Mathematical modeling of Climate change and Desertification: A case study of Yobe State, Nigeria.

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Abstract:

The study addressed the effect of climate change and Desertification in Yobe State, Nigeria. Desertification as defined by the United Nation Convention to Combat Desertification (UNCCD 1994), is the degradation in arid, semi-arid, and dry sub-humid areas resulting in many factors including human activities and climatic variations. Desertification is a silent, invisible crisis that is destabilizing communities on a global scale, as victims turn into refugees, internally displaced people and forced to migrate from their homes. Hence to restore stability in a context where changing weather events are threatening the livelihood of people, then everyone must beware and stand to fight desertification, revoke land degradation and ease the effect of drought. The researcher implemented some mathematical models of climate change on desertification to give a good insight into Desert, Desertification and the causes of desertification, that affects our communities and provide possible ways of reducing its impact to the barest minimal. Furthermore, the research will also help decisions maker to well plan in order to protect our Land and Environment.

Key Word: Mathematical Model, Climate Change, Desertification, Drought, invisible crisis

1.1 Introduction

Climate change and desertification has been an aged long phenomenon that has affected the lives and livelihood of many people around the globe both positively and otherwise. In the last century, these has been a major area of research for many scholars from various areas of disciplines who have provided a huge success to the prediction of possible outcomes in the future climate, and have provided ways of solving those problems. This research is going to be narrowed on Yobe state Nigeria as our case of study to look into some of the effects of desertification and give appropriate solutions (using different climate models) to those problems.

1.2 Background of the study

Humanity have had a long association with arid and semi-arid regions: the first great civilizations in Egypt and Mesopotamia developed at the end of the climatic optimum some 3000 years B.C., at a time when the Sahara appears to have been vegetated as parts of the Sahel are today. Oguntoyinbo (1981) has traced the impact of human activities on climate variability in Africa. He notes that it was not until the time of the Roman occupation of North Africa in about 100 BC that we began to notice successively drier climates in the Sahara, though this period was not as dry as it is today. He argues that the fluctuations in the levels of the Lake Chad reveal the nature of climate variation in the Sahara. He therefore concludes that if the rise and fall of the Lake Chad can be taken to represent climate variability in the arid zone in the period before "instrumental records", it is possible that rainfall in the arid zone has similarly shown dramatic variability which has impacted on land use practices periodically.

By the time the Egypt pyramids were completed (around 2700 B.C.), the climate of the Northeastern and middle east Africa was in a drying phase that resulted in the arid landscapes we have known for much of the last 5000 years (El-Baz 1983). The federal ministry of environment estimated that Nigeria loses "about 350,000 square meters of its land mass to desert condition which is advancing southwards at an estimated rate of 0.6 kilometres a year". This environmental problem has severe economic repercussions on the entire nation as it impacts on the socio-economic life of rural households (reduction in crop and animal production, death of livestock, high prices for food stuffs) and leads to widespread poverty.

Until around the early 20th century, climate scientists were primarily concerned with the study of past climatic states. This was done by observation of the environment using mostly geological, geographical and botanical methods. By the end of the 1950s, important physical measurement methods were developed. The measurement of weak radioactivity of various isotopes was the basis for the dating of organic material and enabled the determination of flux rates in different environmental systems.

Two out of three of the geographical landscape in Africa is classified as drylands, of which 319 million hectares has been estimated to be highly vulnerable to desertification. These areas are concentrated in Sahelian (used to refer to the semi-arid) regions bordering the Sahara desert to the south and includes parts of Chad, Nigeria, Niger, Burkina Faso, Mali, Senegal, Mauritania and the Gambia (some authors include Sudan, Somalia, Ethiopia and Eritrea in the Sahel) region, Horn of Africa and Kalahari in the south. Increasing concentration of poverty in the drylands of sub-Sahara Africa has been documented, where 41% of the total population lives in extreme poverty, which is partly attributed to desertification. Drought and desertification are at the core of serious challenges and threats facing sustainable development in Africa, with far reaching adverse impacts on human health, food security, economic activity, physical infrastructure, natural resources and the environment, with incidence in national and global security.

4.3 Objective of the study

The context of desertification and climate change has a wide range of branches, where some scholars have questioned whether the phenomenon exists at all. It is evident through the reports and proofs that desertification is affecting the lives and livelihood of people directly or indirectly. Hence this research is going to discuss the nature, causes of desertification in Yobe and also provide a proposal to the state government on how to combat its wide spread in the state.

1.4 Definition of key terms

1.4.1 Desertification

UNCCD (1994) defines desertification as "land degradation in arid, semi-arid and dry sub humid areas resulting from various factors, including climatic variations and human activities".

1.4.2 Climate

This is a word from ancient Greek "**klima**", meaning inclination. Climate is commonly defined as the weather averaged or the statistics of weather over a long period. The standard averaging period is 30 years, but other period may be used depending on the purpose. It is measured by assessing the patterns of variation in temperature, humidity, atmospheric pressure, wind, precipitation, atmospheric particle count and other meteorological variables in a given region over long period of time.

1.4.3 Land degradation

UNCCD (1994) defines land degradation as a “reduction or loss, in arid semi-arid and dry sub-humid areas, of the biological or economic productivity and complexity of rain-fed cropland, irrigated cropland, or range, pasture, forest and woodlands resulting from land uses or from a process or combination of processes, including processes arising from human activities and habitation patterns, such as:

(i) Soil erosion caused by wind or water”;

(ii) Deterioration of the physical, chemical, and biological or economic properties of soil; and

(iii) Long-term loss of natural vegetation.

It can also be referred as a loss of adaptive capacity, or a decline in biological and economic resilience.[6]

1.4.4 Drought

The Wikipedia defines drought as an event of prolonged shortages in the water supply, whether atmospheric (below-average precipitation), surface water or ground water. Drought is a recurring feature of the climate in most parts of the world. However, these regular droughts have become more extreme and more unpredictable due to climate change. A drought can last for months or years, or may be declared after as few as 15 days.[7]

1.4.5 Climate model

A climate model is essentially a representation of the many interactions and dynamics within the climate which includes the atmosphere, ocean, land surface, and ice to make predictions of possible climate change for the future. Climate models are systems of differential equations based on the basic law of physics, fluid motion and chemistry.

1.4.6 Global warming

Global warming is the increase in the average temperature of the Earth's near-surface air and the oceans. It can also be defined as a gradual increase in the overall temperature of the earth's atmosphere generally attributed to the greenhouse effect caused by increased levels of cabondioxide CO_2, chloroflorocarbons CFCs, and other pollutants.

1.4.7 Atmosphere

An Atmosphere (from ancient Greek (atmos), meaning 'vapour', and (sphaira), meaning 'ball' or 'sphere'). The atmosphere is a layers of gases surrounding a planet or other material body that is held in place by the gravity of that body.

2: The Literature Review:

The mission of the UN convention to combat desertification is: "To provide a global framework to support the development and implementation of national and regional policies, programs and measures to prevent, control and reverse desertification, land degradation and mitigate the effect of drought through scientific and technological excellence, raising public awareness, standard setting, advocacy and resource mobilization, thereby contributing to poverty reduction." [6](UNCCD 1996). In this chapter we will look into some literature reviews of many other scholars.

2.1 Reviews

Aubreville (1949)**,** This French forester was the first to introduce the word 'desertification' in his book "Climats, forets, et Desertification de l'Afrique tropical". He witnessed the degradation and disappearance of tropical forests in many humid and sub-humid parts of Africa, and attributed it to a large extent to the slash and burn agricultural practices of the local populations. Aubreville had identified climate change as a potential factor, but could not estimate its importance for lack of adequate data. It is only later on that the concept became commonly associated with arid and semiarid regions. [2]

***Roger (1981)*,** who digitized UNESCO's map showing the world distribution of arid region (UNESCO 1977). This map was constructed on the basis of hydrological data using a water balance approach.

Norman Myers (1984), estimated that some 120000 km2 of agricultural and pastoral land were deteriorating beyond fuel economic use per year (Myers 1984, p. 46). These numbers should be compared to estimates of deforestation worldwide, which range from 100000 to 113 000 km2 per year, with the bulk of the destruction occurring in the tropics.[2]

Warren (1984), said "arid lands are dynamic regions, they have been evolving over thousands of years, mostly in response to climatic changes and humanity has been able to cope with such evolution and by colonizing new and hitherto unaffected areas".[2]

***Dregne (1986)*,** The intensity of desertification processes can range from slight to very severe in terms of the degradation of plant and soil resources.[2]

***Gethner, Robert (1998)*,** A planet's albedo is the percent of incoming solar radiation that is immediately reflected back into space due to coloring of the planet. The earth's albedo, is equal 0.3, so 30% of incoming solar radiation is immediately reflected back into space.

***NAP (2000)*,** revealed that about 35% of Nigeria's landmass is considered arable, with 15% being utilized for pastures, 10% for forest reserve, and 10% for settlement. The same report also reveals that 30% of the country's landmass is regarded uncultivable. Notably, reports from the Federal Ministry of Environment shows that Nigeria is annually losing about 350,000 square meters to desertification, which is regarded as the gravest environmental problem affecting

10 of the 11 northern states. Yet, rural households, especially inhabitants of drylands like those of Gursulu village Yobe state, depend on arable land for their livelihoods.

Parmesan and Yohe (2003), reported that the extent to which traditional forms of agriculture including pastoralism degraded the land was and is to some extent influenced by the nature of the biophysical environment. Steep slopes are clearly more susceptible than gently-sloping land to accelerated erosion; low-lying flood plains and flat lands are more likely to be affected by flooding; regions affected by strongly seasonal climatic regimes are affected by both floods and droughts; areas with highly flammable vegetation are more prone to fire; drylands with sparse vegetation cover are more exposed to wind erosion, and so on. However, over many centuries, and as a matter of necessity, traditional agriculturalists learned how to live 'with' nature. It has been mainly since the 18th and 19th centuries that exponential rates of population increase in much of the Third World, and mechanization and the onset of chemical farming worldwide, have resulted in some very serious problems. Global warming at least partly caused by the increasing release of 'greenhouse gases', with agriculture being a significant contributor is already affecting plants and animals.[9]

E.U (2010), developed strategies that works both to reduce greenhouse gas emissions and prevent damage to the ozone layer, and, to mitigate the unavoidable adverse effects of climate change.[8]

UNCCD (2010), formed an interim secretariat that will fight against desertification and to promote actions that will protect dry-lands. The fight is seen as an opportunity to make critical changes to secure the long-term ability of dry-lands to provide value for humanity's wellbeing. They were charged with:

i. Raising awareness on the causes of land degradation and its solutions.

ii. Mobilizing financial and technical support to fight desertification activities worldwide.

iii. Monitoring and reporting on progress in preparation of the secretary general's report

IPCC (2018), pointed out that there is limited 30 evidence and medium agreement that the extent of deserts will increase in the coming decades. However, the deserts are expected to become drier and warmer more rapidly than other terrestrial areas. They assessed as "*low confidence*" that desertification linked to climate change will directly or indirectly influence soil health and productivity due to accelerated soil erosion in drylands. They also had "low confidence" in the projections of future increases in dust storms with higher aridity.[9]

UNCCD (2021) reported that, Land degradation directly undermines our ability to deliver food and nutritional security. By 2050, crop yields are estimated to decrease by 10% globally due to land degradation and climate change, with some regions suffering up to a 50% reduction. Furthermore, land degradation is projected to fuel an estimated 30% increase in world food prices over the next 25 years. Given the expected growth in global population and food demand by 2050, conserving, sustainably managing, and restoring land resources will be essential in the transition to sustainable food production, requiring at least a 75% reduction in current yield gap.[10]

Barrack Obama at COP26(2021), said "there has been a success to the agreement of nations at the cop25 in France, but yet we are not close to achieving our goal of maintaining a steady clean energy globally although the USA has manage to make that possible". He also added that some parts of the world are becoming more dangerous to live in, hence more than 100 countries have agreed to address deforestation and make use of clean energy by the end of 2030 (every country is needed to achieve this goal).[18]

Boris Johnson (2021) the prime minister of the united kingdom at the COP26 (2021), gave an analogy that if the global temperature exceeds its current **1.5**°C to **2**°C, (our food supply will greatly be affected, locusts, bees and other important insects that aid pollination will all die), **3**°C (more cases of wildfires, 5x drought, 36x heat waves etc), **4**°C (major cities like Miami, Shanghai will all disappear because of over flooding, hurricanes etc.). Hence the world's leaders have agreed to maintain the net global emissions to **1.5**°C and gradually to a lesser degree[17].

2.2 Relationship between climate change and desertification

The European Union analyses the relationship between desertification and climate change in the Mediterranean. The central aim of the report is to identify best practices in dealing with desertification and to make recommendations as to what the Union for the Mediterranean (UfM), the EU and other stake-holders can do to respond to the challenges that might arise due to desertification and climate change in the future.

We should note that desertification is essentially a man-made phenomenon which is exacerbated by climate change. This is because an increase in weather extremes such as droughts and heavy rains as a result of climate change will lead to further land degradation. This in turn aggravates existing problems associated with poverty, forced migration, and in some areas conflicts. While desertification is already responsible for significant forced migration, more than a billion people (one in seven of the current world population) could be forced to leave their homes between now and 2050 if climate change worsens. The Middle East and North Africa (MENA), in particular, is considered to be the region most at risk if such projections prove accurate. The relationship between the two processes does not, however, move in only one direction. It is also possible that desertification may in turn affect climate change, due to the effects of land degradation that reduces surface moisture. Because less water is available for the sun's energy to evaporate, more energy is left over for warming the ground and, consequently, the lower atmosphere. At the same time, wind erosion in dry-lands releases dust and other particles into the atmosphere. By absorbing the sun's rays or reflecting them back out into space, they may help to cool the Earth's surface. However, the energy they absorb can heat the lower atmosphere and in this way reduce temperature differences between the atmosphere's vertical layers; this can lead to fewer rain-showers and thus drier land. Finally, the periodic burning of arid and semi-arid grasslands, often associated with unsustainable slash-and-burn agriculture, emits greenhouse gases. The unsustainable use of fuel-wood and charcoal, a major cause of land degradation, also contributes to greenhouse gas emissions. [9]

2.3 Causes of desertification

The two main causes of desertification are 'Climatic variations' and 'Human activities'

Climatic variations: These include climate change, drought, and moisture loss on a global level

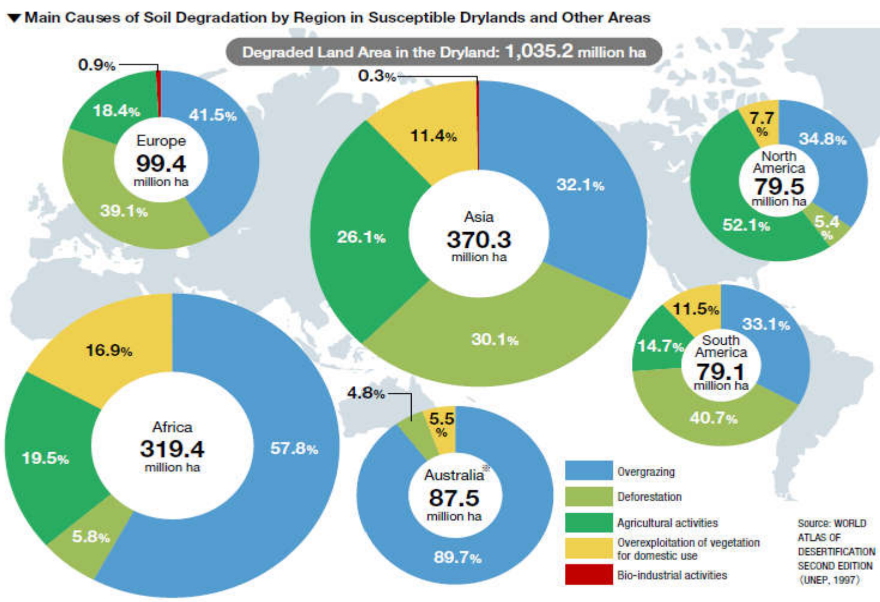
Human activities: These include overgrazing, deforestation and removal of the natural vegetation (cover by taking too much fuel wood), agricultural activities in the vulnerable ecosystems of arid and semi-arid areas, which are thus strained beyond their capacity. These activities are triggered by population growth, the impact of the market economy, and poverty.

Other causes of desertification include:

i. Lack of adjusting to natural fluctuation
ii. Rainfall below normal recorded levels
iii. Low priority often given to environmental protection

iv. International economic forces

v. Ignorance, errors, and natural and man-made disasters can also contribute to land degradation.[9]



Source: Aridity zones and dry-land populations: an assessment of population levels in the world's dry-lands with particular reference to Africa.[12]

2.4 Consequences and risk of desertification

There are several consequences of desertification which can either affects us directly or indirectly. Desertification;

i. Reduces the land's resilience to natural climate variability.

ii. Compromises the soil potential for food production.

iii. Increases possibilities of famine, malnutrition and starvation in a country.

iv. Indirect pressure on area outside the affected areas such as flooding, reduced water quality, sedimentation in rivers and lakes, dust storms and air pollution.

v. Leads to socio-economic instability

The factors mention above have the potential to make worse other challenges facing the region.

2.5 Processes and drivers of desertification due to climate change

The process of desertification includes both biological and non-biological processes, and is attributable to the physical, chemical and biological properties of terrestrial ecosystems. Some of the key drivers of desertification include soil erosion; global warming leading to the rise of CO_2 levels; sea surface temperature anomalies which drive rainfall changes; invasive plants which affect ecosystem services, wildfire which reduces vegetation cover, increases runoff and soil erosion, reduces soil fertility and affects the soil microbial community.

2.5.1 *Anthropogenic drivers of desertification include*: cropland expansion, unsustainable land management practices such as overgrazing by livestock, urban expansion, infrastructure development, and extractive industries. High and growing consumption of land-based resources has also been indicated as the ultimate driver of land degradation, e.g. through deforestation and cropland expansion, escalated by population growth.

2.5.2 *The institutional, policy and socio-economic drivers of desertification:* include land tenure insecurity, lack of property rights, lack of access to markets, and to rural advisory services, lack of technical knowledge and skills, agricultural price distortions, agricultural support and subsidies contributing to desertification, and lack of economic incentives for sustainable land management.

2.6 Effect of climate change on desertification

Desertification is affecting about 45% of the African continent’s land area, out of which 55% is at high or very high risk of further degradation. The major mechanism through which climate change and desertification affect food security is through their impacts on agricultural productivity. There is robust evidence pointing not only to negative impacts of climate change and desertification on crop yields, but also on the losses in agricultural productivity and incomes in dry-lands. The forecasts for Sub-Saharan Africa suggest that higher temperatures, increase in the number of heat-waves, and increasing aridity, will affect the rain fed agricultural systems. Without the carbon fertilization effect, climate change will reduce the mean yields for 11 major global crops – millet, cowpea, sugar beet, sweet potato, wheat, rice, maize, soybean, groundnut, sunflower and rapeseed – by 15% in Sub-Saharan Africa, 11% in Middle East and North Africa by 2050.

Desertification has led to reduction in agricultural productivity and incomes; it has also contributed to the loss of biodiversity in many dryland regions. It is further projected to cause reductions in crop and livestock productivity, modify the composition of plant species and reduce biological diversity across drylands. In sub-Saharan Africa particularly, crop production may be reduced by 17–22% due to climate change by 2050. About 821 million people globally were food insecure in 2017, of whom 31% were in Africa. Sub-Saharan Africa, particularly East Africa, had the highest share of undernourished populations in the world in 2017, with 28.8% and 31.4%, respectively. In North Africa, long-term monitoring (1978–2014) has shown loss of important perennial plant species due to drought and desertification e.g. *Stipa tenacissima* and *Artemisia herba alba*

2.7 Statistic Estimation of desertification

It is estimated that 46 of the 55 countries in Africa are vulnerable to desertification, with some already feeling the effects, the Nile (42% of area), Niger (50%), Senegal (51%), Volta (67%), Limpopo (66%) and Lake Chad (26%) (*The horn of Africa is getting drier*). Despite desertification in the Sahel being a major concern since the

1970s, wetting and greening conditions have been observed in this region over the last three decades. The Sahara is reported to have expanded by 10% over the 20th Century based on annual rainfall. However, cropland areas in the Sahel region of West Africa have doubled since 1975, with settlement area also increasing by about 150%. In Burkina Faso, from 1984 to 2013, bare soils and agricultural lands increased by 18.8% and 89.7%, respectively, while woodland, gallery forest, tree savannas, shrub savannas and water bodies decreased by 18.8%, 19.4%, 4.8%, 45.2% and 31.2%, respectively. In Fakara region in Niger, a 5% annual reduction in herbaceous yield between 1994 and 2006 was largely explained by changes in land use, grazing pressure and soil fertility. Greening has also been observed in parts of southern Africa but it is relatively weak compared to other regions of the continent.[5]

3. Mathematical Implementation

In this section the research is going to be concentrating on the global average temperature and the effect of greenhouse gases which can be modeled using the *energy balance equation (EBE)* [Kaper and Engler 2013,14] and a few equations on predicting weather and climate.

3.1 GLOBAL AVERAGE TEMPERATURE MODELS

$R\frac{dT}{dt} = Q(1-\alpha) - \sigma T^4$ Energy balance equation (3.1)

$R\frac{dT}{dt} = Q(1-\alpha) - \epsilon\sigma T^4$

(3.2)

$E_{out}: T \rightarrow E_{out}(T) = a + bT - (a_1 + b_1 T)n$

(3.3)

(where $a, b, a_1 \& b_1$ are observational data and n is a cloudiness coefficient)

$E_{out}: T \rightarrow E_{out}(T) = A + BT$ (where the values of A and B vary with temperature)

$R\frac{dT}{dt} = Q(1-\alpha) - (A + BT)$ Global surface temperature model

3.2 LIOUVILLE EQUATION

The evolution equation in a climate or weather prediction model are conventionally treated as deterministic, they based on spatially-truncated momentum, energy, mass and composition conservation equation and can be written as

$$X = F[x]$$

This conservation equation can also written in the context of Gleeson1996 as

$$\frac{\partial \rho}{\partial t} = \frac{\partial}{\partial X}(X\rho) = L\rho$$

3.3 SIMPLE FLUVIAL MODELS

3.3.1 Exner Equation

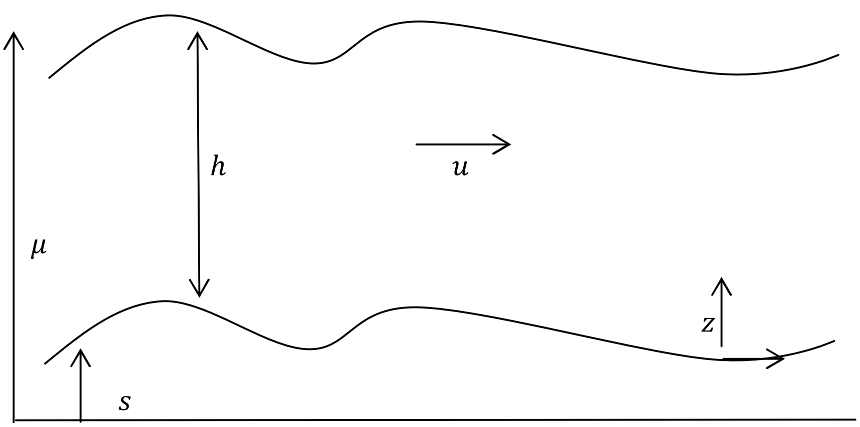


Fig 3.3.1

The figure above is a geometry of a river therefore its free surface is at

$z = u(x, y, t)$, and its bed is at $z = s(x, y, t)$. Hence the depth of the river is

$$h = u - s$$

it is based on the principle conservation of mass for the substrate, and may be written as

$$(1 - n)\frac{\partial s}{\partial t} + \nabla . q = fs$$

3.3.2 St Venant equation

The Navier-Stokes equations is also written in this case of two-dimensional flow

$u_x + w_z = 0$

$\rho_{w(u_t + uu_x + wu_z) = -p_x + \rho_w g S + \mu(u_{xx} + u_{xx})}$

$\rho_{w(u_t + uu_x + wu_z) = -p_x + \rho_w g \sqrt{1 - S^2} + \mu(u_{xx} + u_{xx})}$

Where s is the slope.

3.4 VARIABLE DESCRIPTION AND THEIR UNITS

- T (K, Kelvins) is the average temperature in the Earth's *photosphere* (upper atmosphere, where the energy balance occurs in the model) (1kelvin = 1°c);
- t(years) is time;
- R = (W-yr/m^2K) is the average heat capacity of the Earth/ atmosphere system (heat capacity is the amount of heat required to raise the temperature of an object or substance 1kelvin (=1°C));
- Q = (W/m^2) is the annual global mean incoming solar radiation per square meter of the Earth's surface;
- ϵ = ORL emissivity factor
- A *and* B = are empirically determined parameters
- α = is planetary *albedo* (dimensionless)
- σ = (w/m^2K^4) is a constant of proportionality (*Stefan-Boltzmann constant)*[16]
- E_{in} = average amount of solar energy reaching one square meter of the Earth's surface per unit time

- E_{out} = average amount of energy emitted by one square meter of the Earth's surface per unit time
- S(m) = height of the bed relative to some reference height
- n(dimensionless) = porosity of the substrate
- q(m^2s^{-1}) = bed transport rate
- f_s = source function corresponding to the exchange of sediment between the fluid and the bed.
- $\nabla = (\frac{\partial}{\partial x}, \frac{\partial}{\partial y})$ two-dimensional
- **CONSTANT VALUES OF SOME VARIABLES**
- Values for the parameters are:
- R= 2.912 w-yr/m^2K [Ichii et al. 2003];
- Q= 342 W/m^2
- α= 0.30
- $\epsilon = 0.6$
- σ = 5.67 x 10^{-8} W/m^2K^4

SUMMARY

As this stage, we have seen different climate models which include; the energy balance equation, simple fluvial model, liouville equation etc. All the models provided in 3.1 are similar to each other but all of them are important depending on the initial variables available and will help us calculate the global average temperature.

4.0 INTRODUCTION

We have discovered from our chapters points the review of different scholars and organization on the diverse effects of desertification and climate change our environment and the world at large. We have also discussed some mathematical model that will enable us to clearly see its impact and behaviors. The data that will be used in this chapter was collected from Nigerian Meteorological Agency (NIMET), National Population Commission (NPC) and researches done by different scholars and will be used to display graphs and to solve a few problems.

4.1 DATA COLLECTION

Table 4.1 Population in the sampled villages.[16]

Development area	Population in clustered villages	Male	Female	Total Household	Sampled household	Percentage
Balle	11,635	63	58	2327	116	4.98
Bulanguwa	11,034	54	56	2297	110	4.78
Dagona	10,277	56	51	2055	102	4.96
Dapchi	10,034	45	30	1406	80	5.68
Degeltura	7,882	44	39	1576	78	4.94
Dumburi	10,022	55	50	2004	100	4.99
Futchimiran	4,209	21	26	841	52	6.18
Gumsa	5,147	25	30	1029	61	5.92
Gwio kura	16,377	86	82	3275	163	4.97
Gorgoram	9,046	45	50	1809	100	5.52
Kanama	6,889	34	37	1377	69	5.01
Karasuwa	5,049	25	30	1009	60	5.94
Kaska	13,747	68	70	2749	137	4.98
Machina	18,081	65	70	2616	130	4.96
Muguram	10,905	58	54	2181	119	5.46

Yunusari	8,822	44	49	1764	95	5.39
Yusufari	11,089	56	61	2218	111	5.00
Wachakal	8,140	46	41	1628	96	5.90
Total	170,385	895	884	34077	1779	5.22

Source: National Population Commission (2001)

Table 4.2 Migration per 1000 population in 2002[16]

Development area	In-Migration	Out-Migration
Balle	12	150
Bulanguwa	54	56
Dagona	13	59
Dapchi	30	40
Degeltura	10	6
Dumburi	40	60
Futchimiran	9	38
Gumsa	8	36
Gwio kura	81	82
Gorgoram	6	37
Kanama	25	44
Karasuwa	3	123
Kaska	76	61
Machina	11	140
Muguram	53	56
Yunusari	36	52
Yusufari	43	67

Wachakal	48	52
Total	558	1154

1.1 Chart for Migration per 1000 population

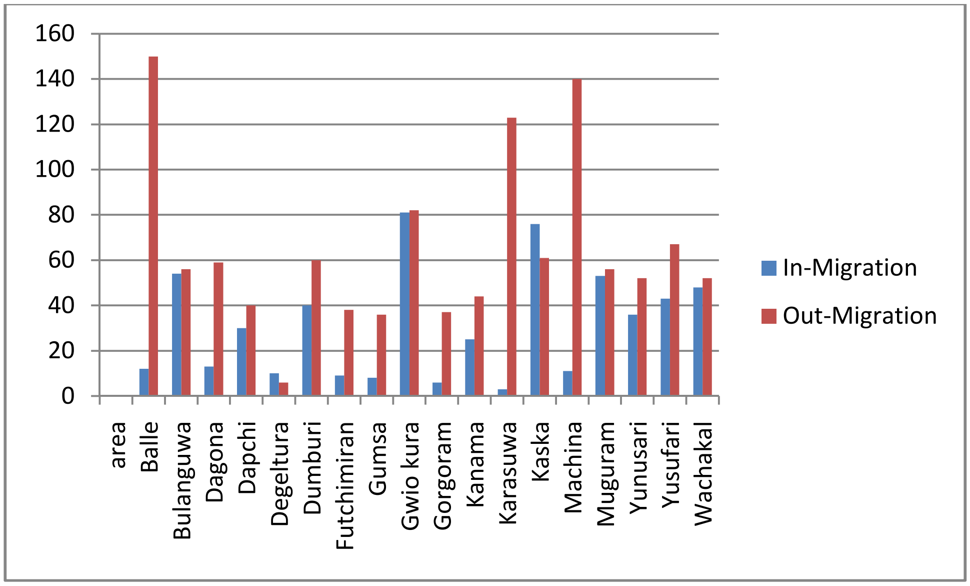


Table 4.3 Showing Social Impacts of Desertification (SID)

Sl. No.	Questions	4	3	2	1	Mean	STD
SID1	Desertification leads to destruction and relocation of houses	73 (25.5)	169 (59,1)	37 (12.9)	7 (2.4)	3.68	.692
SID2	Sometimes whole settlements relocate as a result of desertification	95 (33.2)	126 (44.1)	56 (19.6)	9 (3.1)	3.07	.807
SID3	Conflicts among people do occur as a result of desertification	188 (65.7)	90 (31.5)	8 (2.8)	0 (0)	3.63	.539
SID4	Desertification affects soil fertility	175 (61.2)	111 (38.8)	0 (0)	0 (0)	3.61	.488
SID5	Farming and grazing activities are also affected by desertification	136 (47.6)	141 (49.3)	9 (3.1)	0 (0)	3.44	.558

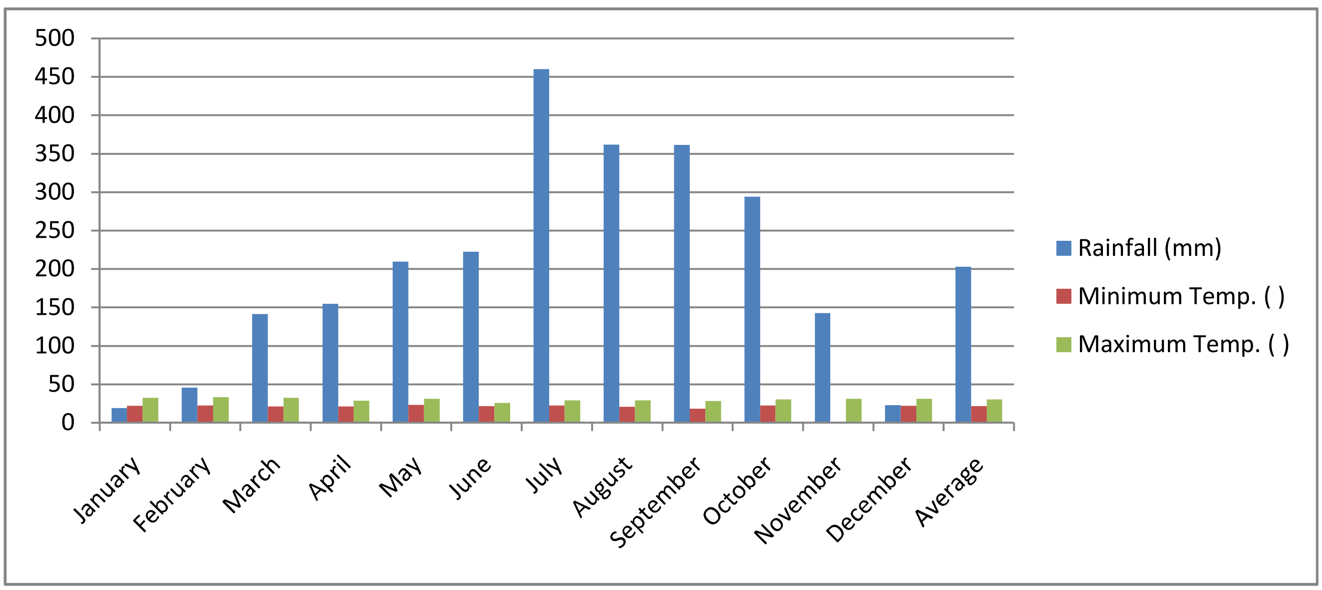
SID6	Desertification leads to drying up of sources of water	89 (31.1)	176 (61.5)	11 (3.8)	10 (3.5)	3.20	.671
SID7	As a result of desertification loss of biodiversity is experienced	68 (23.8)	105 (36.7)	98 (34.3)	15 (5.2)	2.79	.865
SID8	Desertification induced problems lead to overall reduced quality of life among people	144 (50.3)	138 (48.3)	4 (1.4)	0 (0)	3.49	.528
SID9	Desertification leads to migration of people from the area	86 (30.07)	146 (51.04)	39 (13.64)	15 (5.24)	3.02	.778
SID10	Increase in soil erosion is noticed in recent years	99 (34.61)	177 (61.89)	10 (3.50)	0 (0)	3.45	.535
Overall Average		**117(40.95)**	**133(46.70)**	**29(10.18)**	**6(2.18)**	**3.33**	**.661**

The table above shows the responses of the people living in some few villages within our case study with respect to social impacts of desertification in their communities. The table shows that 88.46% agreed that these impacts of desertification are far reaching and the situation is very bad. These impacts manifest in form of destruction, migration from the whole settlement, diminishing grazing fields, drying up of water sources, erosion, and reduced quality of life among the local people[15].

Table 4.4 Average monthly rainfall and temperature anomalies

Month	Rainfall (mm)	Minimum Temp. (°C)	Maximum Temp. (°C)
January	19.06	21.92	32.40

February	45.75	22.49	33.08
March	141.43	21.38	32.48
April	154.9	21.26	28.90
May	209.81	23.14	31.15
June	222.39	21.78	25.71
July	460.22	22.54	29.00
August	361.7	20.84	29.16
September	361.44	18.32	28.32
October	293.98	22.62	30.34
November	142.71	22..97	31.27
December	22.94	22.23	31.13
Average	203.03	21.79	30.25



It was observed that there was an increase in the of daily amount of rainfall and the extension of rainy season which is usually 8 months (March-October) to 10 months(February-November) this was evident even in some states of the northern part of the country (Potiskum L.G.A, Yobe State) for the last few years

(2017,2018). The dry season had been observed shorter and hotter as the years progress. These phenomena are in conformity with the consequences of global warming resulting from increased anthopogenic activities. (Tamunoberetonaria *et. al*. 2013).

Table 4. Anti-desertification plants used in Yobe State, Nigeria[16]

Scientific Name	**Vernacula Name**	**Hausa Name**
Amaranthus spp.	Amaranth	Dangme
Annona cherimola	Cherimoya	
Annona muricata	Guanabana, soursop, graviola	
Asimina triloba	Asimina	
Cleome gynandra	African, cabbage, cat's whiskers	Yar unguwa
Dacryodes edulis	Safou or butter fruit	
Ipomoea batatas	Sweet potato	Dankalin hausa
Irvingia gabonensis	Dika tree	Goron biri(Goron ruwa)
Moringa oleifera	Moringa	Zogale
Oxytenanthera	Drought-resistant	Goradi
Abyssinica	Bamboo	Gwangwala
Prosopis cineraria	Prosopis	Akiye
Simmondsia chinensis	Jojoba	
Solanum scabrum	African nightshade	
Strychnos spinosa	Monkey orange	Girigita

4.2 PROBLEM

The models developed in the previous chapter (3.4) will be used to solve few examples as seen below

1. $R\frac{dT}{dt} = Q(1-\alpha) - \sigma T^4$

Data

$R = 2.912$ W-yr/m^{2}K[Ichii et al 2003], $Q = 342$W/m^2[Kaper and Engler 2013], $\alpha = 0.30$[Kaper and Engler 2013], $\sigma = 5.67$X10^{-8}, $T = 30.71$

$T^* = \left(\frac{Q(1-\alpha)}{\sigma}\right)^{1/4}$ Equilibrium temperature

$$T^* = \left(\frac{342(1-0.30)}{5.67X10^{-8}}\right)^{1/4}$$

$$= \left(\frac{342(0.70)}{5.67X10^{-8}}\right)^{1/4}$$

$$= \left(\frac{239.4}{5.67X10^{-8}}\right)^{1/4}$$

$$= (4.22222)^{1/4}$$

$$= 1.4335℃$$

Hence the equilibrium temperature is increasing at a very slow pace but yet its impact to the surrounding can be clearly noticed with time.

4.3 Discussion

It is clearly evident that climate change is affecting the rate of desertification all over the globe.

Boris Johnson the prime minister of the united kingdom at the COP26 (2021), gave an analogy that if the global temperate exceeds **1.5**℃ to **2**℃, (our food supply will greatly be affected, locusts, bees and other important insects that aid pollination will all die), **3**℃ (more cases of wildfires, 5x drought, 36x heat waves etc), **4**℃ (major cities like Miami, Shanghai will all disappear because of over flooding, hurricanes etc.). Hence the world's leaders have agreed to maintain the net global emissions to **1.5**℃ and gradually to a lesser degree[17].

Evidently, the socio-economic impacts of desertification in all the study locations with the exception of Gumshi were found to be high. Thus, with the unprecedented increase in the rate of deforestation activities such as logging coupled with the nonchalet attitudes of the local communities towards controlling desertification and its impacts, continuous deforestation acts by the local people, lukewarm attitudes of the Government, increasing over dependence of the local communities on fire wood as the dominant source of domestic energy as well as the growing dependence of considerable number of the local communities on fire wood selling as a source of income, desertification can continue taking toll in these areas and its impacts both socially and economically can escalate. The change in the climate and weather system is also responsible for the unstable yield of most farm product[15].

5.1 CONCLUSION

Based on the research so far, we have discovered a framework for developing a better understanding of the nexus between the environmental changes, population response and environmental policy and management. Solutions to desertification must be aimed to increase the amount of food production in the area in concomitance with farm practices that must encourage environmental stabilization. It is also clear that the general public have little knowledge about how their day to day use of unchecked car exhaust, bush burnings, etc is dangerous to them and to the world at large. [15]

5.2 RECOMMENDATION

Here are a few recommendations to the Government, Non-Governmental Organizations (N.G.O), affected communities and every individual to address some of the findings in this research respectively:

A. The government must be all round committed to fight desertification and gain the participation of the local population combat desertification in their local communities. The key area to be given priority is massive tree planting exercise, construction of earth dams, etc this calls for more fund allocation to both State and Federal Forestry Departments in Nigeria. The aim should be a long term sustainable participatory environmental resources management programme.[16]

B. Non-governmental organizations in partnership with the local stakeholders should create a forum for massive reforestation programme, leading to improved environmental management capacity. There is the need for the tapping of underground water for domestic and irrigational purposes. Fadama areas should be protected with trees to avoid drying up of the catchment areas.[16]

C. All affected communities most take the responsibility of ensuring that all government policies concerning desertification are backed up and obeyed by every resident in that community. They are also responsible for the maintenance of amenities provided by the government, N.G.O's and stakeholders to combat desertification.

D. As we have seen in this research how indirectly desertification can affect people who are far away from the affect communities by causing shortage of food supply, flooding, poverty etc. hence everyone must take the responsibility to ensure we combat climate change by reducing the use of excess carbon exhaust and desertification to the barest minimal.

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