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Droughts and Agricultural Development in Africa: The Genetically Modified Organisms (GMOs) Mitigation Strategy in Food Security

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Authors' contributions

This work was carried out in collaboration between the authors. Author JKWN designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Author KON managed the analyses of the study and the literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

Climate change indicators, particularly frequent droughts which have occurred in Africa since the Sahelian drought of 1968-1972 cause devastating effects to the agricultural sector. These effects include; crop failures, water and pasture shortage, famines, hunger and economic underdevelopment to rain fed dependent agricultural systems in Africa. Different stakeholders have proposed various strategies which focus on mitigating the negative effects caused by drought on agriculture. Some researchers have emphatically proposed the introduction of genetically modified organisms/crops (GMO) as a strategy to mitigate the negative effects of drought on food security in Africa. This research investigates whether GMOs are functional solutions to ensuring sustainable food production in arid Africa. Data for the study was collected and analyzed from; interviews with

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subsistence farmers in Kenya, reports from the National Bio Safety Authority, Kenya Agricultural Livestock and Research Organization, drought scenarios in Africa since 1968-72 and attending GMO organized workshops. It was established that GMO crops are accepted by large scale cash crop farmers in 28 countries and banned in 38 countries worldwide. They are not accepted by small scale subsistence farmers who cultivate indigenous crops. Agricultural research should therefore, focus on alternative methods of improving the quality and yields of indigenous food crops which are cultivated by small scale farmers, instead of introducing the GMOs which promote monoculture and agricultural dependency on few selected crops.

Keywords: Genetic engineering; transgenic; Brachiaria grass; fragile ecosystem; mitigation strategy; green house farming; poly cropping.

1. INTRODUCTION

Droughts cause the most challenging and devastating effects on rain fed agriculture in the moisture constrained arid and semi-arid lands of Africa. The frequent droughts occurring in Africa since the Sahel drought of the 1960s have impacted negatively on majority subsistence and pastoral farmers who frequently suffer from famine and starvation caused by crop failure, lack of pasture, animal losses, water scarcity and malnutrition related diseases. The 2005/2006, 2009, 2011 and the 2017 droughts were declared " National Disasters" by the government of Kenya, there by calling for emergency response in terms of immediate relief food and water supplies from the Red Cross and well wishers to the affected families. The response, adaptation and mitigation strategies have been employed by scientists, researchers, national governments and stakeholders in the agricultural sector with a focus on improving the negative effects caused by drought on food security and stimulating economic development in Africa and other arid lands located within the tropics. One such a strategy to mitigate the current problems which agriculture suffers because of drought is the introduction of GM crops which has elucidated heated debate globally. The objectives of the study were to establish: (i) the relationship between drought, food insecurity and GMOs. (ii) Whether genetically modified organisms/food crops can solve the problem of food security, economic development and reverse the negative effects of drought on agriculture, (iii) whether there are other mitigation strategies which can solve the food insecurity problem caused by droughts. In order to answer the questions raised in this study, the researcher consulted the following resources; (i) attended the policy makers workshop on GMO organized by the South African Academy of Sciences, (ii) Analyzed GMO research debates from the ministry of agriculture, the National Bio safety Authority, the National Environment Management Authority (NEMA), the Kenya Agricultural Livestock and Research Organization (KALRO), the multinational companies such as Monsanto, (iii) Interviewed small scale subsistence farmers on the causes of food shortages and acceptability of GMOs, (iv) and analyzed data on drought scenarios in the dry lands of Africa since the 1960s when climate change became a noticeable devastating phenomenon in Africa. The Study is based on the pro-GMO assumption that biotechnology, especially GM crops will provide functional solutions to the problems of food insecurity caused by frequent and prolonged droughts to Africa's arid and semi-arid lands. Proponents of biotechnology argue that in order to increase food production and meet the food demands of the ever growing population, biotechnology (genetically modified organisms) must replace the old methods of food production.

2. DROUGHT EFFECTS ON AGRICULTURE IN AFRICA

The term drought implies the absence of precipitation for a period long enough to cause moisture deficiency, crop failure, water shortages, hunger, starvation and general hardship [1]. Contemporary Africa is vulnerable to frequent floods droughts and environmental degradation in the arid and coastal zones. 60% of Africa's total land area is arid semi-arid land as indicated by the presence of the Sahara desert, Kalahari Desert, Namib Desert and arid lands of Northern Kenya, Northern Uganda and Tanzania. These arid lands are characterized by rocky grounds, thorn and scattered shrubs and they are highly moisture stressed environments (Plate 1).

Droughts in Africa are caused by increase in global temperatures due to increase in the production of greenhouse gases mainly carbon

dioxide and methane from industrial activities, deforestation for firewood provision, over cultivation on fragile soils, overgrazing in the arid lands and failure of the Inter tropical convergence Zone (ITCZ) to move far from Equator. The persistent droughts in Africa have caused devastating impacts on agriculture resulting into; collapse of rain fed agriculture, reduced grain yields, diminishing food security, increased heat stress in livestock and decrease in water volume of major rivers which are used for irrigation, such as; the Nile, the Zambia, the Zambezi, the Volta, the Athi and the Tana [2]. Droughts in Africa have greatly affected pastoral farming activities of the Karayu in Ethiopia, Tueregs in the Sahel, the Masaai in Kenya and Tanzania and the Karamojong in Uganda [3].

Almost the entire continent of Africa suffered severe droughts in the last quarter of the 20th century (Table 1). The 1970's was seen as a decade of unusual and extreme climate conditions on a global scale, for example, Africa suffered the 1968-1973 Sahel droughts, where an estimated 50,000 - 200,000 people died from food shortage, the semi arid lands of Kenya experienced the highest rainfall and floods in 1977 while Ethiopia suffered severe drought in the 1980's. India experienced failure of monsoon winds in 1974 while Brazil experienced the worst frosts in 1975. Drought occurrence is not a phenomenon of the tropics alone, temperate lands do suffer from droughts as well. For example,

Studies of tree rings in the United States of America identified droughts occurring as early as 1220. The longest drought identified by tree ring method began in 1276 and lasted 38 years. Tree ring method identified twenty one (21) droughts lasting five (5) or more years during the period 1220 to 1958. The most well known American drought was the" Dust Bowl" which occurred on the Great Plains in the years, 1931-1936.

Water scarcity in arid lands necessitated the government of Kenya to sink boreholes for pastoralists. During drought periods, many boreholes dry up, thus forcing pastoralists to scramble (compete for the available water resource) for water from the few boreholes.

The 1st decade of the 21st century was seen as the driest in 100 years. The 2008-2009 failure of rains in Kenya's arid and semi-arid lands particularly the Eastern region, put 10 million Kenyans at severe risk of starvation and possible death with loss of over 90% of livestock due to acute water scarcity and lack of pasture (Plates 2 and 3).

The 4th Assessment Report of the (IPCC) Intergovernmental panel on climate change 2007 confirmed that "Africa is one of the most vulnerable continents to climate variability and change because of multiple stresses and low adaptive capability. The diversity of the people, varying ecosystems, natural resources (minerals, plants, water availability) social and political

Plate 1. Typical moisture stressed arid Turkana County, Kenya

histories (the Arab North, the "Black" South of the Saharan Africa and the "white" Southern Africa makes it difficult to find common solutions about the threats posed by the pressing "climate change and food security on the African continent." African people face serious social and economic challenges due to diseases, high poverty and poor nutrition levels with ten poorest nations in the world being located in tropical and sub-tropical Africa [5].

Table 1. Notable drought effects on agriculture in Africa

Year	Drought effects
1968-73	Severe phase of drought in Ethiopia and the Sahel region caused crop failure, famine, and starvation, human and animal deaths.
1980-84	Severe drought in ASAL of Kenya led to crop failure, livestock loss and 274% increase in food prices in the super markets.
1984	Severe droughts in Ethiopia and Kenya led to the introduction of "Food queues" in supermarkets and the importation of yellow maize from USA as a coping strategy in Kenya.
1990-92	Serious drought in the ASAL of Kenya caused: i) 70% of the pastoralists in Wajir, West Pokot and Mandera lost all their livestock. ii) Total crop failure caused many people to die after eating dead dog meat.
1992-1993	Severe La Nina droughts in Zimbabwe decreased agricultural production where the economy shrunk by 12%.
2000-02	Severe droughts in Ethiopia caused the pastoral Karayu community to lose 70% of their livestock's.
2005-06	Severe droughts in ASAL Kenya and Uganda led to 90% livestock loss, making the pastoral Maasai community to migrate to Nairobi city centre with their animals in search of water and pasture. Kenya declared this drought a national disaster.
2009	10 million people faced starvation while 90% of livestock were lost in Kenya due to severe drought that caused massive crop failure, water scarcity and lack of pasture (Plates 2 and 3). The drought was declared a national disaster by Kenya
2011	Droughts caused 12 million people in Djibouti, Ethiopia, Kenya, Somalia and Uganda to face acute starvation and malnutrition, with food prices rising as much as 270% within the year. The drought was declared a national disaster in Kenya.

Source: [1,3,4].

Plate 2. Scramble to draw borehole water in the semi-arid Laikipia County in 2009

Plate 3. Effect of 2009 drought on livestock in Arid Turkana County

3. CHARACTERISTICS OF AGRICULTURE IN AFRICA

Agriculture has great potential and holds the key to rapid job creation, improved health and improved livelihoods for the majority of the poor people living in the tropics. In essence, agriculture goes beyond farms and creates opportunities for growth and development in health, trade, transport, education, energy and information and communication technology.

Agriculture within tropical Africa is rain fed and affected by frequent droughts, rainfall fluctuations and low capital investment inputs which often lead to low and diminishing crop productivity [6]. Most industries in Africa are agro-based with agricultural exports concentrated in coffee, tea, cocoa, sugar, cotton and bananas. The largest importer of these products is the European Union followed by China and USA. These agricultural products are processed at the source where they are produced, for example, sugar industry is located in Lugazi sugarcane belt in Uganda, Tea factories are found in the tea growing Kenya highlands region. Monoculture characterizes commercial farming in Africa, for example, Tea and Coffee are the main cash crops produced in the East African highlands of Kenya Uganda and Tanzania, Cocoa is the leading cash crop in West Africa while maize is the leading cash crop produced in the Maize Triangle in the Republic of South Africa. Farming is largely labor intensive, for example, there is manual tea picking and manual sugar cane weeding and harvesting. Subsistence agriculture is practiced on highly fragile ecosystems such as hilly areas, dry lands and wetlands. Frequent food price fluctuations caused by droughts and floods lead to acute food shortages/food crisis for example, in 2017 due to 2016 drought in Kenya, the price of 2kg maize flour rose from Ksh 85 to Ksh 170 within six months, a price increase of 100%.

There is duplication of cash crop farming in Africa where different countries within the continent grow and export same type of crop for example, coffee is grown in Kenya, Tanzania and Uganda, Maize is grown in Kenya highlands and in South Africa's "Maize Triangle". This type of duplication makes agricultural economies vulnerable at the slightest change in climate patterns. The tropics are characterized by poor internal and external markets due to duplication and exportation of semi- processed goods. About 50% of countries in sub-Saharan Africa depend on agricultural commodities as the main exports. In fact, reliance on single agricultural commodity export ranges between 50% and 75% of total exports.

Agriculture constitutes about 30% of Africa's Gross Domestic Product but provides only 60% of food supply to the population. This means that food demand is higher than food supply. The food balance sheet is therefore characterized by food imports and food aids from the developed countries [6] for example, Kenya imported yellow

maize from USA during the 1984 drought and imported white maize from Brazil in 2017 during the" unga crisis" [7].

There is very low input investment in the agricultural sector, for example, Africa invests only 4% of her Gross Domestic Product (GDP) and Mali invests 11%, Burkina Faso invests 15% and Ethiopia invests 17%. The use of fertilizer is very low in Africa with 8 kg/ha compared to the global average of 100 kg/ha which result into low crop yields in tons per hectare [6]. In sub-Saharan Africa, agriculture employs 60% of the population [3]. Women who provide 80% of the labour force on farms by planting, weeding, harvesting food crops and preparing food for their families do not have land ownership rights but receive only 5% of extension services. Women are also underrepresented in research, training and policy-making positions.

Rapid population growth introduced changes in the traditional extensive agricultural systems where about 7,000 plant species with varieties that could cope with changing climate were cultivated for food since agriculture began about 12,000 years ago to intensive modern agricultural systems with only about 15 plant species and 8 animal species supplying 90% of food. Many traits from wild relatives were incorporated into the modern crop varieties by cross-breeding to improve productivity and tolerance to pests, diseases and difficult growing conditions, unfortunately, many wild races of staple food crops are endangered and are predicted to die out within the next 50 years which could make it difficult for future plant breeders to ensure that commercial varieties can cope with a changing climate [8]). Agriculture which is the main source of livelihood for 75% of the world's rural poor mainly in Africa is also the human activity most affected by climate change, particularly droughts, however, agricultural research and technology does not reach and benefit small scale subsistence farmers on the continent.

Though Africa has a history of extreme food shortage scenarios caused by both natural (droughts and floods) and man-made disasters (civil wars), It is important to note that the top most causes of food insecurity are not only unfavorable weather conditions or lack of land but poverty and other compelling factors such as: lack of early warning systems, lack of defined research outputs, lack of adequate financial investment in farm inputs, poor post harvest food storage, Culture, poor road networks/ Infrastructure, exportation of semi processed or unprocessed goods, abandoning the growing of indigenous crops, limited utilization of water resources for irrigation, limited use of mixed farming and crop rotation methods, high Illiteracy levels in agriculture, Population pressure, uncontrolled Pests and Rural urban Migration in search of office based jobs by the youths [6,5,9,10,1].

4. THE MEANING OF GENETICALLY MODIFIED ORGANISMS (GMO)

The terms; Genetic Modification and Genetically modified foods are defined as follows: Genetic modification is the artificial alteration of an organism's genetic composition. This involves the transfer of genes from one organism into another organism of a different species in order to give the latter specific traits of the former organism. The resulting new organism is then called a transgenic or genetically modified organism. Examples of such organisms include plants that are resistant to certain insects, can withstand herbicides and can also survive in moisture constrained conditions. Though genetic engineering is also being used on farm animals, so far no genetically engineered animal products have been approved by the Food and Drug Administration (FDA) for human consumption ([11], also available at: www.investopedia.com/terms/genetically-modified-gmf.asp). Genetically modified foods, also known as genetically engineered foods or bioengineered foods are those foods produced from organisms that have had their genes engineered to introduce traits that have not been created through natural selection. Genetic engineering means modifying a food by introducing a gene into a fruit or vegetable or animal from another organism. Scientists, consumers and environmental groups have cited many health and environmental risks associated with foods containing GMOs. Many countries have either passed or proposed legislations which regulate the development and use of GMOs in the food supply [12].

5. METHODS OF DATA COLLECTION

Data for this study was collected from the follo wing sources; (i) The researcher attended the policy makers workshop on GMO organized by the South African Academy of Sciences, (ii) Analyzed GMO research debates from; the ministry of agriculture, the National Bio safety

Authority, the National Environment Management Authority (NEMA), the Kenya Agricultural Livestock and Research Organization (KALRO), the multinational companies such as Monsanto, (iii) Interviewed small scale subsistence farmers on the causes of food shortages and acceptability of GMOs and analyzed data on drought scenarios in the dry lands of Africa since the 1960s when climate change became a noticeable devastating phenomenon in Africa, (iv) reviewed literature on GMOs from journals, text books, Newspapers and internet surveys. The analyzed data was presented in the form of critical discussions, photographs, tables and illustrating examples. The results were organized and presented under the following sub headings; the GMO as a mitigation strategy in food security, anti-GMO school of thought, negative impacts of GMO, the pro-GMO School of thought, acceptable strategies for agricultural development and food security provision, conclusion and references.

6. RESULTS AND DISCUSSION

6.1 The GMOs as a Mitigation Strategy in Food Security in Africa

Commercial cultivation of genetically engineered crops mainly soybean, maize and cotton started in the early 1990s. As at 2016, GM crops were commercially planted by 18 million farmers on 185.1 million hectares of land in 28 developed and developing countries [13].

The most preferred method advanced by some agricultural scientists for mitigating food insecurity in poor countries located within the tropics, is by use of Genetically Modified Organisms. Koffi Annan, the chair of the board for Alliance for Green Revolution in Africa (AGRA) stated that the organization will not include GMOs in its dealings with farmers, but instead will work with indigenous food species. He emphasized that the major causes of Food insecurity in Africa were as a result of poor infrastructure, out dated farming practices, Storage issues and dwindling market prices which discourage farmers from consistent farming as a source of income [14]. From the challenges stated, only a few can be solved by the introduction of GM crops [15]. African farmers who mostly engage in subsistence farming are reluctant to embrace food products that require purchase of seeds every planting season without any allowance to replant the saved seeds after harvest.

The information made available on GMO breeds courtesy of Biotechnological Companies such as Syngenta and Monsanto is limited to promotional and marketing geared towards stimulating purchase rather than disseminating factual information to consumers. A lot of information readily available focuses on the “perceived benefits” to farmers. Some Developing countries such as Burkina Faso, South Africa, Nigeria, Bosnia, Bolivia and Paraguay have embraced GM foods mainly, maize, cotton and rice as the solution to food insecurity without careful scrutiny of the possibility of long term negative effects [12]. This has been largely due to the immediate needs of the people who usually are at risk of starving to death without relief food or short term sources of the same. It is therefore a mix of desperation combined with the unrealistic pursuit of ‘Quick fixes,’ to challenges which require long term solutions [16]. The three major GM seed companies which are; Mosanto, DuPont and Syngenta control more than 65% of the market thus exercising a great deal of control over the prices. Mayet, 2004 claim that African countries such as Rwanda, which are already surviving on substantial amounts of donor funding in their development agenda, may find GMO pursuit an extra burden on their strained economies. Tirado and Johnston, 2010 also claim that the major agenda of GM seed companies is to expand and develop a ready market for their products in third world countries, stimulate dependence by farmers and establish territories in African countries, governments and their agricultural sectors. The two researchers are also critical about the “perceived benefits “of GMOs, where they argue that GMO research focuses mainly on producing increased yields of selected crops such as maize, cotton and rice with little regard to diverse cultures and food ways of African people. Genetic modification is only one of the tools that farmers can use to boost productivity, it does not eliminate other tools such as; hybridization, spray of chemicals and mechanization [11].

A non-profit making independent research organization established that the associated “increased yields “narrative used in the promotion of GM crops are relative or non-existent. It all depends on a variety of factors beyond anyone’s control such as water, market policies, cost of seeds or even the availability of cheaper alternatives. According to the report, there is need for conclusive evidence to support the claims purported by the GM seed companies [11].

The advent of research on Genetically Modified Organisms in agriculture has created dilemma and changed the content and nature of how the governments should respond to the persistent problem of underdevelopment and food insecurity in arid and semi-arid lands of Africa. Two extreme schools of thought pulling in different directions have emerged; the pro GMO and the anti-GMO. The pro-GM school of thought does catalogue the benefits of genetic engineering and normally dismiss all the risk concerns raised by the anti-GMO school of thought. They try to justify that genetic engineering is the solution to eradicating food insecurity and stimulating economic development in the Arid and Semi Arid Lands (ASAL) of Africa [17]. On the other hand, the anti- GMO school of thought is deeply worried about the risks and dangers that would afflict the ASALs should genetic engineering be developed, commercialized and applied [18]. The two schools of thought have tended to confuse many African policymakers and the general public because of lack of scientifically proven reliable information. There is uncertainty, confusion and division among governments in Africa on how best to respond to food insecurity and on how to achieve long term agricultural growth, food security and economic development.

6.2 Anti- GMO School of Thought

The anti-GMO school of thought argues that there is uncertainty as to the effects of GMOs on health of consumers as well as the impact on the environment. For example, GMO may replace conventional fruits or vegetables from the environment which may in turn impact the animals, insects and other organisms that traditionally used those plants to survive. Other threats include genes from the GMOs moving to convectional crops (out crossing); the GM genes may also be transferred from the food to the human consumers [19]. This school of thought is concerned that the agribusiness where a few seed varieties which need fertilizers and pesticides do well has actually eroded indigenous crop varieties and caused hunger and malnutrition to subsistence farmers [20]. Developed countries can help arid African countries to be food secure by supporting the revival of seed saving practices to ensure food variety and security at family levels. This is because biotech companies have patented their products and do not allow farmers in the western world to save seeds from year to year while, 90% of subsistence farmers in Africa save their seeds for replanting [21]. If subsistence farmers in Africa cross pollinate their seeds with GMO or adopt GMO seeds, they will be exposed to hunger and food insecurity since they will not be able to protect seed varieties which they have taken generations to develop and share. At the same time, farmers whose indigenous crops were cross pollinated by GM pollens were sued by those GM companies [20].

A good example of the dilemma and non acceptability of the suitability of GMOs as a recommended solution to food insecurity is the food shortage case of Southern Africa states in the spring of 2002. Due to erratic rainfall and floods, more than 15 million people were left at the mercy of donors due to acute food shortage. International concerns led to the distribution of relief food, but the then touted as 'controversial decision' by Zimbabwe, Zambia, Malawi and Mozambique to decline relief food due to inclusion of GMOs raised concerns as to the motives of such a plan [18]. These particular relief efforts courtesy of the United States government via USAID contained GMO maize and those African countries despite the crisis, refused to accept them. The US then tried to link the entire crisis on poor governance and mismanagement in the affected countries. Research by European Union consultants and Zambian scientists concluded that the maize offered as relief had the genetic characteristics that would interfere and dominate the indigenous varieties through cross breeding. A similar scenario had been witnessed in Mexico where surplus relief maize was used as seeds by farmers and eroded the natural varieties [22]. Refusal of this brand of relief food by African governments has repeatedly been met by harsh criticisms [20], but one has to consider the negative long term effects of such assistance to the economies of these countries in particular from the European Union's policy on GMOs. African countries like other sovereign states are justified to protect their interests by ensuring economic stability which reduces dependence on donor funding [21]. The European Union heeding to its population's pressure is yet to yield into the GMO phenomenon. EU does not engage in any form of commercial GMO based agriculture. It is known to import organic Agricultural produce paying the extra costs involved. European Union is also known to discontinue trade with countries that actively pursue biotechnological based farming; it discontinued trade with America which was one of its biggest organic producers before 1996 on bio-tech farming basis. Bodies such as

the Agricultural Biotechnology Support Program (ABSP) and Program for Bio-safety Systems (PBS) are both pro- GMO and are funded by USAID. They have over the years maintained the 'GMO are "safe" narrative while labeling governments that oppose them as retrogressive thus permeating policies with great success making some countries to lower their bio-safety protocol standards [19]

As at 2016, 38 countries had banned GMO crop cultivation, although some of them allow imports of corn and soybean as animal feeds. The countries which have banned GMO crop cultivation include:-

> Australia, Azerbaijan, Bosnia, Herzegovina, Bulgaria, Croatia, Cyprus, Denmark, France, Greece, Hungary, Italy, Latvia, Lithuania, Luxembourg, Malta, Moldova the Netherlands, Northern Ireland, Norway, Poland, Russia, Scotland, Serbia, Slovenia, Switzerland, Ukraine and Wales, Algeria and Madagascar.

The World watch institute report established that sustainable means of combating food shortage is not dependent on the constant development of new crop varieties and breeds but on proper management of indigenous traditional crops that will be both suited for the regions climatic conditions and will also restore the biodiversity of the region [12]. It is important for food producers to be aware of the environmental and health consequences of GMOs. In the long-run, it has been established that the often suggested need for these biologically enhanced organisms are unnecessary in cases where indigenous alternatives are readily available especially in Africa [8]. The anti GMO school of thought insists that Traditional African farming systems have a diversity of seed varieties and vast amount of ecological knowledge, they have many types of seeds with better nutritional value which have evolved with resilience to local pests and diseases and are adapted to different soils and weather patterns which provide concrete resilience strategy than developing a single crop which can fail to give various nutrition values, and which can also fail with changes in climate extremes especially droughts [8].

Therefore, GMOs do not offer solutions to Africa's peasant farmers who are better suited to manage indigenous crops. The argument that GMOs will increase yields and improve food production is not correct since the success and application of GM seeds does well on large farms with a lot of resources while majority (90%) of African families survive on subsistence and small scale farming [23]. A controversial case documented in Kenya and which gained worldwide attention was when the Monsanto backed "African Harvest group" declared after extended research that it had developed a new pest resistant sweet potato which would increase a farmer's income by up to 39%. These claims were however exposed as baseless when independent research confirmed that the GM sweet potatoes not only performed poorly compared to the organic counterparts but were also susceptible to the pests they were engineered to repel. This claim questioned the capitalistic agenda of the GMO multinational companies.

Some farmers from poor nations have suffered irreversible negative impacts when the "high yielding" GMO narrative failed them after heavy investment. A practical example is when Monsanto which controls 95% of India's cotton seed market hiked prices that left farmers with debts. 250,000 farmers were reported to have committed suicide due to debts incurred in purchasing expensive seeds wrongly marketed as high yielding. When the yields failed to meet the financial projections, peasant farmers resorted to suicide among other desperate acts out of frustrations [21,8].

It has been established that genetic engineering benefits large Agribusiness companies such as Syngenta and Monsanto most which are researching on production technologies that respond to Global Marketplace. They do not invest in genetic engineering of indigenous crops which are not globally traded and which are the bases of food security for subsistence farmers in Africa [24].

Focused research has led to specialized genetic modification and greatly reduced the biodiversity of crops and livestock. A focus on the biological factors that determine crop yields such as Environment and crop management need dedicated investigation as research indicate they directly influence the increase in crop yields. This should be pursued with more if not equal commitment to that assigned to GMOs. It is rather disturbing when the research community blatantly ignores exploring other alternatives. However, when one considers that the research companies are privately funded, then the capitalistic agendas of these institutions become

obvious because, there is simply no profit in traditional organic cross breeding as it cannot be patented or regulated [25].

Research communities have not allocated enough resources on organic crops while GMOs receive the bulk of research funding. Denmark for example, spent only 4 million EUR in organic crop research while 20 million EUR was spent by the Danish Research Council on GMO research [26].

The biosafety laws of most African countries have serious shortfalls which must be addressed in order to convince farmers to adopt the GMO. Some of the gray areas include; (i) there is a lot of emphasis on regulating the importation and introduction of GMOs developed elsewhere into the country, but these laws are silent on measures put forward to regulate and promote domestic scientific research, (ii) the biosafety laws do not have explicit measures for promoting research on biosafety in general and risk assessment in particular [27].

6.3 Negative Impacts of Genetically Modified Foods

The anti-GMO School of thought has established some negative impacts associated with either consumption or application of GMOs as follows: (i) That though the genes being transferred occur naturally in other species, there are unknown consequences to altering the natural state on an organism through foreign gene expression. Such alterations can change the organism's metabolism, growth rate and response to external environmental factors. These consequences may influence the GMO itself, the natural environment in which the organism is allowed to proliferate. Potential human risks linked to GMO consumption include the possibility of exposure to new allergens in GMO foods and the transfer of antibiotic resistant genes to gut Flora [28].

(ii) The American Academy of Environmental Science has consistently linked GM foods with infertility, weakened immune systems and insulin imbalance among human consumers. In the worst case pitted against these products, research on mice indicates that GM products when consumed reduced the natural digestive enzymes thus making the mice allergic to non – GMO foods. The food samples used in these researches were those already in the American market targeting human consumers [29,19].

(iii) The "Responsible Technology" community who carried out research on the effects of the consumption of GMO products established that the genetic material such as those inserted in Soybean continues to survive in the human body as they get incorporated into the bacteria found in the human digestive tract. In addition, the genetic advantages which enable these crops to be herbicide resistant also encourage farmers to use more herbicide amounts thus increasing the amount of residue from herbicide that stays within the food post-harvest [20]. An even higher risk potential is the anti-biotic resistant genes that are incorporated in some GM crops which may lead to super infections that are also antibiotic resistant [29,28].

(iv) Many ASAL countries in Africa have limited financial resources that are needed to deal with emergent risk events that may be caused by adoption of GMOs or even the resources needed to develop and implement effective regulations. By default, most developing countries are also rich in biodiversity by virtue of their vastly unexploited natural resources which unfortunately are at the highest risk of having their pure gene pool contaminated with the GMO adoption [23].

Good examples of such areas are the centers of genetic origin and biodiversity in Ethiopia and the Mediterranean region which need utmost protection from gene contamination by GM crops [19]. Either way the researchers who are available to train local researchers or offer consultancy services are all from the Multi-National companies, Foundations or Research groups that are pro-GMO, therefore, limiting objective research while giving opportunity for bias. (v) The Cabinet Secretary for Agriculture Mr. Willy Bett while advising the Government of Kenya on GMO Research, stated that:- The National Performance Trials (NPTS) which the Kenya University Biotechnology Consortium (Kubico) was advocating for on Genetically Modified Organisms (GMOs) would adversely affect traditionally grown crops through cross pollination and that the Kenyan Farmers were not convinced that GMO crops are safe and pose no threats to Conventional Agriculture [30].

6.4 Pro –GMO School of Thought

A Mid protest from anti- GMO school of thought, a new report by ISAAA has revealed a sharp increase in GM crop acreage from 150 million hectares in 2010 to 185.1 million hectares in

2016. In Africa, where regulatory processes such as NEMA and Biosafety have in the past created barriers to biotech crop adoption rates, noticeable advances are being realized, for example, in 2016, South Africa and Sudan increased the planting of biotech maize, soybean and cotton from 2.29 million hectares in 2015 to 2.66 million hectares in 2016.

As at 2016, GM crops were commercially grown in 28 countries with the top 11 genetically modified crop producing countries shown in Table 2.

The proponents of GMOs point to many benefits of introducing desirable genetic traits into food. For example, scientists may engineer fruits and vegetables to have higher yields, resist certain diseases, pests and be able to tolerate pesticides and herbicides. They argue that biotech maize has toxic proteins that kill pests and therefore secure the plant against insect invasion. Basing on the army worm invasion and destruction of thousands of acres of maize in the maize producing areas of Trans Nzoia, Uasin Gishu, Bungoma, Nakuru and Busia in Kenya, and the ministry of agriculture projected drop in maize harvests from 37.1 million bags in 2016 to 32.8 million bags in 2017 representing 11.5% decline, Scientists call upon the government of Kenya to allow field trials and commercialization of bio-tech maize variety which are pest resistant [31]. The 20th Century Green Revolution owed much of its success to the introduction of plants that could produce higher yields in more adverse conditions such as arid lands. Some African countries such as Kenya, Malawi, Nigeria, Ghana, Ethiopia and Uganda are in fact making advances in regulatory review and commercial approvals to accept and adopt a variety of biotech crops mainly maize, rice and potatoes in order to solve the frequent problems of food shortages caused by droughts. Although [32] claims that the listed African countries which seem to be pro-GMOs in their official policy, hold these positions as a result of lobbying, hand – outs and smart marketing by the heavy presence of interested Parties, for example, the Multinational seed producers (Monsanto, Syngenta), local Agribusiness industry players, Government based research bodies that are foreign funded or supported in GMO research and the government policies that allow adoption of these crops, these countries understand the importance of introducing GM crops on their food balance sheet.

6.5 Acceptable Strategies for Agricultural Development and Food Security in Africa

Understanding the fact that, 60% of the farmers practice small scale subsistence crop and livestock farming in Africa and that there are many other causes of food insecurity, namely; inadequate research, inadequate agricultural financing, lack of value addition, poor food distribution, pests and diseases, delayed response to early warning systems, inadequate utilization of water resources, poor post harvest storages, poor crop and pasture selection techniques which contribute to low yields, crop failure, and general food scarcity for both human beings and livestock, there are readily available, applicable, cheap and acceptable strategies to the 60% small scale subsistence farmers than the GMOs which require heavy financial investment and will be available to few large scale commercial farmers [2,23,27,20]. This section discusses some of the causes of food

Table 2. Top 11 genetically modified crop producing countries

S/No.	Country name	GM crop grown	Million hectares
1	USA	Cotton, corn, soybean	73.1.
2	Brazil	Maize, cotton, soybean	42.2
3	Argentina	Maize, cotton, soybean	24.3
4	India	Cotton	11.6
5	Canada	Corn, soybean, sugar, canola oil	11.6
6	China	Largest exporter of soybean	3.9
7	Paraguay	4th largest exporter of soybean	3.9
8	Pakistan	Rice	2.9
9	South Africa	Largest producer of GM maize	2.7
10	Uruguay	Largest producer of soy seeds	1.6
11	Bolivia	Soybean	1.0

Source; available at; http://www.gmofreegazette.com/general/top-11-genetically modified crops producing countries

insecurity identified in this study together with the readily available mitigation strategies which can be employed to solve the problems of food insecurity in Africa.

(i) Evidence based conclusive research: In 2016, National Bio safety Authority (NBA) approved Water Efficient Maize for Africa (WEMA) field trials to be carried out by Kenya Agricultural Livestock Research Organization (KALRO) and African Agricultural Technology Foundation (AATF) on condition that:- The two seek a permit from NEMA. In fact NBA instructed KALRO and (AATF) to work closely with the: **"**Kenya Plant Health Service (Kephis) during field trials to safeguard Public Health". WEMA aimed at producing a drought resistant maize variety as a way of promoting food security among Africans. By giving this condition, NBA was acknowledging the fact that GMOs pose an environmental Public Health problem to Kenyans. The National Environmental Management Authority (NEMA) has emphatically stated that it is **"**taking due care to avoid GMOs entering Kenya's Market Chain" and that NEMA must be assured that KALRO and AATF have the capacity to mitigate against cross pollination to safeguard citizens against consuming untested foodstuffs that could contain harmful toxins. In the *Daily Nation, April 4/2017* [32]. The Director General NEMA agrees "No License for National Field Trials on GMO will be issued before the design is scrutinized to ascertain safety of the entire research process". As at April 2017, licensing of research and Field Trials for GMOs had not been approved. This shows how the government and anti-GMOs in Kenya have not accepted GMO crops until Scientists submit proven rehabilitation and mitigation strategies in the event that the WEMA (GMO) variety contains harmful toxins to humans and the environment.

(ii) Financial investment: According to World Bank report, raising crop yields by 10% reduces poverty levels by about 7%. Agriculture contributes 32% of Africa's Gross Domestic Product –GDP and employs 65% of the workforce hence the need to make it Sustainable. Africa is endowed with immense natural wealth for example; it has 10% of the Worlds renewable water resource and 60% of arable land, most of which remains uncultivated [33]. Investment in Africa should target the small scale subsistence farmers who account for 60% of the food produced in Africa in order to improve food security, drive the economic development and increase the welfare of the citizens. Banks have been reluctant to finance agriculture due to the inherent weather related risks and lack of collateral, however, banks and other financial institutions must start looking at sustainable agribusiness both as an invaluable venture and for its role in food security. In order to realize good benefits by agricultural financiers, there is need for integrated strategies approach which can lead to curtailing of costs and risks. Some of the strategies may include providing non financial products such as market intelligence using ICT and technical support in capacity building [34].

The African Union by using the following development mitigation strategies tried to address the Agricultural funding which is a major factor in the agribusiness transformation and development; a) The Comprehensive African Agricultural Development Programme CAADP,(b) the Malabo and Mabuto declaration where African Countries were required to allocate 10% of their national budgets to Agriculture in order to achieve a hunger free continent as stipulated in African Union –AU Agenda 2063.

(iii) Post harvest food storage and preservation: Many African countries, Kenya included face huge post-harvest losses, they do not have post-harvest Policies and there is no single institution of higher learning in Kenya that offers a course in post harvest management. Dr Thomas Dubois, the regional director of the World Vegetable Centre for Eastern and Southern Africa-WVCESA while addressing the First All Africa post-harvest Congress and exhibition in March 2017 in Nairobi emphasized that African Countries need to allocate more resources on food preservation as mitigation strategy to avoid food losses. He noted with concern that when funds are allocated to enhance food security, about 95% of these funds is directed to food production. Efforts should deliberately be made to enhance food storage, market access and food distribution. Africa must design right technologies which can identify the stages at which value chain food losses occur and before any technology is taken to farmers, it must first be tested. Re cycling of post harvest residues back to farms keeps soil nutrients and soil fertility [30].

(iv) Drought Resistant Animal Feed (Brachiaria grass): Arid lands make up 80 per cent of the total land area in Kenya. This is where 90 per cent of livestock is reared and livestock farmers found in these regions need resilient animal feed

since the land is moisture stressed. Brachiaria grass seems to be a reliable adaptation strategy. The wild grass is native of Africa and has been used to transform livestock production in South America. It fixes soil minerals such as nitrogen, phosphorous and carbon, which are often lacking in arid areas. Brachiaria looks like Napier grass, but grows taller and produces seeds which replenish the grass after harvest. The wild grass is disease and drought resistant, it produces nineteen (19) tonnes of green fodder per acre and about (9) nine tones of fodder after drying [35].

KALRO needs to take the lead and sensitize pastoral communities to adopt, grow and feed their livestock on this grass during droughts in order to avoid the great losses incurred during drought episodes. Pastoralists need the livestock food not the GMO breed of livestock.

(v) Commercialization and value addition: Discussion with subsistence farmers established that little attention is paid to the value chain through which agricultural commodities and products reach the final consumer. This neglect results in great losses. Commercialization and value addition to agricultural products in Africa is the strategy that will economically empower the farmer and eradicate food insecurity [36]. For example, in 2017 West Pokot County, dairy farmers' income from sale of raw milk to the processor Brookside Company rose by 10% to 330 million. The 10% increase in incomes was attributed to commercialization of dairy milk farming. Farmers in the area had formed dairy groups to enable them buy milk in bulk and transport it to the Brookside Cooling Centers in the area. Previously, most rural farmers used their milk products at subsistence level with the surplus being spoilt and thrown away. Brookside Company came in and supported Local Dairy Cooperatives by installing Cooling equipment in Lelan, Tapach and Kaptalamwa areas. Many dairy farmers have joined cooperative societies in the region and they are getting financially empowered while having the excess milk also preserved for domestic consumption.

(vi) Greenhouse agriculture: The technology where crop diseases and water use are controlled was researched and developed by International Crop Research Institute for the Semi-Arid Tropics (ICRISAT). It is a farming technology which ensures food security for the urban poor is spreading fast among small scale farmers near urban centers in Kenya (IGBP, 2008). The technology offers an environment in which temperature, humidity and pests are easily controlled. The greenhouses are made of wood and polythene; they measure 240 square metres and the cost of putting up such greenhouse including the installation of drip irrigation pipes ranges between Kshs 100,000-300,000 Crops grown are mainly horticultural crops such as; tomatoes, cucumbers, cabbages, spinach, carrots and capsicum (green pepper/ *pilipili hoho*), throughout the year. A combination of drought, increased food prices, growing demand from an expanding urban population and proximity to ready market is a big benefit to many greenhouse farmers in Ongata Rongai, Kitengela and Kiserian near Nairobi city. Farmers in Nyandarua, Bungoma, Machakos, Bomet, Kitale and Narok have started greenhouse agriculture.

(vii) Sustainable agriculture or agro-ecology uses ecological principles to farm: It involves maintaining the natural environment while using ecological principles for sustained farming practices, mixed cropping or poly cropping which ensures that the farm is never bare since crops are harvested at different times e.g. a farm planted with beans, maize and coffee or tea bushes, poly-cropping also increases plant diversity and attracts several other plant species and herbivores [23]. This type of poly cropping ensures sustainable food production throughout the year (Plate 5). Crop rotation and dry land farming are important farming methods which suppress pests and diseases that might attack particular crops and not others while practicing dry land farming where such crops as cassava, green grams, cow peas, sorghum and katumani maize are grown using drip irrigation [37].

(viii) Irrigation projects, ground water resource tapping, rain water harvesting during floods and concrete irrigation plans on major rivers such as Tana and Athi in Kenya can eradicate the food security problems in Africa's drylands. The government of Kenya set aside KES 6 billion in the 2017/2018 financial budget for an irrigation project which will target 15,000 acres of land and benefit 6,000 households in the semi-arid Murang'a County. The project will use the Tana and Athi rivers, it benefit farmers from Maragua Ridge, Kamiti, Gaturi, Kirimiri and Ithanga where farmers will grow rice, onions, yams and other indigenous food crops. The irrigation project aims at solving the perennial food shortages in Murang'a within the coming three years. This was revealed by Devolution Planning Cabinet Secretary while distributing relief food supplies to effected families in lower Murang'a County [38].

Plate 4. The Brachiaria grasss farmer in Machakos County

Plate 5. Poly cropping of bananas, maize, cassava and vegetables in same plot ensures household food security throughout the year in semi-arid Kitengela, Kenya

(ix) Prompt emergency response to early warning systems: Food Shortage mainly maize flour experienced in Kenya where the price of 2kg maize flour rose from ksh 90 to ksh 162 between the months of February and May 2017 would not have occurred if the agriculture ministry had promptly responded to the early warning by climate scientists and grain millers. In 2016, poor rains saw the Horn Africa experience a dry spell. Harvests of most foods dwindled and the yields of maize, potatoes, beans and rice went down causing about four million people being affected by starvation. The Meteorological department had warned that even the 2017 March – April long rains would be suppressed and the harvests would be below average. Maize Millers had also issued an alarm, saying that there was no adequate maize in the grain reserves. It was until on March 30th when the Cabinet Secretary, National Treasury in his budget speech, removed 50 per cent duty on imported maize, allowing for importation of about 29,900 tons of maize from Mexico and South Africa to fill the deficit after the impact was beyond remedy. The crisis resulted into blame games on the political scene.

(x) Pests and disease control research mechanisms: Agricultural Scientists need to provide well researched solutions to some of the causes of food destructions which cause food insecurity in Africa. As at March to June 2017, Kenya's maize plantations were invaded by fall army worm which threatened to make the food situation worse in 2018. At least 8,000 acres of maize plantations in Trans Nzoia County and 600 acres in Uasin Gishu County were attacked by the destructive Fall Armyworm in March – June 2017, thus putting the Country's food security at high risk over the next one year. The fall army worm is a native of both North and South America. It thrives well in warm temperatures with little rains while its multiplication and spread is reduced by heavy rains and low temperatures; it has damaged maize crops in African countries of Namibia, Malawi and South Africa in the past (10). Where are agriculture scientists' and researchers in Africa to solve the food insecurity caused by pests? The solution is to eradicate the army worms on the continent in order to secure vast acres of food crops but not necessarily to plant new variety seeds which have not been tested and approved for commercialization.

6.6 A Summary of the March-July Causes of Food Crisis in Kenya 2017

The food crisis harshly referred to as the "*Unga crisis*" could never have occurred if the relevant ministries had timely responded to the early warning systems from the meteorological forecasts and prepared for the predicted disaster by buying and filling the grain reserves.

With maize flour shortages in retail shops, fall army worm pests having affected the staple maize crop food in the "maize granary" region and poor rainfall that could affect yields, Kenyans could still experience high food prices for more months to come. Four improved varieties of brachiaria grass have been planted in various counties to provide Livestock feed. 2016 was a gloomy year for the country's agricultural sector though the government was made aware of the worsening situation by the meteorological department. Production of maize decreased in 2016 due to below average rainfall, high costs of farm inputs and the residual effects of Maize Lethal Necrosis Disease (MLND), stated by the Kenya National Bureau of Statistics in the Economic Survey 2017.

Production of the cereal reduced from 42.5 million bags in 2015 to 37.1 million bags in 2016. Both the maize produced and maize taken to the market in 2016, declined. The value of marketed maize declined by 7.2 per cent. While the value of marketed rice and wheat also went down, their poor performances were quickly compensated with increased imports of the commodities. However, maize imports declined sharply from 480,100 tonnes in 2015 to 148,600 tonnes in 2016. There was no maize in Tanzania and Uganda, from where Kenya plugs its deficit. The ravaging drought had ensured that they too (Tanzania and Uganda) were as maize deficient as Kenya. Kenya's remaining option was to import maize from overseas, particularly Mexico, which is the largest producer of white maize [7]. The 2017 "Unga crisis" did not require GMO maize variety to solve, rather strategically responding to the early drought warnings by importing the maize well in advance.

7. CONCLUSION AND RECOMMENDATION

The study therefore concluded that: The sustainable means to combat food shortages is not dependent on new crop varieties but rather further study and improved crop management of indigenous breeds better suited for Africa's climatic conditions biodiversity [39]. It is therefore important to craft solutions that target the underlying causes instead of short-cut (GMO) methods which only aim at treating the symptoms. Each African country faces a combination of different factors such that a blanket solution such as GMO cannot cater for situations that need localized formulation of relevant policies, mitigation, adaptation and coping strategies [1].

African governments should continue to seek better understanding of what they allow into their countries. The long term benefits and losses should also be weighed at the same time sensitizing the citizen about what GMO's really are. Africa needs to use AGRA to reshape its farming practices to ensure long term food security. The time to act is now and that action means doing more research on indigenous crops which are best suited for Africa's climatic conditions, soils and are also highly nutritious. GMO's are not a sustainable strategy to food security and climatic change in Africa since they require artificial growing conditions. Lack of diversity on the other hand leads to over dependence on a few select crops and livestock which may not meet the nutritional thresh hold leading to health risks. This then becomes a

counter-productive result, since food insecurity which GMOs are touted as combating should primarily improve the health of the consumers and not cause complications. African countries faced with multiple issues that affect developing nations must find better alternatives than those which seek to increase the rate of dependency on one commercialized crop as projected by GMO products [36]. Agricultural investment should be channeled to improving the quality and yields of indigenous food crops which are grown by 90% of small scale subsistence farmers in Africa.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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