The International Journal of Multi-Disciplinary Research
ISSN: 3471-7102, ISBN: 978-9982-70-318-5

THE IMPACT OF CLIMATE CHANGE ON SUSTAINABLE AGRICULTURE AND FOOD SECURITY IN ZAMBIA

(Conference ID: CFP/591/2018)

Darlington Arnold Mangaba
mangabadarlington@gmail.com
Department of Agriculture,
School of Research and Graduate Studies,
Gideon Robert University, Lusaka, 10101, Zambia

Abstract

Agriculture is the world's only source of food, feed, oil, fibre and other products that play a major role in fostering food security, food sovereignty and socio-economic development. Many countries that have taken serious investments in the agricultural sector have achieved meaningful economic growth, stability and resilience. It is however noted that the reliability of the agricultural sector, in as far as boosting of economic growth is concerned, has dwindled in the recent past due to adverse changes in the climatic conditions. Today, the whole world is striving to address the impact of climate change on agriculture, food security and economic development. It was the focus of this paper to identify and analyse the effects of climate change on agricultural productivity and food security as well as to suggest measures that can be embraced in a bid to mitigate the detrimental effects of climate change.

Key words: *Climate Change, Sustainable Agriculture, Food Security, Greenhouse Gases, Global Warming.*

1. Introduction

1.1 Background

Agriculture is the basic industry that supplies the world with food, feed, oil, wool, and many more products that are used as raw materials in the processing industries and it plays a major role in economic development, to which Zambia is no exception. The Agricultural sector is one of the sectors that contribute significantly to the growth of the Zambian economy. The sector's contribution to the Gross Domestic Product (GDP) currently stands at about 18% to 23% (CSO, 2015)[1]. Many countries, world over, have succeeded in growing their economies through massive investment in the agricultural sector in the recent past. Denmark and Netherlands are examples of countries that have grown their economies through livestock production while the United States of America and India grew their economies through diversified cropping agriculture. India has not only become self-reliant in food grains but has also acquired sufficient resilience to tide over the adverse conditions owing to successful implementation of crop diversification, research, extension services, and the provision of agricultural inputs (Hazra, 2002)[2].

The face of agriculture is however slowly changing. Both rain-fed and irrigated agriculture have of late faced challenges that are posed by various changes in the climatic conditions. Climate change has led to the rise in the global temperatures causing atmospheric imbalances while the greenhouse effect causes the atmosphere to retain excessive heat. Changes in the sun's energy and its reflectivity affect the amount of energy reaching and entering the earth's system. These climatic changes affect the water cycle, earth's temperatures and life patterns, for both plants and animals. The effect of climate change on plant and animal life has negatively impacted agricultural productivity hence affecting food security and socio-economic growth, stability and resilience in the final end.

1.2 Problem statement

The problem at hand is the diminishing agricultural productivity and sustainability of the earth which is posing a great threat on food security.

1.3 Objectives

1.3.1 General Objective

The general objective of this paper was to identify the causes of climate change and suggest measures that can be employed in a bid to mitigate the adverse effects of climate change on agricultural productivity and food security.

1.3.2 Specific Objectives

The specific objectives of the study were:

1. To identify the various causes of climate change.
2. To analyze the impact of climate change on agricultural productivity and food security.
3. To establish measures that can be applied in mitigating the adverse effects of climate change on agricultural productivity and food security.

1.4 Purpose of the Paper

The purpose of this paper was to raise awareness of the causes and effects of climate change so that their perception may deter people from engaging themselves in activities that perpetuate climate change.

2. Literature Review

2.1 Definition of Climate Change

Climate change refers to the alteration to the usual global or regional climatic patterns. Particularly, climate change is a shift apparent from the mid to the late twentieth (20^{th}) century onwards and this change is attributed to the increased levels of atmospheric carbon dioxide produced by the use of fossil fuels. Climate change is usually defined as the shift in the 'average weather' in a place. It includes patterns of temperature, precipitation, humidity, wind and seasons.

2.2 Causes of Climate Change

The primary cause of climate change is the burning of fossil fuels, such as oil and coal, which emits greenhouse gases into the atmosphere. Other human activities, such as agriculture and deforestation, manufacturing and construction, also contribute to the proliferation of greenhouse gases that cause climate change. The earth's temperature depends on the balance between energy entering and leaving the planet's system. When incoming energy from the sun is absorbed by the earth system, the earth warms up. When the sun's energy is reflected back into space, the earth avoids warming. When absorbed energy is released back into space, the earth cools down. Many factors, both natural and human, can cause changes in the earth's energy balance. Basically, factors accounting for global warming include; variations in the sun's energy reaching the earth, changes in the reflectivity of the earth's atmospheric surface and changes in the greenhouse effect, which affects the amount of heat retained by the earth's atmosphere. Recent climate changes, however, cannot be explained by natural causes alone. Research indicates that natural causes do not explain most observed warming, especially warming since the mid-20^{th} century. Rather, it is extremely likely that human activities have been the dominant cause of that warming (Stocker, et al., 2013) [3].

2.2.1 Natural Causes of Climate Change

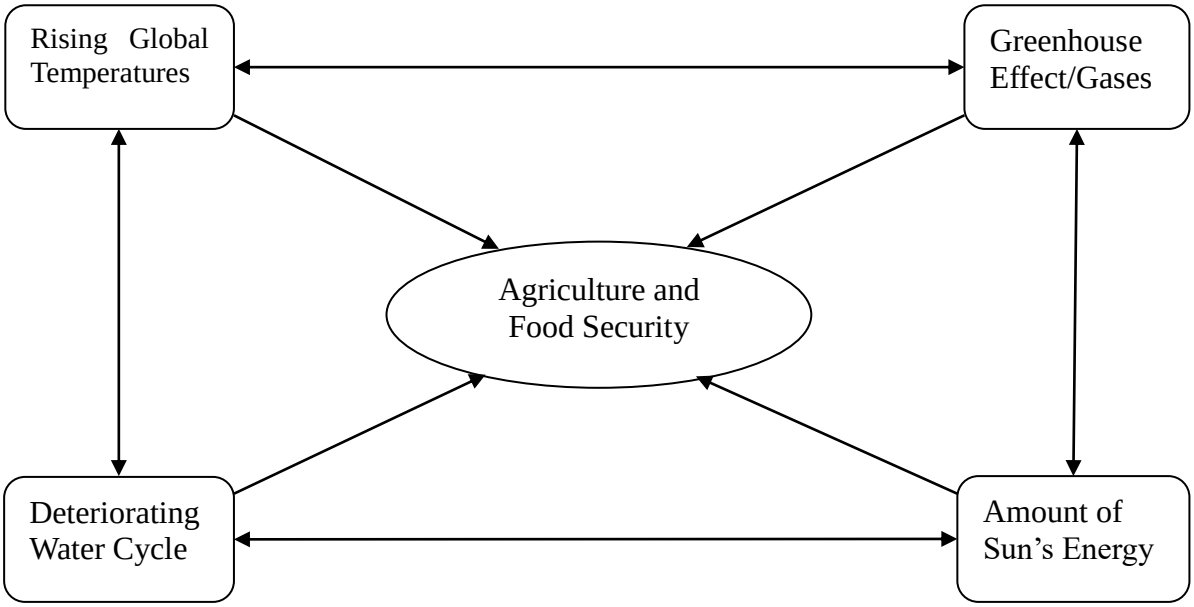
The earth's climate has been affected by natural factors that are external to the climate system, such as changes in volcanic activity, solar output, and the earth's orbit around the sun. Of these, the two factors relevant on timescales of contemporary climate change are changes in volcanic activity and changes in solar radiation. In terms of the earth's energy balance, these factors primarily influence the amount of incoming energy. Volcanic eruptions are episodic and have relatively short-term effects on climate. Changes in solar irradiance have contributed to climate trends over the past century but since the Industrial Revolution, the effect of additions of greenhouse gases to the atmosphere has been over 50 times that of changes in the Sun's output (Stocker, et al., 2013) [3].

2.2.2 Human Causes of Climate Change

Climate change has also been attributed to human activities, such as the burning of fossil fuels and the conversion of land for agriculture, manufacturing and construction. Since the beginning of the Industrial Revolution, these human influences on the climate system have increased substantially. In addition to other environmental impacts, these activities change the land surface and emit various greenhouse gaseous substances to the atmosphere. These in turn can influence both the amount of incoming energy and the amount of outgoing energy and can have both warming and cooling effects on the earth. The dominant product of fossil fuel combustion is carbon dioxide, a greenhouse gas. The overall effect of human activities since the Industrial Revolution has been a warming effect, driven primarily by emissions of carbon dioxide and enhanced by emissions of other greenhouse gases. Such climate change could have far-reaching and/or unpredictable environmental, social, and economic consequences.

2.3 Conceptual Framework

The framework below proposes that agriculture and food security are affected by the four elements of climate change. These elements of climate change are; the rising global temperatures, the greenhouse effect, the deteriorating water cycle and the amount of the sun's energy reaching and entering the earth's system. The framework further proposes an interactive relationship among the four elements of climate.



2.4 Impacts of Climate Change

Climate patterns play a fundamental role in shaping natural ecosystems and the human economies and cultures that depend on them. This climate we have today is not what it used to be, because the past is no longer a reliable predictor of the future. Our climate is rapidly changing with disruptive impacts.

The rising levels of carbon dioxide and other heat-trapping gases in the atmosphere, such as methane, have warmed up the earth, causing wide-ranging impacts which include; rising sea levels, melting snow and ice, more extreme heat events, fires and droughts, and more extreme storms, rainfall and floods. It is for such effects that scientists have projected that these trends will continue and, in some cases, accelerate, posing significant risks to human health, forests, agriculture, freshwater supplies and other natural resources that are vital to agro-productivity, economic growth, environmental safety and enhanced quality of life.

Because many systems are tied to climate, any change in climate can affect many related of where and how people, plants and animals live, such as food production, availability and use of water, and health risks. Taking an example of changes in the usual timing of rains or temperatures can affect plant flowering and fruiting, when insect activities such as pollination, fish spawning, food and water supplies for both domestic and agricultural uses.

Agriculture feeds and clothes the world. Although the long-term effects of climate change are still largely unknown, scientists can observe short-term effects of climate change on crops and animals. In addition, scientists can prognosticate the changes that are likely to occur in agriculture if global climate change causes changes in temperatures and rainfall.

2.5.1 Impacts of Climate Change on Agriculture and Food Supply

There are innumerable potential effects climate change could have on agriculture. It could affect crop growth and quality, livestock health, and pests. Climate change could affect farming practices, as well as pest control and the varieties of crops and animals that could be raised in particular climactic areas. These could, in turn, affect the availability and prices of agriculture products as well as the costs of doing business.

Agriculture and fisheries are highly dependent on the climate and they control the world's food supply chain. Increases in temperature and carbon dioxide (CO_2) can increase some crop yields in some places. But to realize these benefits, nutrient levels, soil moisture, water availability, and other conditions must also be met. Changes in the frequency and severity of droughts and floods could pose challenges for farmers and ranchers and threaten food safety (Hatfield, et al., 2014)[4]. Moderate warming and more carbon dioxide in the atmosphere may help some plants to grow faster. However, more severe warming, floods, and drought may reduce yields. Livestock may be at risk, both directly from heat stress and indirectly from reduced quality of their food supplies. Fisheries will be affected by changes in water temperatures that make waters more hospitable to invasive species and shift the ranges or lifecycle timing of certain fish species. Meanwhile, warmer water temperatures are likely to cause the habitat ranges of many fish and shellfish species to shift, which could disrupt ecosystems.

Generally, climate change could make it more difficult to grow crops, raise animals, and catch fish in the same ways and same places as we have done in the past. The effects of climate change also need to be considered along with other evolving factors that affect agricultural production, such as changes in farming practices and technology.

2.5.2 Impacts of Climate Change on Crops

Despite technological improvements that increase corn yields, extreme weather events have caused significant yield reductions in some years (Ziska, et al., 2009)[5]. Changes in temperature, atmospheric carbon dioxide (CO_2), and the frequency and intensity of extreme weather could have significant impacts on crop yields. For any particular crop, the effect of increased temperature will depend on the crop's optimal temperature for growth and reproduction (Hatfield, et al., 2014) [4]. In some areas, warming may benefit the types of crops that are typically planted there, or allow farmers to shift to crops that are currently grown in warmer areas. Conversely, if the higher temperature exceeds a crop's optimum temperature, yields will decline.

Higher CO_2 levels can affect crop yields. Some laboratory experiments suggest that elevated CO_2 levels can increase plant growth. However, other factors, such as changing temperatures, ozone, and water and nutrient constraints, may counteract these potential increases in yield. Elevated CO_2

has been associated with reduced protein and nitrogen content in alfalfa and soybean plants, resulting in a loss of quality. Reduced grain and forage quality can reduce the ability of pasture to support grazing livestock (Hatfield, et al., 2014) [4].

More extreme temperature and precipitation can prevent crops from growing. Extreme events, especially floods and droughts, can harm crops and reduce yields. For example, in 2010 and 2012, high night-time temperatures affected corn yields across the U.S. Corn Belt, and premature budding due to a warm winter caused $220 million in losses of Michigan cherries in 2012 (Hatfield, et al., 2014) [4]. Dealing with drought could become a challenge in areas where rising summer temperatures cause soils to become drier. Although increased irrigation might be possible in some places, in other places water supplies may also be reduced, leaving less water available for irrigation when more is needed.

Droughts are damaging because of the long-term lack of water available to the plants. Heat waves can cause extreme heat stress in crops, which can limit yields if they occur during certain times of the plants' life-cycle (pollination, pod or fruit set). Also, heat waves can result in wilted plants (due to elevated transpiration rates) which can cause yield loss if not counteracted by irrigation. Strong winds can cause leaf and limb damage, as well as 'sandblasting' of the soil against the foliage. Heavy rains that often result in flooding can also be detrimental to crops and to the soil structure and can erode topsoil from prime growing areas, resulting in irreversible habitat damage. Most plants cannot survive in prolonged waterlogged conditions because the roots need to respire. Heavy winds and rains can down large trees and damage houses, barns and other structures involved in agricultural production.

Many weeds, pests and fungi thrive under warmer temperatures, wetter climates, and increased CO_2 levels. Currently, U.S. farmers spend more than $11 billion per year to fight weeds, which compete with crops for light, water, and nutrients (Hatfield, et al., 2014) [4]. The ranges and distribution of weeds and pests are likely to increase with climate change. This could cause new problems for farmers' crops previously unexposed to these species. Though rising CO_2 can stimulate plant growth, it also reduces the nutritional value of most food crops. Rising levels of atmospheric CO_2 reduce concentrations of protein and essential minerals in plant species. This direct effect of rising CO_2 on the nutritional value of crops represents a potential threat to human health. Human health is also threatened by increased pesticide use due to increased pest pressures and reductions in the efficacy of pesticides (Hatfield, et al., 2014) [4].

2.5.3 Impacts of Climate Change on Livestock

Changes in climate could affect animals both directly and indirectly. Heat waves, which are projected to increase under climate change, could directly threaten livestock. In 2011, exposure to

high temperature events caused over $1 billion in heat-related losses to agricultural producers (Hatfield, et al., 2014) [4]. Heat stress affects animals both directly and indirectly. Over time, heat stress can increase vulnerability to disease, reduce fertility, and reduce milk production. Drought may threaten pasture and feed supplies. Drought reduces the amount of quality forage available to grazing livestock. Some areas could experience longer, more intense droughts, resulting from higher summer temperatures and reduced precipitation. For animals that rely on grain, changes in crop production due to drought could also become a problem.

Climate change may increase the prevalence of parasites and diseases that affect livestock. The earlier onset of spring and warmer winters could allow some parasites and pathogens to survive more easily. In areas with increased rainfall, moisture-reliant pathogens could thrive (Melillo, et al., 2008) [6]. Potential changes in veterinary practices, including an increase in the use of parasiticides and other animal health treatments, are likely to be adopted to maintain livestock health in response to climate-induced changes in pests, parasites, and microbes. This could increase the risk of pesticides entering the food chain or lead to evolution of pesticide resistance, with subsequent implications for the safety, distribution and consumption of livestock and aquaculture products (Hatfield, et al., 2014) [4].

Increases in carbon dioxide (CO_2) may increase the productivity of pastures, but may also decrease their quality. Increases in atmospheric CO_2 can increase the productivity of plants on which livestock feed. However, the quality of some of the forage found in pasturelands decreases with higher CO_2 levels. As a result, cattle and other types of livestock would need to eat more to get the same nutritional benefits as they would from good quality feed.

2.5.4 Impacts of Climate Change on Soil Processes

The potential for soils to support agriculture and distribution of land use will be influenced by changes in soil water balance. Increases in soil water deficits, i.e. dry soils becoming drier, increase the need for irrigation though they have beneficial effects of improving soil workability in wetter regions and diminish soil poaching and erosion risks.

3. Methods and Materials

The study was conducted by an in-depth review of existing literature related to the topic.

4. Findings of the Paper

The paper brought out the following key findings:

1. Climate change has been caused by both natural phenomena and human activities.
2. The causes of climate change are basically associated with emissions of greenhouse gases into the atmosphere.
3. Climate change has detrimental effects on human, plant and animal lives as well as on the environment and agricultural production and food security.
4. There are measures that can be employed in a bid to counteract the adverse effects of climate change. Various human activities can be tailored towards minimisation and avoidance of greenhouse gases emissions.

5. Measures to Mitigate Climate Change

5.1 Mitigating Climate Change

Climate Change Mitigation refers to efforts or measures adopted in order to reduce or prevent emission of greenhouse gases. Mitigation can mean using new technologies and renewable energies, as alternatives, making older equipment more energy efficient, or changing management practices or consumer behaviour. It can be as complex as a plan for a new city or as a simple as improvements to a cooker design. Efforts underway around the world range from high-tech subway systems to bicycling paths and walkways. Protecting natural carbon sinks like forests and oceans, or creating new sinks through the development and support of silviculture or green agriculture are also elements of mitigation.

The United Nations Environment Program (UNEP) takes a multifaceted approach towards climate change mitigation in its efforts to help countries move towards a low-carbon society. Climate change mitigation consists of actions to limit the magnitude or rate of long-term climate change (Fisher, et al., 2007) [7]. Climate change mitigation generally involves reductions in human anthropogenic emissions of greenhouse gases (Fisher, et al., 2007) [8]. Mitigation may also be achieved by increasing the capacity of carbon sinks, for instance, through reforestation (Edenhofer, et al., 2014) [9]. Mitigation policies can substantially reduce the risks associated with human-induced global warming (Oppenheimer, et al., 2014) [10].

5.2 Mitigating Climate Change through Agriculture

To feed the planet's ever-growing population while dealing with climate change will require a new way of thinking. Current farming methods are depleting the earth's resources and producing alarming quantities of greenhouse gases. It is estimated that agriculture operations currently produce 13 percent of human-based global greenhouse gases (GHG) emissions (Edenhofer, et al.,

2014) [9]. The environment is paying a huge price in biodiversity loss and deforestation while the global economy leaks billions of US dollars per year on conventional agriculture's economic side-effects.

Shading agriculture green will not only ease pressure on the environment and help cope with climate change but will also create opportunities to diversify economies, increase yields, reduce costs, and generate jobs which will in turn help reduce poverty and increase food security. Increasing farm yields and improving ecosystems services will be a boon to many people who depend on agriculture for their livelihood, particularly in developing nations where most farmers live on small packages in rural areas.

Huge gains can be made for a greener future by simply reducing agricultural waste and inefficiency. Nearly 50 percent of food produced today is lost through crop loss or waste during storage, distribution, marketing, and household use (Oppenheimer, 2014) [10]. Some of these inefficiencies, especially crop and storage losses, can be addressed with small investments in simple farming and storage technologies.

Agriculture has to be made simple and environmentally friendly. The destructive forms of agriculture must be replaced by the sustainable forms which do not accelerate forest degradation and the emission of greenhouse gases. In the long-term, the agricultural plants will play the role of carbon sinkers hence reducing detrimental impacts of climate change.

5.3 Mitigating Climate Change through Forestry Development

Forest goods and services support the livelihoods of many people, most of whom are poor and live in developing countries. They also sustain over 50 percent of the Earth's species, regulate our climate through the carbon cycle and protect the watersheds. Yet this priceless resource, a fundamental component of our ecological infrastructure, is being threatened by deforestation and forest degradation at a rate of 13 million hectares per year (Edenhofer, et al., 2014) [9]. Halting deforestation and accelerating silviculture may be good investments. Funding reforestation and paying off landholders for conservation could raise value added in the forest industry and at the same time increase forest carbon sinks.

5.4 Mitigating Climate Change through Energy Utilisation

The growth of populations and incomes reciprocate the demand for energy. Our craving for energy services is one of the biggest challenges to mitigating climate change and building a greener future. As much as the global community is wrestling with climate change, it must also grapple with current patterns of energy consumption, including energy security, pollution, and enduring energy poverty. The current, leading fossil fuel energy system is high in carbon emissions thus

environmentally unsustainable. The rising energy demand is higher in developing countries, due to industrialization, where rising fossil fuel prices and resources constraints are putting additional pressure on the environment and the economy.

To contain this impasse, the world must turn to the once considered an 'unrealistic' alternative, the renewable energies. The renewable forms of energy take care of the fossil fuels' negative externalities, like carbon emissions and health impacts.

5.5 Mitigating Climate Change through Manufacturing

Manufacturing has a major impact on the environment as a result of its carbon emissions and must be factored into the climate change equation. At the same time, the sector's economic importance cannot be ignored. Changing the way industries make things will go a long way towards mitigating manufacturing's negative environmental impacts. In some cases, simply re-designing a product can improve not only the product's life span, but also lead to a more efficient use of resources, easier recycling, and less pollution during the manufacturing process and life of the product.

Modern innovations like recycling heat waste and closed-cycle manufacturing can save both resources and money. Remanufacturing and reconditioning, both labour-intensive activities, can create jobs and require relatively little capital investment.

5.6 Mitigating Climate Change through Transport Management

Current methods of getting from one place to another are generating serious problems for both human wellbeing and the environment. Transport gobbles up over half of the planet's liquid fossil fuels and is responsible for almost a quarter of energy-related greenhouse gas (GHG) emissions (Edenhofer, et al., 2014) [9]. Our motorized lifestyle is causing widespread air pollution. A green, low-carbon transport sector has the potential to reduce GHG emissions from the sector.

The world needs to its transportation system to more energy-efficient and environmentally friendly forms. For this transformation to happen, however, there needs to be a major shift in the way we think about investing in transport. There is need to shift passengers away from private vehicles to public and non-motorized transport, and freight users from trucks to rail or water transport. Finally, make vehicles cleaner, through both efficiency improvements and cleaner fuels.

5.7 Mitigating Climate Change through Tourism Management

Nothing seems to be able to quell the human urge to visit foreign places. Tourists are travelling more often and to more distant destinations, using more energy-intensive, fossil fuel-based transport and the sector's greenhouse gas (GHG) contribution to global emissions is on the increase. Other unsustainable practices, such as excessive water use, waste generation, and habitat encroachment are threatening ecosystems, biodiversity, and local culture.

Green tourism aims to reduce poverty by creating local jobs and stimulating local business, while establishing ecologically sustainable practices that preserve resources and reduce pollution. Investing in energy efficiency and waste management can reduce GHG emissions and pollution. Under the right circumstances, natural areas, biodiversity, and cultural heritage, three of the main reasons people travel in the first place, can all reap the benefits of sustainable tourism.

5.8 Mitigating Climate Change through Constructions, Buildings and Cities

(Edenhofer, et al., 2014) notes that approximately one third of the world's energy use takes place inside buildings. This has earned the building sector the dubious honour of being the Earth's biggest contributor to greenhouse gas (GHG) emissions. Moreover, the construction industry consumes more than one third of the planet's resources and generates huge quantities of solid waste. Clearly, any attempt to improve resource efficiency must take buildings into account.

Improving energy efficiency in buildings through greener construction methods and retrofitting existing structures can make an enormous difference in reducing GHG emissions. Green construction can also have a positive effect on productivity, public health, and even employment. Cities are growing quickly, especially in developing countries. Urban areas are now home to some 50 percent of the planet's population, use a good 60 percent of available energy, and account for an equal share of carbon emissions (Edenhofer, et al., 2014) [9]. Rapid urbanization is affecting water supplies, public health, environment, and quality of life, especially for the poor. Fundamental changes in urban development will have to take place in order to build a sustainable future.

Fortunately, the very density of cities may turn out to be their strongest advantage. Characterized by proximity, variety, and density, cities can be fertile ground for collaboration between local and national governments, civil society, private partnerships, and academia, all of whose input will be essential to the greening of our urban areas. With the right policies, practices, and infrastructures in place, cities can be green models for efficient transport, water treatment, construction, and resource use.

5.9 Mitigating Climate Change through Prudent Waste Management

As countries' economies grow, so does the volume of their garbage. According to estimates, some 11.2 billion metric tons of solid waste are currently being collected around the world every year, and the decay of the organic portion is contributing around 5 percent of global greenhouse gas emissions. The fastest growing waste stream in both developing and developed countries is electrical and electronic products, which contain hazardous substances that make disposal even more of a challenge. Human health and the environment are increasingly at risk, particularly when dumpsites are uncontrolled or volume becomes unmanageable. Illnesses and infections, ground

water pollution, GHG emission, and ecosystem destruction are just some of the impacts of our overfilled global dustbin.

Turning the waste stream, a brighter shade of green, however, can actually create economic opportunities. Managing waste, from collection to recycling, is a growing market. Recycling, in particular, will grow with a greening of the waste sector, and actually creates more jobs than it replaces. Investment in greener waste management can produce many environmental and economic benefits, including resource savings, nature protection, and employment and business opportunities. The best way to manage waste is to produce less of it and minimizing waste is the first essential step towards greening the sector. The goal is to produce as little waste as possible, recycle or remanufacture as much as possible, and treat any unavoidable waste in a manner that is the least harmful to the environment and humans.

6. Conclusions and Recommendations

6.1 Conclusions

Climate change has a lasting effect on agricultural production and food security. Any climate-related disturbance to food production, distribution and transport, internationally or domestically, may have significant impacts not only on environmental safety and quality but also on food access and security. Impacts to the global food supply are the world's major concern because food shortages can cause humanitarian crises and national security concerns.

6.2 Recommendations

The author recommends that the current world population must take keen interest in combating the threatening effects of climate change on sustainable agriculture and food security. It is imperative that every individual works towards achieving a green world by facilitating plant grow as carbon dioxide sinkers. On the other hand, humankind must restrict emission of greenhouse gases in all their activities and improve on the management of waste as it is an equal contributor of greenhouse gases to the atmosphere.

7. Acknowledgment

Any project without contributions from other people does not achieves a meaningful stand. May I therefore take this opportunity to acknowledge the input from Dr. Muvwanga, M.C., for his lavish guidance and supervision. I further extend my gratitude to my lovely wife, Sarah Tembo Mangaba, for her technical and moral support and Mr. Urgent Cheelo, Teacher of Languages and Literature at Kapululira Secondary School, in Chirundu, for proofreading this work.

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