, they are different diseases with unique causes. The key difference between type 1 and type 2 diabetes is that type 1 is believed to be caused by an autoimmune reaction and develops early in life. Type 2 diabetes develops over the course of many years and is related to lifestyle factors such as being inactive and carrying excess weight. It's usually diagnosed in adults. Risk factors for type 1 diabetes are not as clear.

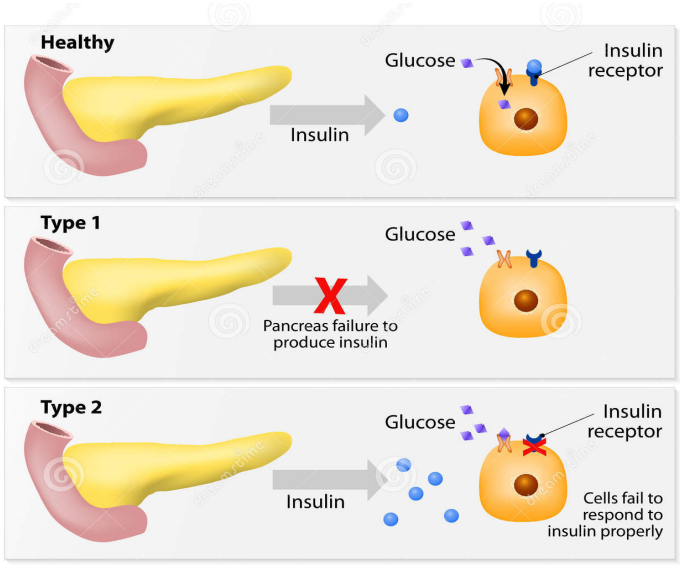


Figure 4-1. The key difference between type 1 and 2 diabetes

Causes of type 1 diabetes: The body's immune system is responsible for fighting off foreign invaders, such as harmful viruses and bacteria. Type 1 diabetes is believed to be caused by an autoimmune reaction. In people with type 1 diabetes, the immune system mistakes the body's own healthy cells for foreign invaders. The immune system attacks and destroys the insulin-producing beta cells in the pancreas. After these beta cells are destroyed, the body is unable to produce insulin. Research into autoimmune diseases is ongoing. Diet and lifestyle habits do not cause type 1 diabetes.

Causes of type 2 diabetes: People with type 2 diabetes have insulin resistance. The body still produces insulin, but it's unable to use it effectively. Researchers aren't sure why some people become insulin resistant and others don't, but several lifestyle factors may contribute, including being inactive and carrying excess weight. Other genetic and environmental factors may also play a role. When you develop type 2 diabetes, your pancreas will try to compensate by producing more insulin. Because your body is unable to effectively use insulin, glucose accumulates in your bloodstream.

Both types of diabetes are chronic diseases that affect the way your body regulates blood sugar or glucose. Glucose is the fuel that feeds your body's cells, but to enter your cells it needs a key. Insulin is that key. People with type 1 diabetes don't produce insulin. People with type 2 diabetes don't respond to insulin as well as they should and later in the disease often don't make enough insulin. Both types of diabetes can lead to chronically high blood sugar levels. That increases the risk of diabetes complications. Our team focused on decreasing type 2 diabetes.

4.2.2. (b) Optunia's Effect on Diabetes

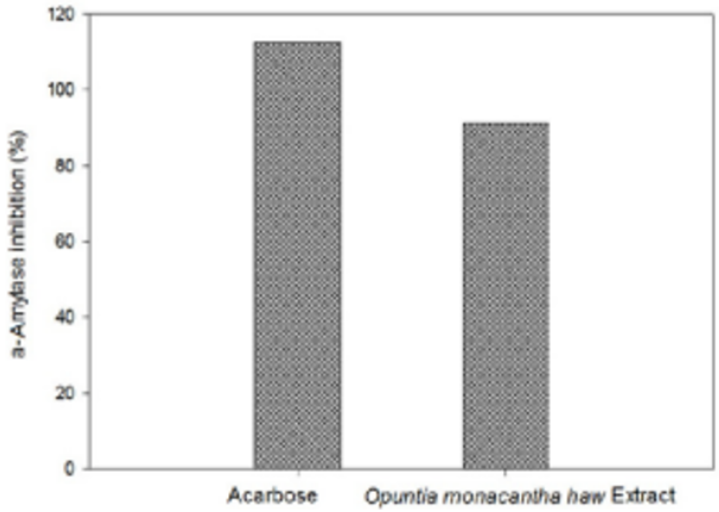


Figure 4-2. a-amylase inhibitory activity

Opuntia belongs to the cactus family, which blooms from April to May every year and ripens purple fruits from November to December. Opuntia is short, vital, and easy to grow among cacti. Opuntia contains about 5% phenolic and flavonoid, which have anti-cancer effects and anti-mutant effects, and various minerals and amino acids that function as nutritional tonic, and have a particularly great effect on diabetes.

The decrease in serum glucose levels observed upon ingestion of Opuntia may be due to two different mechanisms: the postprandial effect attributable to dietary fibers and the hypoglycemic effect due to specific hypoglycemic substances in the ingested plant. While the dietary fiber is neither digested by gastrointestinal enzymes nor absorbed, it does modify the absorption of certain substances such as biliary salts, cholesterol, and glucose.

In a crossover study, Chandalia et al. demonstrated a 10% reduction in 24-hour plasma glucose concentration in patients on a high soluble fiber diet compared with the standard diet previously recommended by the American Diabetes Association. Soluble fibers, such as the large quantities of pectin and mucilage found in the prickly pear cactus, increase the viscosity of food in the gut, slowing or reducing sugar absorption.

Opuntia extract showed antibacterial effects along with strong antioxidant activities, including radical elimination, and flavonoids such as taxifolin were reported to be one compound distribution. In order to analyze the anti-diabetic effect of Opuntia, a-amylase inhibitory activity was observed. Carbohydrates in food are essential enzymes for carbohydrate metabolism in humans, microorganisms, and animals because they are decomposed into sugars that are easily absorbed by a-amylase.

The inhibitor of a-amylase has the advantage of controlling blood sugar by inhibiting the digestion of starch in the small intestine and delaying the absorption of glucose. Figure above shows the a-amylase inhibitory activity of each solvent fraction of the centipede stem. Opuntia's inhibitory activity was expressed as 91.12%. It is thought that opuntia has excellent inhibitory activity of a-amylase, which breaks down a-D-(1,4)-glucan bonds in carbohydrates.

Some research suggests that prickly pear may additionally help control cholesterol levels. In 2003, a study indicated that prickly pear extract might lower LDL but had no effect on levels of HDL cholesterol or triglycerides. Another study at the University of Vienna in Austria found that prickly pear decreased total cholesterol (by 12%), LDL (15%), triglycerides (12%), blood glucose (11%), insulin (11%) and uric acid (10%), while body weight, HDL and other lipid measurements did not change.

Recently, polysaccharides of Opuntia ficusindica (POLOF) and Opuntia streptacantha (POLOS) were isolated and evaluated for their hypoglycemic properties by Alarcon-Aguilar et al. (2003). When each of the two polysaccharides was injected intraperitoneally in healthy mice, no hypoglycemic activity was observed. POLOF administered orally caused a significant hypoglycemic effect in orally-induced hyperglycemic mice. Due to the oral administration of both POLOF and the hyperglycemic-inducing agent, the hypoglycemic effect of POLOF may function similarly to dietary fiber in reducing the intestinal absorption of glucose.

On the other hand, POLOS produced a significant decrease in serum glucose levels in mice with subcutaneously-induced hyperglycemia. Considering that subcutaneously-induced hyperglycemia bypassed the intestinal absorption of glucose, POLOS may be a hypoglycemic agent possibly working by increasing insulin sensitivity, as previously hypothesized by FratiMunari, Del Valle-Martinez et al.

4.2.2. (c) Health Effects of Opuntia

Nutrition	Existence	Nutrition	Amount
Vitamin C	O	Calories	42g
Vitamin E	O	Protein	1g
Vitamin K	O	Fat	0.59
Beta-carotene	O	Carbohydrates	10g
Potassium	O	Fiber	4g
Magnesium	O	Sugar	0g
Calcium	O	Cholesterol	0mg
Phosphorus	O	Sodium	5mg

Table 4-1. Nutrition of Opuntia

Opuntia has various nutrients which are good for health. Potassium and betalains help to improve digestion and food absorption because they are anti-inflammatory. Except for the nutrition table above, opuntia contains amino acids, fatty acids, and antioxidants which protect cells and help to reduce triglycerides and bad cholesterol levels in the human body (WebMD, 2020).

4.2.3 Climate Change

4.2.3. (a) Environmental Effects

Known as one of the CAM plants (agaves and cacti), cacti are beneficial to the environment. The first environmental contribution concerns its potential for carbon capture or carbon sequestration. Carbon dioxide emissions are one of the leading causes of climate change worldwide. In other words, any material that solves the carbon dioxide can serve as a potential source in the future. CAM plants generate high biomass with less water than C3 or C4 plants; You can also think of it in a structure of CAM photosynthetic pathway. CAM's pathway is more efficient in converting water and CO2 to plant dry matter. The temperature heavily affects the upshots of nocturnal gas exchange; At night, temperature decreases reducing the internal water vapor concentrations in CAM plants. This also contributes to water efficiency. Thus, We can infer that CAM species are the ideal plants for arid and semi-arid habitats. Considering that Eritrea is a country that suffers from drought and still anticipate the same problem, CAM plants' water efficiency can be a great strength for Eritrea.

Treatment	Natural rangeland	Barley crop (alone)	Cactus crop (alone)	Alley cropping (cactus + barley)
Above-ground biomass (tonnes ha^{-1})	0.51	0.53	1.87	7.11
Underground biomass (tonnes ha^{-1})	0.33	0.11	1.8	1.98
Barley grain yield (tonnes ha^{-1})	1.51	0.82		2.32
Barley grain + straw + weeds (tonnes ha^{-1})	1.36	4.24		6.65

[a] Average rainfall in Sidi Bouzid is 250 mm $year^{-1}$. All treatments were without fertilizers.

Table 4-2. Total biomass changes and barley crop yields in Sidi Bouzid

Cacti's strong vitality will also help them adjust to an unstable environment like Eritrea. They are grown to absorb the carbon and is built on large scale in areas where precipitation is inadequate or unreliable. They can grow where evaporation is so great that rainfall is ineffective for crop growth (Osmond et al., 2008). C3 and C4 plants suffer irreparable damage once they lose 30% of their water content, while many cacti can survive an 80-90% Cactus ecosystem goods and services 166 loss of their hydrated water content and still survive. This is due to the ability of CAM plants to store large quantities of water; to shift water around among cells and keep crucial metabolism active; and to tolerate extreme cellular dehydration (Nobel, 2009). The thickness of cacti helped them not only store the water but also keep them vital even with the unstable precipitation rate.

4.2.3. (b) Food and Water Insecurity

Under the continuous threat of climate change, how to achieve food security without compromising the natural resource base is one of the great challenges for underdeveloped countries.(Inglese, P., 2017) From this perspective, FAO, Food and Agriculture Organization of the United Nations, said the prickly pear cactus will be a key player in food security due to its ability to thrive in arid and dry climates. The reason why they especially pointed out this species is that while most cacti are inedible, Opuntia species have much to offer. This could be the answer to the world's food security woes.

Apart from food, cacti also play an important role in water. It can stores water in its pads, thus providing a botanical well that can provide up to 180 tonnes of water per hectare — enough to sustain five adult cows, a substantial increase over typical rangeland productivity. At times of drought, livestock survival rate has been far higher on farms with cactus plantations. In the future, there will be inevitable pressure on water resources because of climate change. According to Ali Nefzaoui, the researcher for ICARDA (the International Center for Agricultural Research in the Dry Areas), the projected threat to water security makes the cactus one of the most prominent crops in the 21st century. (FAO)

4.2.4 Education (Foraging, Added Value, Recipe)

Mr. Hashim Abdallah, Ambassador to the Public of the United Nations Global Communication Department, said when NGOs or other support groups try to give assistance to underdeveloped countries, they must consider a sustainable way. Short-term assistance means funding or food support. It can not be the solution for developing countries because it exists only for the moment. It's impossible to solve the bedrock of the problems through it.

Thus, we suggest a "sustainable" way. To suggest the Prickly pear cactus as a sustainable long-term assistance, education is essentially needed. Therefore, in this section, we will cover foraging, added value and recipe for the self-sufficiency of Eritrean.

4.2.4. (a) Cultural Practice & Land Farming

Basics

Zones
Generally zones 9-11; some varieties, such as *O. humifusa*, are cold hardy to zone 4

Height/Spread
Varieties range from 6- to 12-inch tall, 18-inch wide low-growing cactus to 10- to 15-foot tall trees.

Exposure
Full sun

Bloom Time
From June to July

Color
Prickly pear flower color varies by type, usually yellow, red or purple. Fruit colors can also vary in shades of green, red and yellow-orange.

Trait
Prickly pear cactus are deer resistant since they have a spiny nature.

When	Cuttings can be started at any time, but if they are planted in summer or spring you may have better results . Seeds should be started in late spring.
Where	Prickly pears grow in well-draining soil where there is full sun.
How	Transplant at the same level as they are currently growing; deeper planting may cause them to rot. Handle carefully, not just for your own safety, but the pads can get top-heavy and break off. An extra pair of hands can be useful because prickly pears can be awkward and heavy to lift and place in the hole.
Other	Wear heavy long sleeves and thick gloves to guard against being poked by a spine or touching the skin-irritating glochids. See more on starting from seed or pad cuttings under Propagation.

Those content above is about the basic information of Opuntia regarding their traits and when, where or how to raise them. By educating those information to Eritrean, harvesting Opuntia could settle down as a part of an Eritrean's agriculture.

CARE

Pruning: It's not necessary to prune prickly pears, but they can be cut back. Remove individual pads as needed to maintain size and shape. Use sharp knife to cut the pad off at the joint or line where it connects to the next pad and tongs to hold them. Pads can be shared with friends or calloused off to be planted elsewhere. See more on propagating below.

Soil: Prickly pears prefer alkaline to neutral soil. More importantly, however, since residual moisture or puddling can cause the plant to rot, the soil needs to drain well.

Amendments & Fertilizer: Fertilize young plants with a balanced 10-10-10 fertilizer. For established plants, a 5-10-10 or even 0-10-10 water-soluble fertilizer will promote more fruit and flowers. Use a fertilizer that is high in nitrogen if you are growing for the pads.

Watering: Prickly pears are extremely drought tolerant. For the first month, don't water newly propagated pads. After that, water every two to four weeks for the first year — twice a month in summer and once a month other times of the year. In most areas, rainfall will be enough to maintain established plants. Supplement in times of drought with the twice-a-month/once-a-month seasonal schedule.

Image 4-2. A new prickly pear growing from a pad cutting. Photo by: Selma Jacquet / Alamy Stock Photo.

Propagation: It may take 3 to 4 years before your plant produces flowers and fruit since initial growth from seed is slow. The seeds need shade to germinate and should be kept moist until that time.

Propagation from pads yields faster results and is much simpler.

Here's how:

- By following the pruning instructions above, pads that are at least 6 months old can be cut off .
- Set the pads out in a dry area with light shade and allow the cut end to form a callus. This prevents the new plant from rotting at the base and can take 2 to 4 weeks in dry , warm weather, longer if it is humid or cool.
- Once fully calloused over, plant pads in a mixture of half sand and half soil at a depth of 1 inch. Your plant can rot, if it is planted any deeper.
- Don't water it for the first month, as there is enough moisture within the pad to maintain itself.
- Prop it up with rocks or other means of support until roots grow over the next month or so. After a month, there should be enough roots that your plant can erect on its own, but continue the support if it's still a little wobbly.
- You can follow the watering guidelines above and water it at this time as well, making sure to let it dry out completely in between.

On new plants, fruit and flowers will usually appear by the second or third pad that grows.

Diseases and Pests: Prickly pears don't normally suffer from insect problems or any severe diseases, although they can be affected by rot if grown with poor drainage. (Hagen, 2022)

4.2.4. (b) Added Value

Opuntia has a variety of added values. Opuntia can be processed into other forms of food as well as used as daily necessaries. The various uses of Opuntia will play an important role in Eritrean's livelihood by increasing their economic power and farm efficiency.

Cladodes	By-products
Pickles	Pigments from the peel
Dressing	Dietary fiber
Candy	Soap
Marmalades	Shampoo
Flour	Body cream
Alcohol	Gel reductive
Beverages	
Bread	
Tortillas (Mexican food)	
Sauces	
Cake	
Jelly	
Source: Vigueras and Portillo, 2002	

Table 4-3. Added Value of Opuntia (Louhaichi,m.,2015)

The fruit and stems can be processed as marmalades, juice, candy, patties, salad, pickles, nectars, jams, dehydrated sheets, cookies, flour, bread, crystallizations, soup, and various other preparations.

Its by-products are soap, shampoo, body cream, gel reductive and other products.

Opuntia can also be used as livestock feed. This add value of Opuntia is good for Eritrea, an arid and semi-arid area where grain is difficult to grow, to increase forage production. With proper management, Opuntia and Nopalea varieties have been reported to be able to produce 50-60 times more forage per unit area than food native to semi-arid pastures. This can be a great alternative to livestock feed considering Eritrea's climate, global food problems and grain prices. (Louhaichi,m.,2015)

Case Study : Prickly Pear Seed Oil Export from Algeria

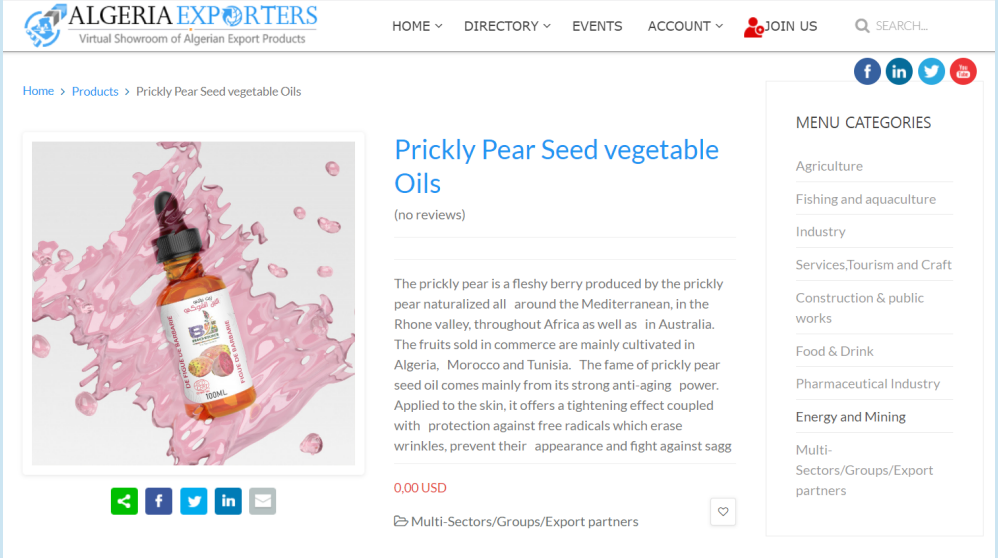


Image 4-3. Prickly Pear Seed vegetable Oils from Algeria

Algeria has its first cactus pear processing unit. The country formed a cooperative to begin cultivating the prickly pear in 2013. This cooperative consists of farmers, scientists, and traders. They built their first processing factory in 2015, and another one in 2018. The infrastructure − based in Sidi−Fredj and covering 5,000㎡ − can transform about 2 tonnes an hour. The processing plant became an important means of income improvement for the inhabitants. One of its principal functions is the production of essential oils extracted by prickly pear cactus. The other functions include the packaging of cactus pear, and the production of pharmaceuticals, juice, jam, and livestock feed (Inglese,P., 2017).

4.2.4. (d) Cactus Into Biofuel

One of the major downsides of planting the prickly pear cactus is it can be highly invasive. Cactus have a sweet juicy fruit that attacks livestock to eat, but its spines are dangerous for them, as shown in image 4-4. The spines make animals challenging to eat, blinding them or damaging tongues and even digestive systems. (Kibet, R., 2020)

There are several cases of turning invasive cacti into fuel cooperating organizations and governments in other countries such as Kenya and Mexico. It can be one of the valuable technologies for Eritrea since it would be a method to control unnecessary cactus and produce biofuels that can replace firewood in the household. We will focus on and analyze the case of Kenya since its technologies would be feasible to introduce to Eritrea, considering conditions, applied subjects, and processes. (Langat, A.,2021)

Image 4-4. A goat feeds on prickly pear

Case Study: Kenya

In Kenya, the prickly pear cactus has taken over thousands of hectares of grazing land. It threatens much livestock that feeds on them, which would be a significant concern for herders in Kenya. NGOs and scientists cooperated in fighting back against the invasive cactus and turned them into biofuel. It is not only practical to reduce the number of exotic cacti but also economically vulnerable to households. The Twala Tenebo Cultural Women's Group gathered more than 200 women and participated in a program cooperating with NGOs, government officials, and local groups. The process of producing biofuel for cooking is as follows. After the chaff-cutter grinds the whole plant down, as shown in image 4-5, it is mixed with water and cow dung if possible. For the bacteria to act on the green matter, the gas is fermented for 21 days, like in image 4-6. Finally, the gas is produced and transported to a storage bag for household cooking (Langat, 2021).

Image 4-5. Crushing plants using the chaff-cutter grind

Image 4-6. A woman who refills a biogas digester with prickly pear pulp

4.2.4. (e) Prickly Pear Cactus Recipes

Introducing the recipes of prickly pear cactus is also essential to households to increase the effectiveness of using this plant. We will explain the best method for picking them and several recipes that can be useful to households to eat prickly pear cactus.

The morning is the best time to pick cacti since they contain a more citrus taste. The younger pads are more suitable to use than the older pads because of the different and less desirable taste; they are also easier to peel and work with. For the storage method, generally, it cannot be stored fresh in a refrigerator for more than a week. However, the juice or fruits can be frozen for further use, and the pads can be stored as sliced and pickled in a refrigerator.

The following are several recipes from the Conservation Aides at the Southern Nevada Field Laboratory (Bishop, 2022, p.1).

- Prickly Pear Lemonade
  - Ingredients: 1/4 cup cactus juice, two lemons, 3 cups sugar, and 4 1/2 cups water
  - Directions: combine the juices, add the sugar, and stir. Once the sugar is dissolved, add the water (Bishop, 2022, p.1).

Image 4-7. Prickly Pear Lemonade (Bremner, 2021)

- Cactus Jelly
  - Ingredients: 4 cups cactus fruit juice (½ lemon juice can be substituted if desired), 5 cups sugar, and 2 packages of pectin
  - Directions: put juice in a large pot and bring to a hard boil. Add sugar and boil for an additional three minutes or until the mixture becomes a gel. Pour the mix into sterilized jars and seal (Bishop, 2022, p.1).

Image 4-8. Prickly Pear Jelly (Texan, 2009)

- Grilled Nopales
  - Ingredients: cactus nopales, and olive oil
  - Directions: take the prepared nopales after being cut, brush olive oil onto the skin, and grill to the desired level of tenderness (Bishop, 2022, p.1).

Image 4-9. Grilled Nopales (Watson, 2021)

- Stuffed Nopales
  - Ingredients: 8 pads, 1 garlic clove peeled and cut in halves, 1 medium onion peeled and chopped thinly, 8 slices cheese. (Pepper Jack or Mexican cheese will make a sharper taste, while Gouda or cheddar will be milder.) 1/2 cup flour, 3 eggs cracked and separated, 1 cup olive or corn oil, Salt as desired, Tomato sauce or salsa if desired
  - Directions: Despine the paddles. Put the cactus paddles and garlic in a large pot with water, cover and bring to a boil. Boil for about 15 minutes until the pads are tender but not mushy. Drain and rinse the pads.

    Next, fillet the pads by cutting them in half horizontally, but leave the last inch of the paddle where it would connect to the main plant uncut. Stuff the pads with the cheese and onion. Drag the pads through the flour and set aside.

    Beat the egg whites into a stiff peak and gently stir in the remaining yolks. Heat the oil. Dip the pads into the egg mixture and fry. Serve with additional sauce if desired (Bishop, 2022, p.1).

Image 4-10. Stuffed Nopales (Gerado Lopez, 2021)

4.3 Cost and Budget

4.3.1 Self Help Africa

4.3.1. (a) About Self Help Africa

Self Help Africa is an international development charity that promotes long-term agricultural development in rural Africa. It was founded in 1984 and has its headquarters in Dublin, Ireland. This organization focuses on improving agriculture and food production, supporting women, promoting entrepreneurship, and adapting to climate change. It mainly works in Sub-Saharan Africa, such as West Africa, Uganda, Malawi, Kenya, Zambia, Ethiopia, and Eritrea. It conducts various integrated development programs for rural communities in Africa with its African staff and local partners. The partners are as follows: Irish Aid, UK Aid, European Union, Us Aid, ILCU Foundation, Big Lottery Fund, FAO, and Google. Self Help Africa's activities in Africa are related to the Sustainable Development Goals (SDGs). The core goal of this organization is achieving a world free from poverty and hunger, corresponding with SDGs 1 and 2. In addition, its projects respond to many other SDGs, for example, improving access to safe and clean water, supporting sustainability, encouraging collaboration and partnership, and climate change adaptation (selfhelpafrica, 2022).

Image 4-11. Logo for Self Help Africa (selfhelpafrica, 2022)

4.3.1. (b) Self Help Africa's Projects in Eritrea

Self Help Africa is conducting several directly implemented and partner-led projects in Eritrea. The specific project goal for Eritrea is to support local smallholder farmers, promote crop diversity for food security, and help farmers overcome challenging conditions. The following two programs are currently conducted in Eritrea: Improved CSO capacity to support Community Sustainable Seed Systems and Improve Food Security in Eritrea (CSSS), and Climate Smart Agriculture Research and Innovation Support for Dairy Value Chains (DeSIRA), as shown in Table 4-4. The first one aims to contribute to the future where small farmers can successfully use crop diversity to ensure food security. It was a four-year seed enterprise project led by Vita, and it works to improve access to good quality seeds for potatoes and cereals. The second project promotes developing the Eritrean dairy value chain to enhance food and nutrition security, reduce poverty, and create job opportunities. It aims to increase dairy consumption for its nutritional benefits by improving the productivity of the dairy sector. This project will create 5600 net equivalent jobs, and 20000 cassava farmers will be linked to market opportunities (selfhelpafrica, 2022).

ERITREA PROGRAMMES

	Programme	Donor	Total Budget	Time Frame	Implementing Partner	Programme Area
01	Improved CSO capacity to support Community Sustainable Seed Systems and Improve Food Security in Eritrea (CSSS)	European Commission	€501,213	2019 ▼ 2023	Vita (lead partner)	Debub, Maekel and Anseba Zobas (regions), Eritrea
02	Climate Smart Agriculture Research and Innovation Support for Dairy Value Chains (DeSIRA)	European Commission	€4,248,057	2020 ▼ 2024	Teagasc (lead partner) and Vita, UCD, UCC, Natural Resources Institute Finland (LUKE)	Debub, Maekel and Anseba Zobas (regions), Eritrea

Table 4-4. Information about Self Help Africa's programs in Eritrea

4.3.1. (c) Relevance of Organization

We analyzed Self Help Africa as suitable for conducting our policy recommendations about cactus in Eritrea. The reasons for suggesting this organization as the implementer of our project are as follows. First, our project is consistent with Self Help Africa's activities in that the main goal is to ensure food security focused on small householders in rural African areas. Self Help Africa helps households increase food production, diversify crops to grow, and access markets for surplus produce. We want to educate small householders in Eritrea on how *Opuntia spp.* is helpful for Eritrean in various aspects, how to cultivate this plant, and how to create added value with this crop. We found out rural areas in Eritrea lack technologies and infrastructures to promote food production and value addition systems. We judged that this organization could contribute to creating a framework for promoting cactus in Eritrea based on the projects it has worked on so far.

Second, Self Help Africa has their own partners who could conduct the project in Eritrea. We could find this organization has a relationship with various partners who are well-informed about the local situation. We noticed that no suitable companies in Eritrea could lead and participate in our projects; Self Help Africa would be best considering this problem since it has various partners in Eritrea. In addition, this agency has experience in carrying out projects similar to ours in Eritrea, as shown in Image 4-12, which increases the feasibility.

Lastly, this organization has its own fund system and partner who could financially support its activities. Securing funds is essential in the project's progress, especially in developing countries like Eritrea. Self Help Africa has a solid foundation for receiving donations, and this is a great advantage in increasing the feasibility of the project. As a result, we analyzed Self Help Africa is suitable to conduct our project, considering goals, local partners, and funding aspects.

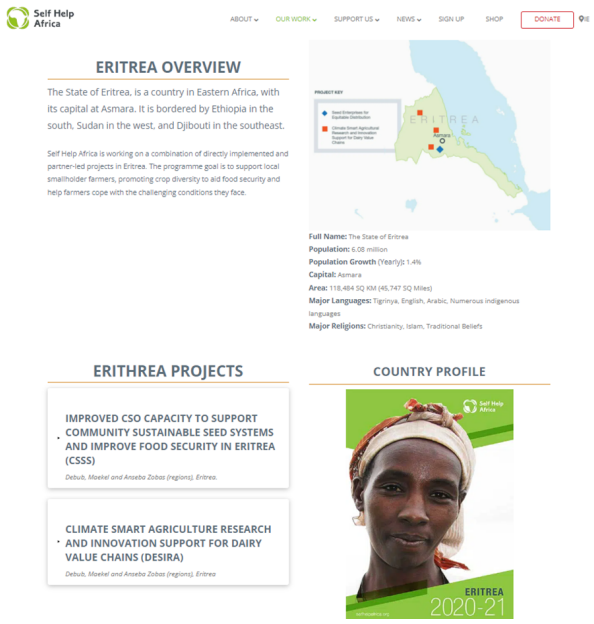


Image 4-12. Self Help Africa's Website about Eritrea

4.3.2 IFAD

4.3.2. (a) About IFAD

The International Fund for Agricultural Development (IFAD) is an international financial institution of the United Nations. It aims to support rural people in Africa to improve their agricultural production. It was founded in 1977 in response to the 1970s' global food crisis. It is based on the idea that food insecurity and famine are caused by structural problems relating to poverty not by failures in food production. Poverty is predominantly prevalent in the countryside rather than in the city. IFAD decided to help rural people in Africa because most developing countries' poor people are living in rural areas. Thus, it offers its financial support to projects designed to introduce and improve food production systems and policies related to food for rural areas. (IFAD)

Three strategic objectives of IFAD

- Increasing the productive capacity of poor rural people
- Increasing their benefits from market participation
- Strengthening the environmental sustainability and climate resilience of their economic activities

Image 4-13. Logo for IFAD (IFAD)

4.3.2. (b) IFAD's Projects in Eritrea

- Overall states of IFAD's projects in Eritrea

The COSOP is aimed to contribute to enhancing the food and nutrition security of smallholder farmers through resilience-building interventions. Following are loans and grants for achieving the strategic objectives. Figure 4-3 is a portfolio under this COSOP, and it will include ongoing projects (NAP, FReMP) and a new IFAD 11 investment (IADP). In addition, a new investment might be envisaged. Based on the COSOP 2020-2050 data, Eritrea is eligible to receive 80 percent in grant funds and 20 percent as optional loans on highly concessional terms (IFAD, 2020).

	IFAD8			IFAD9			IFAD10			IFAD11			IFAD12			IFAD13		
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
NAP US$40 million																		
FFReMP US$37.7 million																		
IADP US$45 miliion (under design)																		
New Investment (IFAD12)																		

Figure 4-3. Sequencing of IFAD's ongoing and future portfolio

- National Agriculture Project (NAP)

The main objective of the NAD is to contribute to food security and poverty alleviation in Eritrea and increase households' income together with improved food security. The development goal is to raise the production and productivity of small-scale agriculture through increased yields of strategic crops. Among the policy and institutional goals supported by this program, we chose three that fit our program. (i) Establishing a national framework for smallholder agriculture and laying the groundwork for mid- to long-term development of this agricultural sector. (iv) Enhancing sustainable productivity by using improved seeds of better crop varieties.

The project began in December 2012 and was completed in December 2021. IFAD lent and granted Eritrea about $27 million. The total project finance is about $36 million. The project was carried out with the Eritrean government and implemented by the Ministry of Agriculture. As a result of the program, 183,060 households were state-funded with the achievement rate 225.18%. After the program, crop production increased by 53 percent (IFAD, 2022).

	Hectares cultivated			Total outputs (Quintals)		
Crop	After NAP	Before NAP	% change	After NAP	Before NAP	% change
Vegetable	20.77	13.87	50%	2994	2,640	13%
Fruits	5.37	3.48	54%	663	354.6	87%
Forage	2.29	1.06	116%	319.5	61	428%
Other crops	1.2	1.01	19%	27.2	22	22%
Total	**29.6**	**19.4**	**53%**	**4,004**	**3,077**	**30%**

Source: NAP Outcome Survey, 2021

Table 4-5. Changes in crop product output before and after NAP intervention

4.3.2. (c) Relevance of Organization

We selected opuntia as the solution of the diabetes problem caused by climate change in Eritrea. Since Opuntia-related activities are related to the agricultural sector, our recommendation is suitable for IFAD's purpose of supporting agriculture in Africa. Agriculture is an important factor in Eritrea, but there are many restrictions. Agriculture accounts for about 24% of Eritrea's GDP. Agriculture is their main source of livelihood and accounts for a large portion of commodity exports. However, periodic droughts in Eritrea exacerbated agricultural conditions. Eritrea has 26 percent of arable land, but only 4 percent of it is cultivated. About 65% of Eritrea's rural population is poor, and 37% suffer from high food insecurity. Food safety is guaranteed only 25 percent in less rainy years. IFAD cited the factors limiting Eritrea’s agricultural development as irregular rainfall, inefficient agricultural systems, inadequate skills and weak institutional capabilities, and non-fertile soil. To solve this problem, IFAD's proposed solutions include 1) improved seed production and distribution, and 2) promotion of sustainable natural resource management. Of the various solutions, these two proposals are consistent with the opuntia we are dealing with, so we saw IFAD as a suitable organization for our project.

4.3.3 Vita

4.3.3. (a) About Vita

Vita is an Irish development partner supporting farmers and communities in Africa for over 32 years. It was founded in 1989 by Fr. Kevin Doheny as Refugee Trust International (RTI). It changed its focus to include livelihoods such as reducing extreme poverty and vulnerability. Reflecting this change, RTI changed its name to Vita in 2005, and the geographic focus moved to Ethiopia and Eritrea, where Vita established local offices in 2005 and 2010 respectively. Its goal is to facilitate thriving rural climate-smart economies with access to services, markets, and livelihoods for all. Vita now has several regional partners, including Irish Aid and the European Union. To create sustainable, climate-smart livelihoods, Vita partners with rural communities in Ethiopia and Eritrea. It combines knowledge-backed expert collaborations, community-led initiatives, transformational technology, and innovative financing models in its approach(Vita, 2022).

Image 4-14. Logo for Vita (Vita, 2022)

4.3.3. (b) Vita's Projects in Eritrea

As a part of its goal to tackle hunger and build sustainable livelihoods in the Horn of Africa, Vita has been working in Eritrea since 2000. By cooperating intensively with local government and local civil society partners, Vita works towards household food, water, and energy security.

Projects currently being implemented in Eritrea include: Increasing access to quality potato and cereal seed, Fuel-Efficient Stoves, Access to Safe Water, Dairy, Soil Fertility.

- ***Increasing Access to Quality Potato and Cereal Seed :*** A major focus of Vita's work in Eritrea to date has been developing community-based seed multiplication systems, working closely with local researchers and extension workers in the Ministry of Agriculture and leveraging the expertise of Teagasc and Self Help Africa. These projects continue to work with clusters of farmers to grow high-quality potato, wheat, and pearl millet seed, improving access to clean, quality seed for the wider farming community and contributing to improved livelihoods and food security.
- ***Fuel-Efficient Stoves :*** These improved efficiency stoves, an adaptation of the traditional household stove used across Eritrea, are built by local women, using locally-available supplies. Vita trains women in the construction techniques required for building the stoves. As the stoves only use half the fuel of traditional cooking stoves, less fuel is required and less smoke is emitted. This means that fewer trees need to be felled for a community's energy requirements, and less time is spent collecting firewood. This allows women and children to spend more time doing other household tasks, studying, participating in income-generating activities, and **participating in the social and civic life of their community.** Over 16,000 people have benefited from Vita's improved cookstove programmes since 2016.
- ***Access to Safe Water:*** Vita has repaired 389 broken down water points in rural Eritrea since 2016, providing access to safe water for over 234, 000 people. The has reduced the exposure of communities to disease and infection, and relieved the significant burden faced by women of walking long distances each day to fetch water. Vita supports the training of Water User Associations at community level to manage the water point and conduct regular maintenance and basic repairs, to reduce the need for external assistance and ensure the water points remain functional.
- ***Dairy :*** Vita in collaboration with Teagasc have worked closely with the Ministry of Agriculture in supporting small scale household dairy production since 2014, including the introduction of improved breeds from Ireland that are cross-bred with local cows for higher milk yields. This work has culminated in a major research-led initiative today, coordinated by Teagasc, that is focusing on the climate-smart transformation of dairy value chains in Eritrea. This project is expected to both create economic opportunities and increase access to dairy products for rural households across the country.
- ***Soil Fertility :*** Vita is working with farmer and producer groups and local agricultural researchers to test climate-smart approaches to soil fertility management that can increase crop yields, while protecting and restoring the natural resource base that rural livelihoods depend on. A key component of this project is building local and national capacities in soil analysis, classification and advisory services to farmers.

4.3.3. (c) Relevance of Organization

We found out Vita is a proper organization for conducting our cactus project in Eritrea. The reasons why we suggest Vita as the implementer of our project are as follows.

First, our policy recommendation is focused on food and water insecurity, especially for households. This has a connection with this organization's work because Vita works towards household food, water, and energy security. Since 1989, It has developed core expertise in facilitating communities to develop sustainable futures by growing food to feed their families, accessing water and household energy, and developing skills to forge sustainable and healthy livelihoods.

Second, Vita cooperates with local government and local civil society partners in Eritrea who implement most of the project work on the ground. It means Vita has the base for executing this program. The innovative Eritrea-Ireland Development Partnership, which consists of The Ministry of Agriculture, Vita, Teagasc and Self-Help Africa, provides an overall framework for Vita’s work in the country.

Lastly, it has its own fund system which is the most crucial part for implementing a project. Vita is funded by the Irish Government through Irish Aid and the Embassy of Ireland in Ethiopia, the European Union, philanthropic organizations, religious communities, the Irish agri-food sector, public donations, and private individuals.

Image 4-15. Logo for Vita's partners, investors, and friends (Vita, 2022)

As a result, we looked over whether Vita is suitable to apply to our project, considering goals, local partners, and funding aspects.

V
CONCLUSION

We now know that SDG 13: Climate Action is essential to all forms of living. It has become more urgent and critical for us to treat climate change as not only a threat to the environment but also to the very existence of human life on Earth. Addressing climate change is at the heart of a better, sustainable future for the generations to come.

Environmental problems caused by climate change such as rising temperature, drought, and deforestation cannot be separate from us as they are directly linked to all aspects of life. For instance, it leaves long-lasting consequences on human health and contributes to the prevalence of certain diseases. As the complete goal of SDG 13 suggests, we need to combat both climate change *and* its impacts.

Food insecurity is the most critical factor that makes developing countries more vulnerable to the impacts of climate change.

We investigated chages in temperature and percentage of forest area loss from 2009 to 2020 across 243 countries. Through this process, we found that Eritrea experienced one of the most drastic rates of temperature rise and forest area loss. Moreover, we discovered significant correlation between the number of patients suffering from diabetes-related diseases, and temperature change and forest area loss.

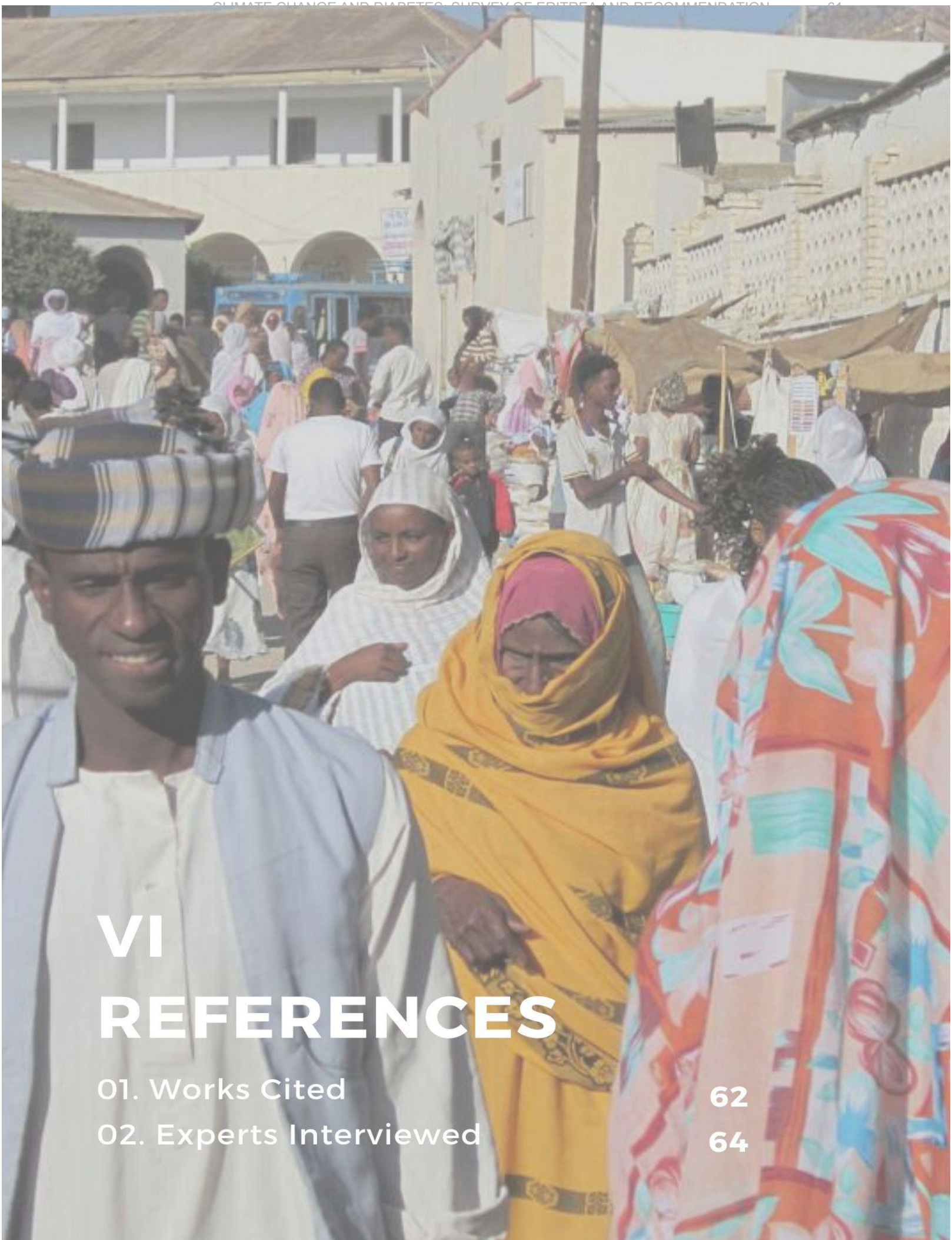
In this report, we explored the relationship /correlation between climate change (temperature rise and deforestation) and the prevalence of diabetes. As a result, we have argued that the prevalence of diabetes in Eritrea has occurred mainly from climate change. To minimize the health risk people in Eritrea face, we have urged domestic policymakers of the country to take action.

By adapting this suggestion, we are expecting that Eritrea would overcome climate change and Eritrean could minimize their suffering.

By analyzing the correlation between climate change and diabetes, we have found out there are certain relationships. We would like to suggest this analysis as one of the recommendations. It could serve as a better resource and reference point for policy makers in Eritrea.

We suggested *Opuntia* (prickly-pear cactus) as an explicit solution in our policy recommendations. Cactus would be a realistic solution for Eritrea to adapt to the environment devastated by climate change. It also could positively impact diabetes from the chemical and nutritional compositions. The government of Eritrea increasingly recognizes that cactus could play a significant role in household income and poverty alleviation. Based on various data, we concluded cactus is beneficial to Eritrea in many ways; however, professional knowledge of growing and utilizing this crop is lacking. Therefore, we highlighted education on managing cactus, consuming it properly, and creating value-added using it through this paper. We noticed that securing funds and finding partners who can proceed with this project are crucial. Therefore, we introduced three NGOs and Fund programs suitable for our policy recommendation; Self Help Africa, IFAD, and Vita.

Through a recommendation of pickled cactus, we aspire to have Eritrea's policymakers adopt the new crops within the domestic industry, activate the partnership with other private sectors and global organizations, and finally give out a fair working chance to small to medium-sized workers in rural areas. Eritrea has reported several problems that cover different agenda of SDGs.



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