Modeling of Metabolic Syndrome Outbreaks Due to Climate Crisis and Reconsidering the Direction of International Development Cooperation in Eritrea

Ye Eun Kim*, Ye Eun Lim*, Minhyek Jeon*, Sieun Choo*, Seongju Kim*,

Kieun Kwon*, Sooseong Hwang*, Jinsang, Lee

Abstract

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. The paper surveys the effect of climate change on the prevalence of diabetes in the country of Eritrea. In our effort to find the country that was most severely impacted by it, we investigated changes in temperature and the 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 changes in its climate. Moreover, we discovered a significant correlation between the number of patients suffering from diabetes-related diseases, temperature change, and the loss of forest areas. Upon further inspection of Eritrea's social, environmental, and scientific conditions, it was clear that climate change not only is a serious issue but also one that increases the prevalence of diabetes in Africa. In this study, we propose a sustainable solution is required to mitigate climate change and pursue the well-being of the people in Eritrea.

Keywords *Eritrea, diabetes, climate change, sustainable development*

대부분의 개발도상국가들은 열악한 보건의료 제도와 부족한 재정, 모니터링 제도의 부재로 기후변화에 취약하다. 본 연구는 기후 변화에 따라 에리트레아의 당뇨병 발병률에 미치는 영향에 대해 분석하는 것을 목표로 한다. 모두 243 개 국가의 기온변화와 산림 벌채율의 2009-2020 년도별 편차 값을 중심으로 분석하여 가설 검증을 위해 공분산 분석을 이용했다. 기후 변화 현상과 에리트레아의 대사 증후군의 발생 빈도가 높은 상관관계가 있다는 것을 정량적으로 증명하였다. 아프리카 국가의 경우 사회, 환경, 과학기술의 외생 변수에 대한 추가 조사를 통해 기후변화가 당뇨병 발생률 증가를 촉진하는 것을 보여주었다. 본 연구에서는 기후 변화에 대비해서, 에리트레아 국민의 건강을 증진 시키기 위한 지속 가능한 솔루션을 제안 한다.

주요단어: 에리트리아, 당뇨병, 기후변화, 지속가능개발

1. Introduction

We utilized an algorithm model to analyze the climate impact in Eritrea. We employed three criteria in selecting the target country: temperature rise, deforestation, and GDP per capita. First, the temperature rise was a 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. Based on an analysis of 243 countries, Eritrea fell in the 90th percentile and ranked the 12th for temperature variation. It shows that Eritrea observed significant climate change and, thus, is in need of corrective measures.

Deforestation causes a wide range of environmental phenomena such as drought, water pollution, and air pollution. The data on the loss of forest areas in different countries was obtained from KOICA (Korea International Cooperation Agency) during the 1990s and the 2000s. We made a list of countries that reported drastic changes in the forest area. Based on an analysis of temperature rise and deforestation, we compared countries that met both criteria and narrowed them down to twelve countries based on temperature variation. Then the countries were filtered to six countries (Greenland, Egypt, Armenia, Albania, Algeria, and Eritrea) with a threshold of 60000km2 or less for forest areas. We applied GDP per capita to determine the least developed countries. As a result, Eritrea has the lowest GDP per capita.

2. Literature Review

Recent studies in public health focus on the correlation between climate change and type 2 diabetes(T2D), considerably through diabetes' vulnerability to exposure to extreme climate change. Ratter-Rieck et al.(2023) conveyed research on how climate change indicators evoke a risk to people with diabetes by examining physiological and altered responses to a consequence of global warming. While Ratter-Rieck's work clinically assesses the environmental association of diabetes, it imposes only a limited extent of mitigations restricted to partnerships and personal caution.

Al-Shihabi(2023) then proposed a more detail-oriented approach to how extreme climates may worsen the diabetics, causing and deepening heatstroke, dehydration, and cardiovascular disease. His study confirmed that diabetes and temperature rise were positively linked through a direct relationship between mortality rate and temperature rise. It also reargued that people with diabetes are more vulnerable to extreme cold, supported by a positive relationship between extreme cold and their morality. While this work was able to draw a more clear link between climate change–especially temperature change– and diabetes, it did not specify the target countries. Also, no suitable recommendations have been suggested for underdeveloped countries, especially in Africa.

In addition, Zilbermint(2020) also proposed a recommendation that governments implement appropriate policies and that medical providers foster the development of preventive plans to tackle this issue. Zilbermint's work actively engages new stakeholders in the T2D-climate change issue which was not well perceived in AI- Shihabi's work. Nonetheless, there are concerns about potential overreliance on external support by developing countries and disproportionate benefits to the bio-industry from these solutions.

Meo et al.(2021) investigated the green environment and the prevalence of diabetes, found that the green environment affects the prevalence of diabetes. They found a notably lower prevalence of diabetes mellitus in European countries with abundant green spaces compared to those with fewer ones. They explained that the green environment minimizes air pollutants and rapid climate change by introducing an Environmental Performance Index (EPI) score that evaluates a country's ecosystem vitality with seven categories. However, the paper was conducted mainly in Europe, thus more related research analysis on African countries is needed.

This study quantitatively analyzes the association of temperature rise with diabetes as a characteristic of climate change. The study explores the Opuntia as a sustainable solution for Eritrea, encompassing not only climate change mitigation but also diabetes management and regional economic revitalization.

3. Data Analysis

We took Eritrea as a model case chosen from 243 countries. Eritrea has the highest increase in temperature and has the most severe forest destruction. Our study finds health-related issues regarding climate change and focus on population mortality.

The data we analyzed are the GHO(The Global Health Observatory) Eritrea dataset 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 importantdiseases 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 3-1. Part of Merged disease dataset

Normally covariance is in the range of -1 to 1. Negative values show the inverse proportion relationship, whereas positive values indicate a proportion relationship. As the absolute value gets bigger, the relationship becomes more reliant. Therefore the positive covariance denotes a direct relationship and is represented by a positive number.

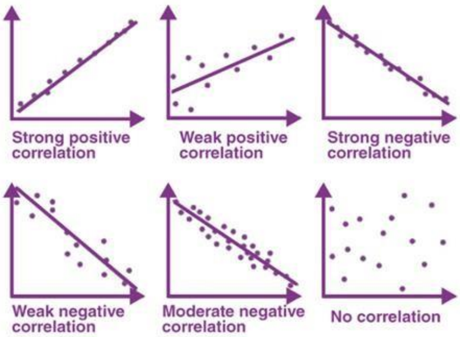


Figure 3-2. Covariance value (“Correlation”)

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 diseasethat increases its mortality rate as the temperature goes up and the forest area decreasesin size. In the covariance formula, the covariance between two random variables X andY is 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, X is themean of the X-variable, 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. A correlation between two random variables or bivariate data does not necessarily imply a causal relationship.

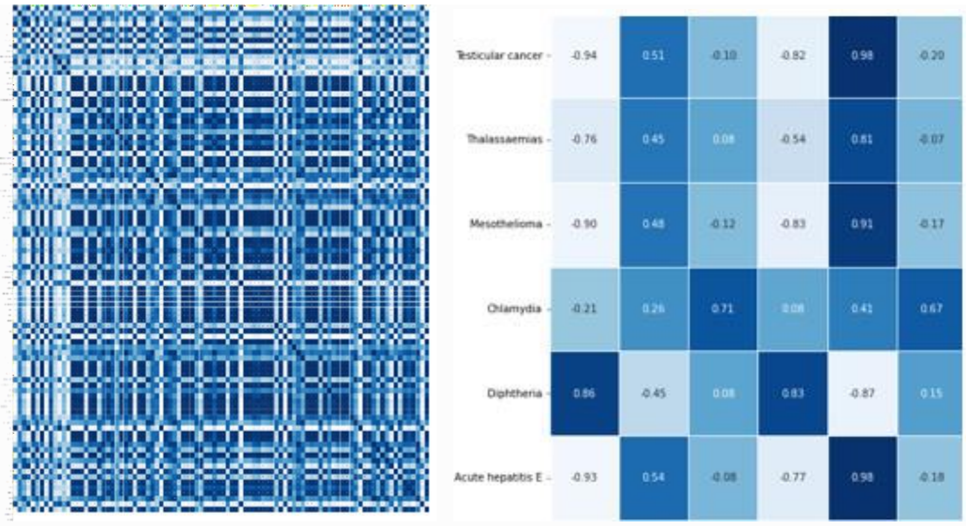


Figure 3-3. Correlation Heat map

Based on the heat map, we filtered types of diseases with a certaincorrelation value to select diseases that show the highest correlation between the two factors. Considering that the forest areas 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. A total of 42 types of disease were selected among 131 diseases.

Among 42 diseases, we then filtered them 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. We classified 14 diseases into 3 groups 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). Many diseases revealedwaterborne diseases, pulmonary diseases, and their relation to Eritrea’s climate change.Even though diabetes-related diseases were the most frequent in Eritrea, the quantitativeapproach to diabetes and its relationship with Eritrea’s climate change has not been conducted.

4. Diabetes

A. Types of Diabetes

Type 1 and type 2 diabetes are different diseases. 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 to adults. For type 1 diabetes, the immune system is responsible for fightingoff foreign invaders, such as harmful viruses and bacteria. 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 beta cells are destroyed, the body is unable to produce insulin. Diet and lifestyle habits do not cause type 1 diabetes.

In the case of type 2 diabetes bring insulin resistance. The body still produces insulin, but it's unable to use it effectively. It is known that lifestyle may contribute inactive and carrying excess weight with Type 2. In that case the genetic and environmental factors can affect Type 2. P a ncreas works to produce more insulin. But the body system is unable to effectively use the insulin, glucose accumulates in the bloodstream. Both types of diabetes are chronic diseases that affect the way human body regulates blood sugar or glucose. Glucose is the fuel that feeds your body's cells, but toenter your cells it needs a key. Both types of diabetescan lead to chronically high blood sugar levels. This research focuses on Type 2.

B. Correlation Between Diabetes and Climate Change

In 1991, Eritrea was independent from Ethiopia. However, the conflict between two countries continued for more than 20 years. Many citizens were forced into compulsory military services, which led to the desertionof the arable land of Eritrea (Sims, 2019). In 1999, Eritrea was not able to pay attention to prepare for climate change or the improvement of health care system. Furthermore, the weather conditions were worsened with serious drought (Samson, 2021). The drought in 1999 was fatal to the country since the agriculture sector was seriously damaged. The agriculture sector accounts for 11.7 percent of GDP, and nearly 80 percent of Eritrean's workforce are engaged in the sector (CIA, 2022). The drought in Eritrea boosted the desertification. With the economic hardship, the poverty ratio was worsened (Jordan, 2017). As the poverty rate increases, the economybegan to collapse. Drought deepened the water shortage problem, and brought water insecurity and food insecurity. Diabetics share a large part of the people in the country. Malnutrition also contributes diabetes as it is directly related to 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).

The climate of Eritrea ranges varied as the Red Sea and highlands areas have very high and sub-humid(Climate Change Portal, 2022). Most of the country reaches nearly 70% of humid and the mean annual temperature was more than 27°C. As explained by climatology data of mean temperature between 1991 and 2020, about 25% of the country was warm to mild weather with the mean temperature of around 22°C (Climate Change Portal, 2022). Overall, Eritrea experiences an arid climate; 70% of its land area has an average annual rainfall of less than 350 mm, which is identified as a hot and arid climate. The research investigated some of the features of Eritrea and found that the country is suffering from diabetes more severely than other countries in Africa. We assume that the prevalence of diabetes in Eritrea has a correlation with temperature rise. The country is the most vulnerable country in climate change.

WHO (2020) shows that 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 the population ranks Eritrea #37 in the world *(Diabetes Mellitus in Eritrea, 2022).* There was a significant correlation between diabetes and the temperature rise.

C. Deforestation

According to the image of forest and woodland in Eritrea extracted by the Landsat data using supervised classification, 30% of Eritrea's land surface was covered by forest a century ago, which dwindled to less than 1% now. The deforestation caused serious environmental problems in Eritrea. Temperature rise leads to a high rate of evaporation of moisture from the soil (Ghebrezgabher, 2016). It indicates that across Eritrea a large portion of the woodland was shifted to dry forest (UNCBD, 2006). Forests have the ability to purify water and air pollution which are connected to illnesses like diabetes.

The rainy season has been increasingly delayed over time. Large areas have been deforested, when there is a big possibility to longer dry spell events which leads to a water deficit (Leite-Filho, 2019). It means dry spells can be caused by deforestation and affect 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) (Leite-Filho, 2019). 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 the quality of drinking water (Bastaraud, 2020).

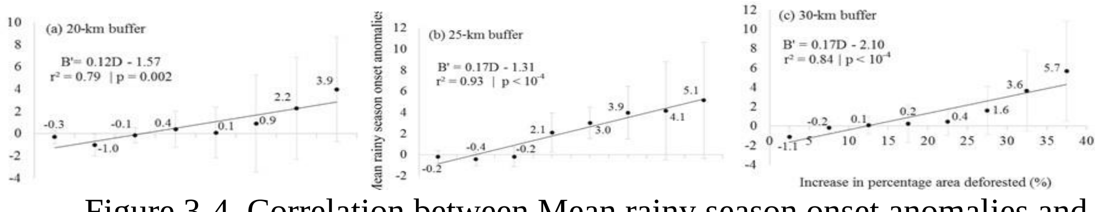


Figure 3-4. Correlation between Mean rainy season onset anomalies and Increase in percentage area deforested

Source: *Liete-Filho. A. T., Sousa Pontes. V. Y.. & Costa. M. H. (2019). Effects of Deforestation on the Onset of the Rainy Season and the Duration of Dry Spells in Southern Amazonia, In JGR Atmospheres, 124(10), 5268-5286.*

From a global perspective, there is an extreme rainfall and it's predicted to be intensified by climate change (Bastaraud, 2020). These regimes of extreme rainfall are likely to be associated with drinking water contamination. These are directly related to the urban water management such as the design of water storage components (Breinl, 2020).

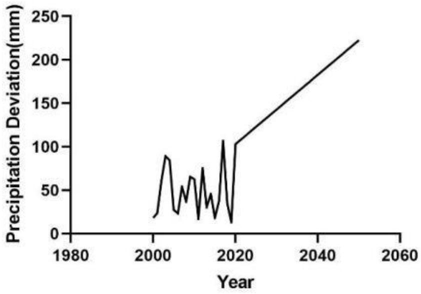


Figure 3-5. Precipitation Deviation in Eritrea

Eritrea is subject to harsh climatic conditions, including cyclical drought and flooding during rainy seasons (ACAPS, 2022). The precipitation deviation in Eritrea would escalate every year. This means a threat to water resources would be increased in Eritrea. The freshwater is important as diabetes related to the quality of water in Eritrea. A little dehydration can have a notable impacton them (Water and Diabetes, 2019). 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. That is why diabetes patients are more prone to dehydration (Staying Hydrated, 2019).

There are many household using fuelwood for cooking, and the wood market is an income source for many people(FAO, 2022). Eritrea's air quality has been worsened due to biomass (UNEP, 2015). According to the 2016 survey, ambient PM 2.5 brought about 3.2 million cases of diabetes and 206,000 deaths from diabetes (Frumkin, 2019). CEIC reported that 2016 mean annual PM 2.5 data was higher(50.514 mcg/Cub m) than 2015 (50.17mcg/Cub m). The Ministry of Land, Water and Environment reported that air pollution concentration in Asmara, the capital, is higher than the standard recommended by the WHO (Eritrea, 2021). Eritrea has higher NO2 levels, which leads to greater insulin resistance. Increase of insulin resistance in the human body can lead to type 2 diabetes. These data indicate Eritrea's air pollution situation can be considered as one of the affecting factors in the increase of diabetes.

D. Predictions and Scenario

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

i. Climate related: forest area, precipitation, temperature
ii. Diabetes 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.

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

$$Y_i = \beta_0 + \beta_1 X_i$$

For training data, we used data from 2000 to 2019 and set the learning rate as 0.01. To solve the problem of under fitting, 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 0(=0) and 1(=1) to any two values. Formally, the algorithm updates value as follows:

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

Figure 3-9. Gradient descent

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

$$repeat\ until\ convergence \{$$

$$\theta_0 = \theta_0 - \alpha \frac{1}{m} \sum_{i=1}^{m} \left(h_\theta(x^i) - y^i\right)$$

$$\theta_1 = \theta_1 - \alpha \frac{1}{m} \sum_{i=1}^{m} \left(h_\theta(x^i) - y^i\right) * x^i$$

$$\}$$

Our regression coefficients converge to the point where J(w) is minimized whichcan 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 2023 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 2023 to 2050

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

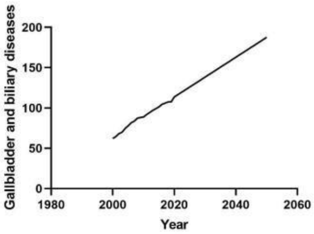
<table>
<tr>
<td>

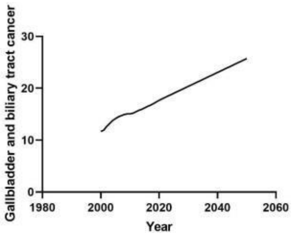
Figure 3-6. Incidence frequency of Gallbladder and biliary diseases per 20 years</td>
<td>

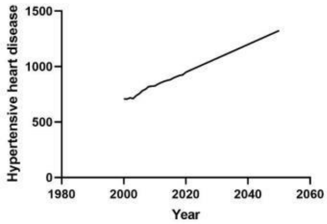
Figure 3-7. Incidence frequency of Gallbladder and biliary tract cancer</td>
<td>

Figure 3-8. Incidence frequency of Hypertensive heart disease per 20 years</td>
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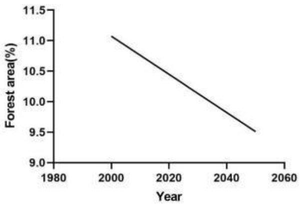
<td>

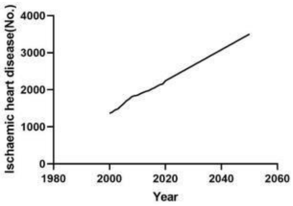
Figure 3-9. Proportion of forest area per 20 years</td>
<td>

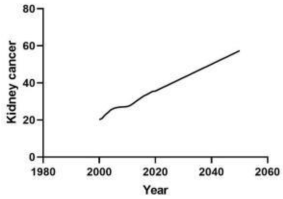
Figure 3-10. Number of Ischaerric heart disease per 20 years</td>
<td>

Figure 3-11. Incidence frequency of Kidney cancer per 20 years</td>
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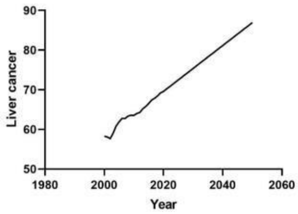
<td>

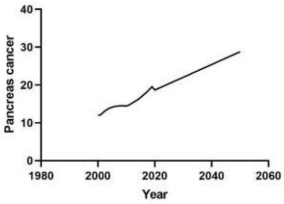
Figure 3-12. Incidence frequency of Liver cancer per 20 years</td>
<td>

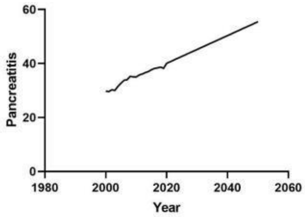
Figure 3-13. Incidence frequency of Pancreas cancer per 20 years</td>
<td>

Figure 3-14. Incidence frequency of Pancreatitis per 20 years</td>
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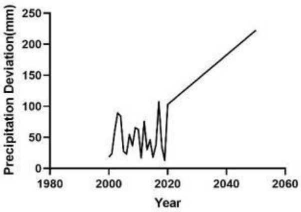
<td>

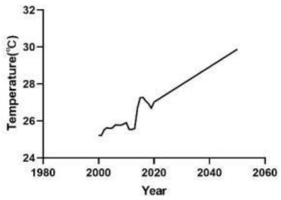
Figure 3-15. Precipitation deviation per 20 years</td>
<td>

Figure 3-16. Temperature per 20 years</td>
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4. Recommendations

4.1 Eritrean Case

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. We suggest an alternative crop where Eritreans can resolve the food security problem while finding a decent job opportunity.

The Eritrean 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 succulent prickly pear is suitable for Eritrea as an alternative crop since it is lesslikely to be affected by Eritrea's erratic and torrential rainfall patterns. Finding new crops, such as cactus, is important as it can be beneficiary for food security. Nonetheless, there is still a lack of means to produce large quantity of them and commercialize available resources. The Ministry of Agriculture, Eritrea shows that less than 25% of wild cactus plants are currently used, although cacti covers 18,000 hectares of the arable land. Therefore,Eritrea needs to expand cactus production, and develop its capacities to produce prickly pears. Technologies and knowledge of growing methods, value addition, and marketing strategies will be desired in Eritrea (Asmelash, 2021).

4.2 Opuntia

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

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 acidsthat 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 fibersand the hypoglycemic effect due to specific hypoglycemic substances in the ingested plant. While the dietary fiber is neither digested by gastrointestinal enzymes norabsorbed, it does modify the absorption of certain substances such as biliary salts, cholesterol, and glucose.

Chandalia et al. demonstrated a 10% reduction in 24-hourplasma glucose concentration in patients on a high soluble fiber diet compared with thestandard 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 reportedto 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% (Kwon Jin-Hong, 2017). 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 LDLbut 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.

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 Frati Munari, Del Valle-Martinez et al(1989).

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 betalainshelp 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).

The CAM plants such as agaves and 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. Comparing with natural rangeland, barley crop (alone), and cactus crop (alone), alley cropping with cactus and barley produces the highest above ground (7.11 tonnes ha^-1) and underground biomass (1.98 tonnes ha^-1), barley grain yield (2.32 tonnes ha^-1), and barley grain, straw, and weed yield (6.65 tonnes ha^-1) (Nefzaoui, A., Inglese, P., & Belay, A. T., 2010). 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 sufferirreparable 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.

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). Pickly pear cactus will be a key player in food security due to its ability to thrive in arid and dry climates (FAO).

Cacti also play an important role in water. It can stores water inits pads, thus providing a botanical well that can provide up to 180 tonnes of water perhectare-enough to sustain five adult cows, a substantial increase over typicalrangeland productivity. At times of drought, livestock survival rate has been far higheron farms with cactus plantations. 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).

4.3 Value Added

Opuntia has a variety of added values. Opuntia can be processed into other formsof 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. 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 added value of Opuntia is goodfor 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).

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 tons an hour. The processing plant became an important means ofincome improvement for the inhabitants. One of its principal functions is the production of essential oils extracted by prickly pear cacti. The other functions includethe packaging of cactus pear, and the production of pharmaceuticals, juice, jam, and livestock feed (Inglese,P., 2017).

4.4. Cactus for 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 theirspines are dangerous for them. 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 beone 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 focus on and analyze the case of Kenya since its technologies would befeasible to introduce to Eritrea, considering conditions, applied subjects, and processes. (Langat, A.,2021).

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 toreduce 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 storagebag for household cooking (Langat, 2021).

5. Conclusion

Environmental problems caused by climate change such as rising temperature,drought, and deforestation cannot be separated from us as they are directly linked to all aspects of life. We need to combat both climate change and its impacts. Food insecurity is the most critical factor that makes developing countries morevulnerable to the impacts of climate change.

This study investigated changes in temperature and the percentage of forest area lossfrom 2009 to 2020 across 243 countries. Through this process, we found that Eritrea'sexperience, one of the most drastic rates of temperature rise and forest area loss, this research discovered a significant correlation between the number of patients suffering from diabetes-related diseases, temperature change, and forest area loss.

We explored the relationship /correlation between climate change (temperature rise and deforestation) and the prevalence of diabetes. We had a hypothesis to claim that the prevalence of diabetes in Eritrea has occurred mainly from climate change. There is a strong correlation between climate change and diabetes. We suggest this analysis as oneof the recommendations. It could serve as a better resource and reference point for policymakers in Eritrea.

We suggested *Opuntia* (prickly-pear cactus) is an explicit solution with one of policy recommendations. The use of cactus can be a solution to tackle climate change and positive impact on diabetics. The government of Eritrea increasingly recognizes that cactus could play a significant role in household income and poverty alleviation. We concluded cactus will be beneficial to Eritrea. With a recommendation of pickled cactus, it can bring business opportunities in Eritrea. Hence, it could promote small and medium-sized firms in the rural areas and also beneficial to diabetics.

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