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CLIMATE CHANGE AND CROP VULNERABILITY IN NIGERIA

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ABSTRACT

In Nigeria, food insecurity remains problematic due to dislocations in the agricultural productivity pathways. Food preferences and utilization patterns are skewed in favor of crop-based staples, which availability in quantity and quality, depend on the aggregate crop output. Unfavorable environmental conditions such as caused by climate change would create some level of vulnerability of the crops and thus have implication on food security. Two components of the Agricultural Value Chain, production and storage, appear to be most responsive to changes in environments with production being the most vulnerable since all the activities involved in the process of production occur in the fields and are weather -dependent. Climate change – directed irregularities or deviation from the normal seasonal patterns such as onset and duration of wet and dry periods, short and prolonged dry spells clearly manifest in various levels of crop vulnerability. It would therefore appear that a sustainable crop-based agricultural system can only be achieved where crop vulnerability is considerably minimized. If climate change effects can be incorporated in the design and implementation of national development programs right away, it will help to reduce vulnerability, stabilize food production and better secure livelihoods. The ecosystem approach with crop rotations, bioorganic fertilizers (e.g., from legumes) and biological pest controls, improves soil health and water retention, increases fertile top soil, reduces soil erosion and maintains productivity over the long term.

Key words: vulnerability, climate change, crop productivity.

INTRODUCTION.

Agriculture and the Value Chain.

Agriculture is understood as all the productive occupation of man that mobilize various forms of resources(natural human and material) to produce or provide food fiber and other forms of raw materials and their transformation into various utilizable or consumable forms. This may be explained in the context of the agricultural value chain which involves the components of production, processing, storage and marketing (Fig.1). The separate or the sequences of combined activities involved in the components generate outputs of value. Production is a critical "take off" base or "kick starter" of the value chain especially in crop agriculture, as its quantum outputs and supplies per unit time determine the quantitative input requirements of the other components. Storage has its peculiar constraints as substantial supplies from the production components could be lost due to biodegradation or pest complexes while in storage before or after processing or marketing.

The two components- production and storage appear to be most responsive to changes in environments with production being the most vulnerable since all the activities involved in the process of production occur in the fields and are weather dependent. It would therefore appear that a sustainable crop-based agricultural system can only be achieved where crop vulnerability is considerably minimized.

Crop Vulnerability and Food Security.

In Nigeria, food insecurity remains problematic due to dislocations in the agricultural productivity pathways. Food preferences and utilization patterns are skewed in favor of crop-based staples, which availability in quantity and quality, depend on the aggregate crop output. Unfavorable environmental conditions such as caused by climate change would create some level of vulnerability of the crops and thus have implication on food security. Good knowledge and understanding of the crop as a system and its responses to the environmental history in relation

to climate change would be of immense help in the development of strategic options for reducing crop vulnerability. The objective of this paper therefore seeks to provide that understanding .The paper specifically seeks to:

- discuss climate change, its realities and predictions in Nigeria
- discuss vulnerability of crop agriculture in Nigeria to climate change and its implications for food security
- enumerate opportunities available for development of adaptive capacity of Nigerian crop agriculture to climate change to ensure food security.
- point out constraints to development of adaptive capacity/mitigation mechanisms of crop agriculture to climate change.
- make recommendations.

METHODOLOGY:

The methodology adopted in this paper is extensive review of literature on climate change, its influences on crop agriculture, adaptive/mitigation mechanisms, the authors' experiences in the field and their reasoned guesses in this rather novel area of agricultural research in Nigeria.

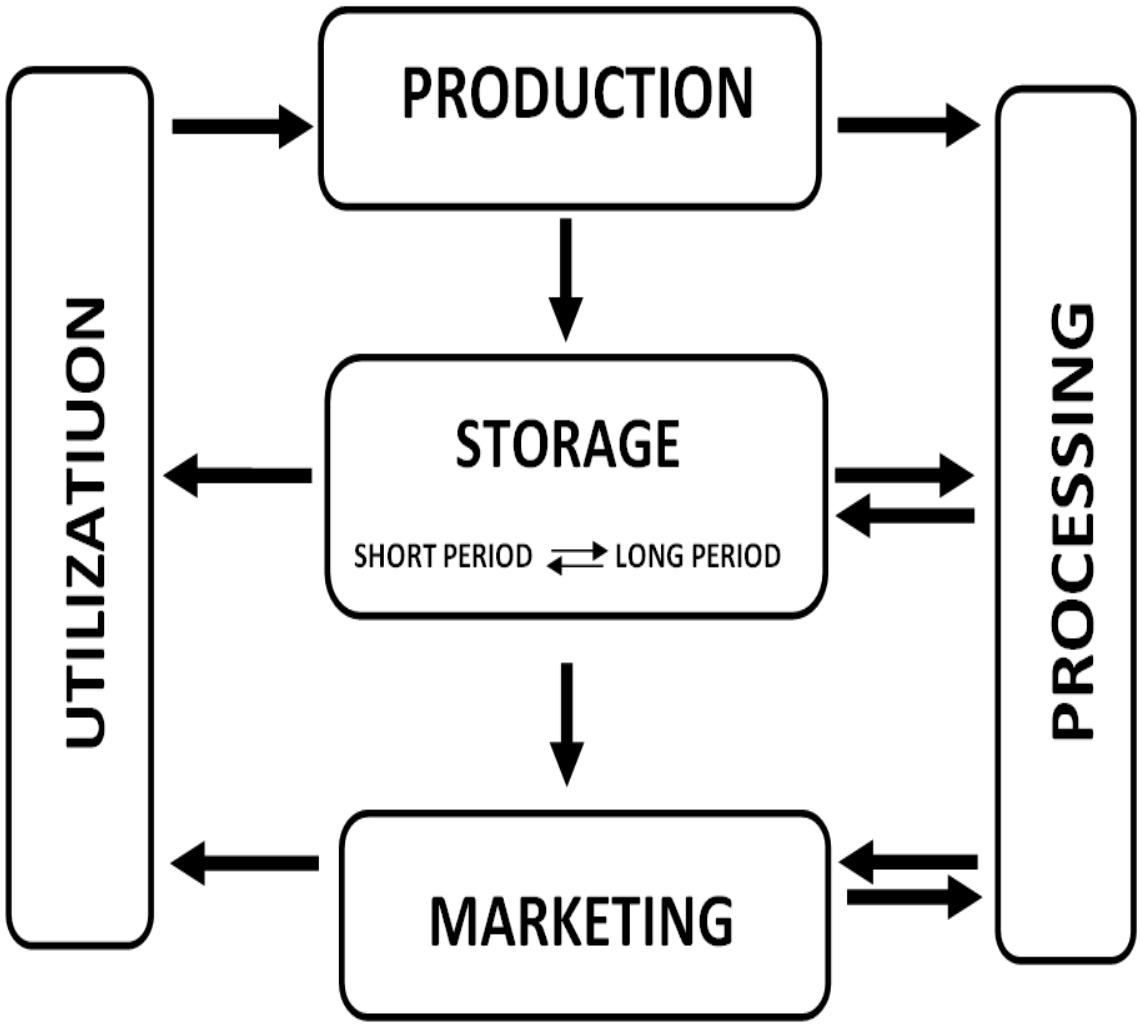

Figure 1: Schematic Presentation of Agricultural Value Chain

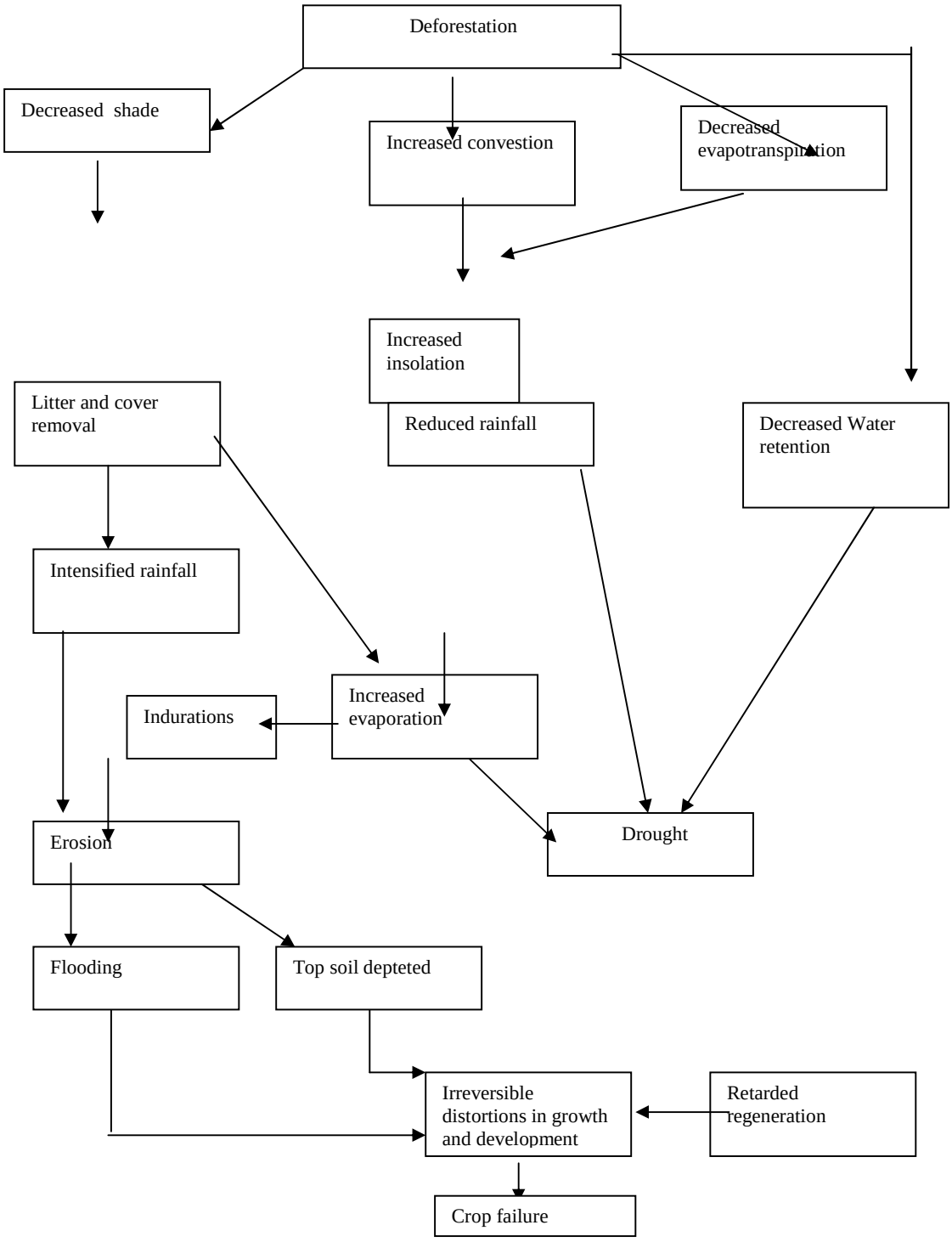

Fig 2 Schematic presentation of the sequential consequencs of deforestation leading to crop failure
Source: Adapted from Okigbo (1991) and modified from Goodland and Irwin (1975).

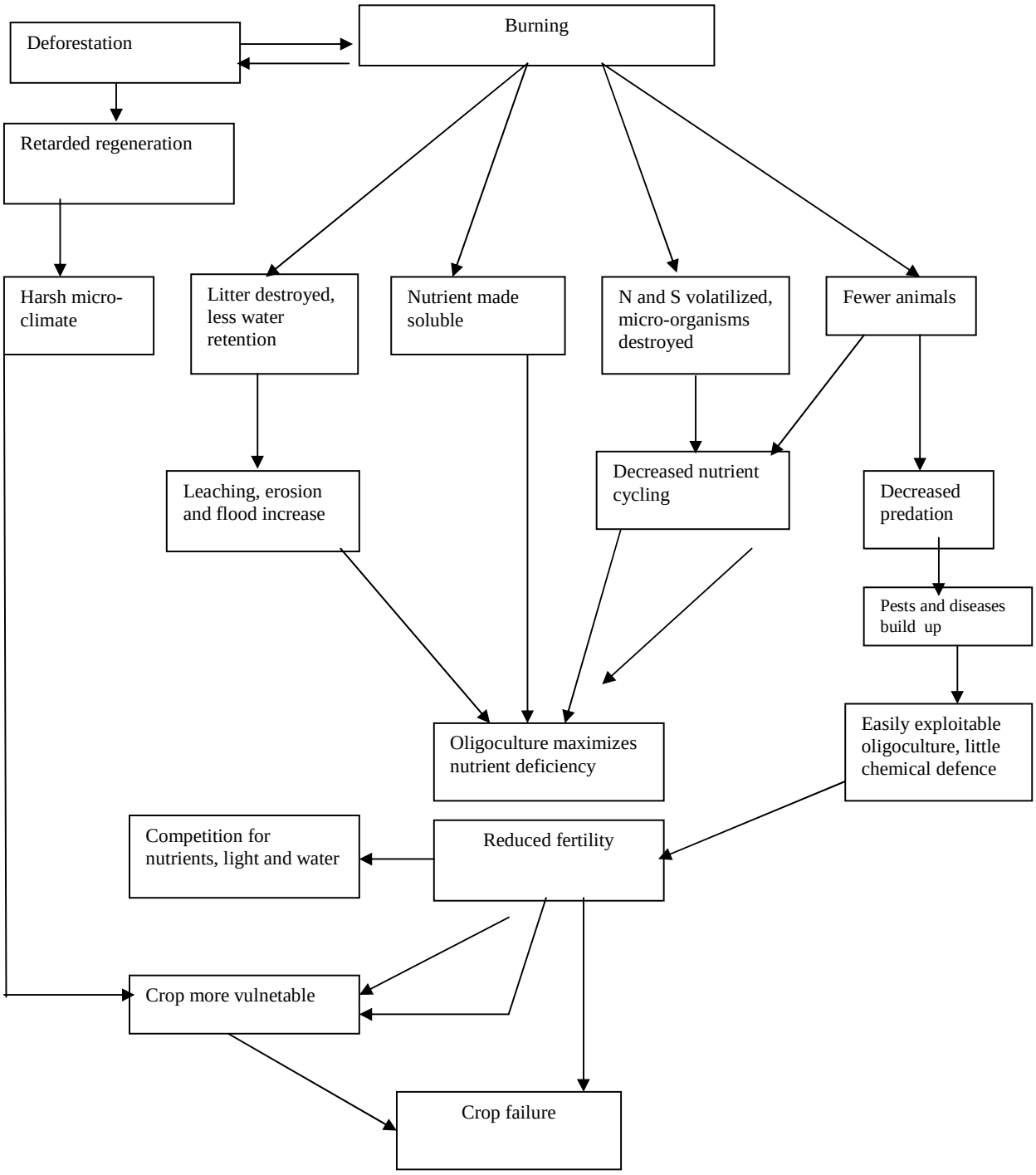

Fig. 3 Relationships between vegetation removal by deforestation and burning and crop failure
Source: Adapted from Okigbo (1991) and modified from Goodland and Irwin (1975).

DISCUSSION

Climate Change: realities and predictions.

The shrinking size and water-holding capacity of Lake Chad, ravaging floods in both north and south of the country occasioned by severe storms and erratic rainfall, desertification and prolonged dry season with high temperatures in most parts of Nigeria, may be warning signs of the reality of climate change. Agriculture is highly sensitive to climate variability and weather extremes, such as droughts, floods and severe storms. The forces that shape our climate are also critical to farm productivity. Changes in rainfall can affect soil erosion rates and soil moisture, both of which are important for crop yields. The IPCC (Intergovernmental Panel on Climate Change) predicts that precipitation will increase in high latitudes, and decrease in most subtropical land regions-some as much as about 20 per cent. While regional precipitation will vary, the number of extreme precipitation events is predicted to increase (IPCC, 2007).

At increasing atmospheric concentrations, greenhouse gases are projected to raise the average world temperature, lead to a rise in sea levels and change seasonal and geographic precipitation patterns. These changes are expected to severely impact agriculture, ecosystems, water resources, coastal areas and human health (Santhaye and Ravindranath, 1998). The IPCC's Fourth Assessment Report summary for Africa describes a trend of warming at a rate faster than the global average, and increasing aridity. Key attributes of the IPCC's Fourth Assessment Report for Africa, sourced from Christensen *et al*. (2007) highlighted, among other things, the following:

- Warming is very likely to be larger than the global annual mean warming throughout the continent of Africa and in all seasons, with drier subtropical regions warming more than the moist tropics
- It is unclear how rainfall in the Sahel, Guinea Coast and southern Sahara will evolve

Major contributory factors to climate change in Nigeria

The Tide Online Newspaper of 18th January, 2011 noted that there was massive deforestation going on in Nigeria, and that deforestation was the next thing that came to mind after gas flaring whenever the issue of climate change is mentioned in Nigeria. Deforestation, poses a lot of danger in that, the forest acts as carbon sink so when the forest is destroyed, the carbon in there is released into the atmosphere. The report further stated that deforestation and gas flaring were the major contributors to carbon emission in Nigeria, and regrettably, the laws protecting the forests in Nigeria have weak mechanisms of enforcement.

Climate change: A Global Concern

Climate change is posing undisputed challenges in all sectors of human endeavor. The general consensus is that green house gas (G.H.G) emissions account for the highest percentage variability in climate change, with clearly devastating effect on water supply, agriculture (crops, animals, forestry, fisheries), transport and health with agriculture exhibiting the highest vulnerability.(Grain,2010;IPCC,2007;Margulls,2010). Several countries of the world have peculiarities on the effects of climate change on their diverse sectors of national livelihoods. Most of these countries are developing adaptation and mitigation strategic plans on immediate to short-term to long –term basis.(Agoumi,2003) Some have attempted to characterize the nature of the effects of climate change for the purpose of identifying the most vulnerable sectors and the patterns of vulnerability for determining the forms of adaptation and mitigation measures (Rudd,2010).

Climate Change: Some Forms and Consequences

The realities, forms and consequences of climate change remain undisputed. Some of the characteristics of climate change and the associated consequences are highlighted in Table 1.

Table 1: Forms, characteristics and consequences of climate change

Forms/Characteristics	Consequences
1. Increasing green house gas emissions and global annual temperayure at 2^{o}C above pre-industrial levels in 2050 (Margulls, 2010).	• Rise in sea levels; changes in seasonal and geographic precipitation patterns, characterized by more intensive rainfall, more frequent floods, droughts and heat waves.
2.Trends of warming in Africa likely at a rate faster than the global average (IPCC,2007)	• Ecosystem dislocation with high vulnerability in crop agriculture and water resources (Santhaye and Ravindranath, 1998). High temperature may be beyond the range of tolerance for current crop varieties and cultivars (Adejuwon,2006).
3. Precipitation increases in high altitudes and decreases in most sub-tropical regions as much as 20% (IPCC, 2007).	• Erosion is exacerbated. • Flooding at low-lying areas become more vulnerable to inundation from sea level. • Damages to settlements and infrastructure (Rudd, 2010). • Rapid rate of organic matter decomposition. • Reduced crop growth (Agoumi,2003).
4. Changes in onset of rainy season and the variability of dry spells.	• Reduced crop growth and may lead to crop failures (Kalu, 2008; Odo, 1999).
5. Destruction of forest ecosystems through deforestation, burning and cultivation methods that reduce tree density (Rajasekaran and Warren, 1994).	• Distorted rainfall pattern. • Drying up of streams • Hot and humid environment within the forest eco-systems with high vulnerability exhibited by vegetable crops, spices, root and tuber crops. • Loss of genetic diversity. • Water logging and salinisation of irrigate lands. • More frequent drought, erosion and floods • Increased carbon dioxide emission • Retarded regeneration and crop failure • Accelerated desert encroachment • Sequential and cyclic impacts are presented in Figures 1 & 2.
6.Combination of shifts in temperature, vegetation cover and species distribution as well as the associated alteration in the dynamics of drought, rainfall and heat waves (Ziervogel *et al*.,2008):the interplay of deforestation and burning (Fig.2).	• Multiple stresses on the biophysical, social and institutional environment underpin crop production. • Weakening of economics livelihood s and food security (Smith and Barchiesi, 2009). • Secondary stresses leading to pest and disease complexes • Increased competition for resources and degeneration of regional and ecotypic biodiversity. • High vulnerability in crops Disastrous impacts on artesanal fishing, wildlife species and forest products.

Climate Change and Nigerian Agriculture

Agro-ecological delineation.

Nigeria is delineated into distinct agro-ecological zones (Kowal and Knabe, 1972). The major zones are the Rain forest in the southern parts, the Guinea savanna in the central and northern parts, and the Sahel in the extreme northern parts. Each zone is characterized by distinct and often overlapping ecological features typified by patterns of vegetation, soil types and land formation, rainfall, temperature, relative humidity, solar radiation which interplay in various forms to determine crop adaptation, biodiversity forms, demographic features and consequently the farming system of the areas.

Seasons and crop vulnerability

Agricultural activities in Nigeria are governed by two distinct seasons of the year, namely the rainy (wet or growing) season and the dry season with ecological variation in the onset and cessation of each. The southern ecologies are generally characterized by long rainy periods of about eight months (March to end of October) and short dry period of about four months (November to February), while the northern ecologies are generally marked by short rainy periods of 5-6 (May/June to October) and longer dry periods of 6-7 months (October/November to April/May/June). Nigerian agriculture is known to be 90% rain-fed. Irrigated agriculture (with vast potential) is scanty and is mainly located in the northern parts of the country, producing mainly vegetable crops. Water supply therefore is a critical factor of the overall crop productivity. Annual crops (for example) must complete their life cycles within the period of the growing season. It would therefore be bad for a plant to flower so late in the season that the fruit and seed development could not be completed before the

onset of the dry season. In the same way, biennial plants need to have sufficiently developed underground storage organs during the wet season to enable them endure the dry periods and continue growth and production in the succeeding year. Similarly, perennial plants possess some mechanisms for timing of their dormant periods and must flower at an appropriate time of the season of the year for fruit and seed development (Bidwell, 1974).Climate change – directed irregularities or deviation from the normal seasonal patterns such as onset and duration of wet and dry periods, short and prolonged dry spells clearly manifest in various levels of crop vulnerability. Rainfall appears to be the most critical factor that accounts for substantial percent of the variability in crop vulnerability. Rainfall moderates or determines the varying magnitudes of drought, flooding, erosion (Agounmi,2003) and pest and disease build ups or incidences when in interplay with associated temperature and relative humidity(Okigbo,1991; Ziervogel *et al*., 2008). The separate or combined effects of these determine the degree of vulnerability of the crop under an eco-typic environment.

Vulnerability Rating of Some Selected Crops

From the fore going, it would appear that the major contributors to crop vulnerability due to changing environment are drought, flooding, erosion, pests and diseases. The vulnerability rating of some selected crops based on these and the possible sources of the response patterns are presented in matrix (Table2)

Table 2: Vulnerability rating of some selected crops on a scale of 1-5 (1-least vulnerable, 5-most vulnerable.

Crops	Drought		Flood/water logging	Erosion	Pest and diseases
	Due to extended dry spells during a growing season	**Due to early cessation of rain**			
Legume: **1.Cowpea**	Overall vulnerability rating = 3, due to : -Low germination per cent under dry soil. -Partial to permanent wilting at the vegetative stage -Flower abortion due to high temperature -Most vulnerable at flowering and podding stages	Overall vulnerability rating = 3 due to: -Physiological distortions resulting in poor pod filling. -Premature senescence and immature seeds in pods -Cowpeas being relatively drought tolerant, low vulnerability may occur if residual moisture can support pod maturity.	Overall vulnerability rating = 4 due to: -Submerging of stands. -Cowpeas not tolerant to water logging. -Desiccation of roots and foliage leading to symptoms similar to drought conditions.	Overall vulnerability rating = 4 due to: -washing away of stands -Exposure of root system to sun and death of stands -Deposits and accumulation of sand and debris -Vulnerable during the entire growth period	Overall vulnerability rating is 5 due to: -Extensive defoliation by insect pests. -Extensive damage to pods by cowpea borers -Most vulnerable from flower through podding stages. *New insect pest and disease organisms may evolve with changing climate and may even be more devastating.
Mitigation /adaptation options	Intensive breeding research to incorporate more drought tolerant genes into existing lines. -Use drought –tolerant varieties where available	Development of cropping systems through research to accommodate new genotypes	Avoid planting in flood prone areas	-Plant fruit trees ,for example, cashew and Vertiver grass on erosion routes	More entomological research to identify and manage/control emerging insect pests and diseases.
2.Pigeonpea	Overall vulnerability rating = 1 due to: -good germination under low moisture regime. - adaptation to low moisture conditions and resumes vigorous growth as moisture becomes available. -Flowers and bears pods even in dry conditions once it has established because of deep root systems. -Most vulnerable at seedling stage.	Overall vulnerability rating = 1 due to: -High inherent adaptation to moisture stress due to strong tap root system. -produces flowers and pods normally at low moisture regimes -Indeterminate varieties are better adapted to grow in water-stressed environments	Overall vulnerability rating = 4 due to: -Submerging of seedlings for more than 48 hours can lead to complete crop loss. -Complete defoliation, root rot and death if flood in ≥7 days. -Vulnerable at all stages of growth.	Overall vulnerability rating = 2, due: - extensive, strong and deep tap root systems -Well developed lateral roots that are ≥ 2m. -High leaf litter reduces speed of water. -Seedling stage is most vulnerable	Overall vulnerability rating = 3, due to: -susceptibility to *Fusrium* wilt,*Phytopthora* and *Alternaria* blights - pod damage by *Helicoverpa armigera* and *Maruca testutalis* can reduce yield -Pigeonpea can compensate for leaf and flower damage sufficiently. -Most vulnerable stage is podding .

Table 2 contnd

Mitigation/adaptation options for pigeonpea	An excellent crop for mitigating effects of drought	Very suitable for drought prone areas	Avoid planting in low-lying areas.	Develop through research suitable production systems intergrating erosion control strategies	Grow genotypes that are disease resistant and tolerant to insect pests. -Develop new varieties through breeding (research).
Cereals: **3.Maize**	Overall rating = 4 due to: - desiccation of leaf tissue (most vulnerable 1st 4 wap). - desiccation of pollen grains leading to poor/zero seed setting (most vulnerable at tasselling and silking. -Poor to zero grain filling (most vulnerable at grain filling stage) leading to physiologically immature seeds. -Not drought resistant. .	Overall rating = 4 due to: -ineffective pollen, poor fertilization, poor seed setting and grain filling leading to poor to zero grain production (most vulnerable from tasseling to grain filling)). -Not drought resistant.	Overall rating = 5 due to: -submerging of root system. - physiological capacity of roots for water and nutrient absorption is blocked - discolouration, wilting and death of the above-ground parts - zero production where water logging is extended to occur frequently. -most vulnerable from germination to grain filling.	Overall rating = 3 due to: -complete washing away of stands - root exposure -lodging -Most vulnerable from germination to maturity	Overall rating = 4 due to: Rodents exhume seeds/seedlings before or after germination -*Striga* infestation -stem borer attack mostly for mid season to late season planted crops. -seed/cob rots due to disease complexes. -attack on cobs/grains before or after maturity by birds. -vulnerable from planting to maturity.
Mitigation/adaptation options	-Vigorous research in development of new lines and production systems. - incorporation of indigenous knowledge and coping strategies in specific environments in research.	-Sincere attempts to conserve genetic diversity of indigenous maize varieties - Use of early maturing genotypes in the cropping systems	Avoid planting in flood prone areas	-Plant fruit trees ,for example, cashew and Vertiver grass on erosion routes	More entomological research to identify and manage/control emerging insect pests and diseases.
4.Rice	Overall rating = 4 due to: -water shortage resulting in poor germination and establishment -impaired growth during vegetative stage (most vulnerable -poor to zero flowering and panicle formation and grain filling (very vulnerable at this stage).	Overall rating = 4 due to: -poor tillering especially for upland rice -panicle abortionin upland rice and wilting of stands before seeds mature - most vulnerable are upland rice varieties	Overall rating = 3,due to: -increasing frequency of over flooding in shallow/swamp rice being cultivated in areas most vulnerable - impairment of germination - higher incidence of iron toxicity. -vulnerable at germination, seedling stage, panicle formation, grain filling,and maturity.	Overall rating = 2 due to: -sheet erosion in upland rice fields. encroachment of sand into both upland and shallow swamps -Most vulnerable from germination to grain filling.	Overall rating = 3 due to: - stemborer attacks (most vulnerable from seedling to maturity). -attack by army worms (most vulnerable from germination to booting stage. -bird attack (most vulnerable from grain filling to maturity. -Blasts and blights (most vulnerable before flowering).
Mitigation/ adaptation options	Developing new production systems to target correct planting dates for specific rice growing areas -Breeding new lines to cope with changes in climate	Further breeding work on short d. Popularise existing short duration lines despite yield compromises -Supplementary irrigation .	Avoid planting in flood prone areas	-Plant fruit trees ,for example, cashew and Vertiver grass on erosion routes	More entomological research to identify and manage/control emerging insect pests and diseases.
5.Sorghum	Overall rating = 2,due to: -Non-uniformity in germination of direct-seeded crop. -delayed establishment of transplants -reduction in weight and number of seeds per panicle -relatively high incidences of	Overall rating = 2 due to: -high tolerance to heat and drought -Possesses low transpiration rate - most vulnerable at seedling stage	Overall rating = 5 due to: -submerging of root system. - physiological capacity of roots for water and nutrient absorption is blocked - discolouration, wilting and death of the above-ground parts - zero production where	Overall rating = 3 due to: -complete washing away of stands - root exposure -lodging -Most vulnerable from	Overall rating = 3 due to: - high susceptibility to *Striga* infestation -stemborer infestation for early planted crops. -Fungal infestation (moulds and smut) at

Table 2 Contnd

	Striga infestation when crops recover. -Drought-tolerant and hardy Most vulnerable at seedling stage.		water logging is extended to occur frequently. -most vulnerable from germination to grain filling.	germination to maturity	flowering and grain filling stage Most vulnerable at flowering and grain filling stage.
Mitigation/ adaptation options	Local tall varieties are highly drought resistant except at early stages of growth.Very suitable crop for mitigation.	Supplementary irrigation and breeding to increase grain yield -Short duration crops may begin to enjoy some popularity.	Avoid planting in flood prone areas.	-Plant fruit trees ,for example, cashew and Vertiver grass on erosion routes	Include Striga management options in design of cropping systems -breeding research to tackle stemborer in the local tall sorghum -
Roots and Tubers 6.Yams	Overall rating = 4 due to: -poor emergence and establishment counts (most vulnerable shortly after planting) -poor vine growth and dessication of leaves -delayed to zero initiation and bulking of tubers. -partial to permanent wilting resulting in loss of stands. -Most vulnerable from vine enlongation to tuber bulking stages.	Overall rating = 3 due to: Cessation of tuber bulking -rottening of immature tubers -poor starch stabilization -Most vulnerable from tuber bulking to maturity stages.	Overall rating = 4 due to: -high intolerance to water logging conditions -submerged stands dying off during or after flood recession.	Overall rating = 4 due to: -Same as in other crops	Overall rating = 4 due to: -attacks by insects,eg.,yam beetles causing extensive tuber damage;crickets causing extensive defoliation and damage to developing tubers -nematodes that cause physiological distortions in the tubers -tuber rot -anthracnose -Most vulnerable from planting through tuber bulking stage to maturity.
Mitigation/ adaptation options	Breeding of drought-tolerant varieties and systematic adaptation through new production systems	Breeding for drought tolerance and incorporating coping strategies of specific locations in the development of cropping systems through research	Avoid planting in flood prone zones	Develop through research suitable production systems integrating erosion control strategies	Incorporate into the cropping systems the new varieties bred against anthracnose. -Use biological control/ management strategies to check insect pests especially the yam beetle
7.Cassava	Overall vulnerability rating = 2 due to: - ability to withstand severe drought -impaired growth for early planted crops -decreased or cessation of tuber bulking which resumes at the end of dry spell. -Most vulnerable 1-5 weeks after planting	Overall vulnerability rating = 2 due to: High tolerance to drought situations. -decreased tuber bulking rate -premature leaf drop -Most vulnerable are the late planted crops.	Overall vulnerability rating = 5 due to: Intolerance to water loggin g -rottening of roots and dessication of the foliage -Most vulnerable from sprouting through the entire life cycle.	Overall vulnerability rating = 4 due to: -washing away of stands -exposure of roots to the sun and their subsequent drying up. -Most vulnerable from sprouting through the entire life cycle.	Overall vulnerability = 4 due to: -attack by insect pesets at the early stages of plant growth e.g.,termites,grasshop pers -meaybugs -spider mites -Most vulnerable from 4-5 weeks after planting through the entire life cycle.
Mitigation/ adaptation options	Another choice crop for mitigation. -1st 1-5 weeks of plant life must have access to adequate moisture. -research to develop suitable production systems to cope with climate change	-Early planting. Exploiting the crop hardiness to evolve new production systems with oil crops like castor.	Avoid planting in flood prone environment.	-As in yam	Popularize new crop varieties with tolerance/resistance to these pests and diseases for incorporation into farming systems.

Opportunities available for development of adaptive capacity of Nigerian Agriculture to Climate Change to ensure Food Security.

Building adaptive capacity enables communities and nations to mobilize the decisions and resources needed to reduce vulnerability and adapt to climate change (Nelson *et al.*,2007).Building adaptive capacity means strengthening attributes including the availability of information and skills, access to technologies, access to economic resources and the effectiveness of institutions (Munasinghe and Swart,2005). Coping with the impact of climate change on crop agriculture will require careful management of resources like soil, water and biodiversity (Sahai, 2010).Recommendations from National Conference on Climate Change and Food Security for India organized by Gene Campaign along with ActionAid as recorded by Sahai (2010) unveils opportunities for Nigeria. Making agriculture sustainable is the key and this is possible only through production systems that make the most efficient use of environmental factors of production (soil, water, air, light, etc.) without damaging these assets. If climate change effects can be incorporated in the design and implementation of national development programs right away, it will help to reduce vulnerability, stabilize food production and better secure livelihoods. Developing sustainability in agricultural production systems rather than seeking to maximize crop, aquacultural and livestock outputs, will help farming communities to cope with the uncertainties of climate change. The ecosystem approach with crop rotations, bioorganic fertilizers (e.g., from legumes) and biological pest controls, improves soil health and water retention, increases fertile top soil, reduces soil erosion and maintains productivity over the long term. The more diverse the agro ecosystems, the more efficient the network of insects and microorganisms that control pests and disease. Building resilience in agro ecosystems and farming communities, improving adaptive capacity and mitigating green-house gas emissions are the ways to cope. This can be addressed at local, state, national, regional and global levels:

Local: The real action for both mitigation and adaptation will have to be at the local level. The pursuit of sustainable agricultural development at the local level is integral to climate- change mitigation and combating climate change effects is vital for sustainable agriculture. Location specific technologies will need to be developed at the level of the agro-ecological unit, to make agriculture sustainable and minimize losses to food and nutrition. Universities of Agriculture and Universities with agriculture faculties may be mandated to generate these adaptive technologies with adequate back-up funds for the research programs.

State: Conserving the genetic diversity of crops and its associated knowledge, in partnership with local communities must receive the highest priority in each state of the federation. A scientific knowledge-intensive, rather than input-intensive approach should be adopted to develop adaptation strategies. Traditional knowledge about each community's coping strategies should be documented and used in training programs to help find solutions to address the uncertainties of climate change, build resilience, adapt crop agriculture and reduce emissions in each state.

National: Adaptation strategies have long duration and need to start NOW.

- Appropriate policy and budgetary support for mitigation and adaptation actions is needed.
- Multiple food and livelihood strategies are needed in rural areas to minimize risk. Food inflation must be contained at all costs. It will worsen with climate change as more frequent and unpredictable droughts and floods will result in shortfalls in food production. Just a few flash floods in Sokoto, Kebbi, Jigawa, Benue, Nasarawa States in 2010 may lead to a loss of thousands of tonnes of rice, maize, millet, sorghum and cowpea, causing prices to go through the roof.
- A carefully planned program for strategic research, along with dedicated funding, is needed to develop solutions to cope with the impact of global warming on crops, livestock, fish, soil etc. Renewable energy must be part of our mitigation and adaptation strategy and we should focus on bringing it to scale.

Pro-poor climate change adaptation strategies should be emphasized as a policy at all levels of governance (local, state, or federal). This can be achieved through (i) Enhanced knowledge about agricultural development pathways that lead to better decisions for climate mitigation, poverty alleviation, food security, and environmental health, used by national agencies.(ii) Improved knowledge about incentives and institutional arrangements for mitigation practices by resource-poor smallholders used by farmers (including farmers' organizations),project developers and policy makers (CIAT,2010).

Regional: Regional strategies for mitigation and adaptation across similar agro- ecologies will help all countries of the West African sub-region to protect their agriculture and food production. The glimpse of a potentially dire future, provided by scientific

observations and predictions, affords African farmers the possibility of collectively responding to new conditions, using traditional knowledge and in-situ methods, supported by agricultural research and extension, to create the seeds and production systems necessary to cope with a rapidly changing environment (ACB, 2009).

Global: Nigeria must negotiate hard to ensure that the emission reduction pledges or commitments are sufficient to ensure at least 50 percent likelihood that the global temperatures rise is capped at 2^0C. If this is not done, the impact on agriculture and food security in developing countries will be devastating. Rising temperatures will be beneficial for the agriculture of cold temperate regions since warmer conditions will allow their single crop zones to become two, even three crop zones. Given that agriculture is the lifeline of the developing world and will bear the worst brunt of climate change, Nigeria must insist that developed countries must reduce their own agriculture emissions while at the same time paying for adaptation, especially in the agriculture sector, consistent with the polluter pays principle. Nigeria should be able to tap from the Global Environment Facility (GEF) initiatives on Climate Change Adaptation and Clean Development Mechanism (CDM) of the Kyoto Protocol for carbon trading (UNDP/FME, 2008).

It must also be noted that climate change holds many dangers- and water is at the centre of its impacts (Smith and Barchiesi,2009).There are numerous options for adapting to climate change impacts on water, and there are variety of enabling mechanisms which need to be developed and coordinated for adaptation to be effectively implemented. Coping with floods, drought, storms and sea-level rise will depend on water storage, flood control and coastal defense. However, providing these functions simply by building infrastructure-such as dams, reservoirs, dikes, and sea walls-will not be adequate. By itself such infrastructures can weaken resilience, especially in a changing climate where the historic hydrology is no longer a viable guide to the future, because of damage caused to livelihood and the environment (Palmer *et al.,* 2008).The environment has a critical role to play. It must be kept intact as much as possible. The environment itself is infrastructure for adaptation- It is 'natural infrastructure'. According to Nelson *et al.* (2007), when based on principles of good governance, sound investment strategies and learning from integrated water resources management, integrating natural infrastructure into adaptation builds resilience.

Constraints to development of Adaptive capacity of Nigerian Crop Agriculture to Climate Change.

The constraints/barriers are numerous, but a few are listed here:

1. Although some level of awareness may exist in the urban areas of Nigeria on the effect of climate change on agriculture, there is a near-complete absence of the knowledge of this phenomenon at the local level where more than 90% of crop production takes place. This fact is corroborated by Ziervogel *et al.* (2008) who reported that while awareness of and reference to climate change are both increasing, much of these are based on media messages, or highly aggregated data from IPCC (DDC) and GCM models. The link between climate change information and adaptation practitioners on the ground remains largely non-existent and many adaptation practitioners in the agricultural sector still rely on generalized assumptions about how the climate change will change or derive very general information about climate change and its impacts from the IPCC reports. Adequate awareness of the negative effects of climate change at the local level could generate pressure on government to tackle climate issues more seriously. A large scale climate literacy program is necessary to prepare farmers, who are today bewildered by the rapid fluctuations in weather conditions that affect their agriculture. Their traditional knowledge does not help them to manage these recent anthropogenic changes.

2. Finance is central to climate change adaptation/mitigation strategies. Nigeria is listed as one of the developing countries that has committed only $0.2 billion out of an estimated $15.93 billion on installing renewable and low-carbon electricity generating technological option to mitigate climate change (GCN,2010). Even at the international arena, finance is central to negotiations on climate change. The 1992 United Nations Framework Convention on Climate Change (UNFCCC) obliges industrialized countries to help the developing world meet the costs of reducing greenhouse gas emissions. However, no agreement has yet been reached concerning the overall sum of the developing country climate costs or how the finance should be raised and spent (GCN, 2010).

3. **Deforestation.** Around 80% of agricultural emissions, including deforestation, occur in developing countries (World Bank, 2007).The unabated excessive exploitation of timber from our forests without a commensurate afforestation programs is a great challenge to climate change mitigation strategy, with consequent effect on food security. Although some laws to guide against excessive timber exploitation exist in

the country, implementation and prosecution of offenders is poor, mainly due to corruption.

4. **Low-level research on climate change issues that relate to agriculture and food security.** Absence of consistent relevant research to tackle identified problems that militate against climate change adaptations and also research to develop appropriate adaptive strategies to ward off the effects of climate change in Nigeria. This problem is also acknowledged by the international community. CIAT (2010) stated that AR4 recognises that, with only a decade of research on climate change adaptation, considerable knowledge gaps remain concerning adaptive capacity of agriculture.

5. **Inadequate expertise on climate change adaptation in Nigeria**. Although some expertise exists at the national level, located in the Special Climate Change Unit of the Federal Ministry of Environment and also at International Centre for Energy, Environment and Development (CEED), the scenario at the state and local government areas is the complete opposite. There is lack of capacity both in human resources and computational capacity to expand the available database.

6. **Lack of reliable meteorological data**. One of the main barriers to producing climate change information remains the lack of reliable meteorological data. This is especially true for complex environments where higher concentrations of station data are needed to capture the complexity of the terrain.

7. Ignorance of global weather conditions Most farmers base their decisions on short-term weather and seasonal climate variability, and stand to gain little from engaging with complex world of climate projections and its difficult- to- apply messages.

8. Poverty. The report of the First National Environment Summit organized by UNDP and the Federal Ministry of Environment, Housing and Urban Development in 2008 in Abuja indicated that poverty was one of the major constraints to the development of capacities to tackle climate change .The report also pointed out that Nigeria, like other African countries had limited capacity to cope with current global warming and its associated challenges.

CONCLUSIONS.

Crop agriculture is the major sector upon which the majority of Nigeria's rural poor depend. The shrinking size and water-holding capacity of Lake Chad, ravaging floods in both north and south of the country occasioned by severe storms and erratic rainfall, desertification and prolonged dry season with high temperatures in most parts of Nigeria, may be warning signs of the reality of climate change. Crop agriculture is highly sensitive to climate variability and weather extremes, such as droughts, floods and severe storms. The forces that shape our climate are also critical to farm productivity. A Nigerian study applied the EPIC crop model to give projections of crop yield in the 21st century. The study modeled worst case climate change scenarios for maize, sorghum, rice, millet and cassava. Making agriculture sustainable is the key opportunity to climate change adaptation in Nigeria and this is possible only through production systems that make the most efficient use of environmental factors of production (soil ,water ,air, light, etc.) without damaging these assets. Pro-poor climate change adaptation strategies should be emphasized as a policy at all levels of governance (local, state, or federal).Although several constraints militate against climate change adaptation strategies to provide food security in Nigeria, research efforts should be intensified in this direction with appropriate government and private sector involvement.

RECOMMENDATIONS

National strategic plan for climate change: There is NOW a dear need to have a national strategic plan in place to tackle the ominous consequences of climate change on agriculture and to harness any possible inherent advantage .Such a plan would involve the critical and relevant stakeholders, namely,Interministerial agencies, National Agricultural Research Systems (NARS)-Agricultural Research Institutes, Universities of Agriculture, Faculties of Agriculture in the Universities, Colleges of Agriculture and relevant Polytechnics,Federal Ministry of information and the National Orientation Agency, with the Federal Ministry of Environment co-coordinating

Characterization Study: It is needful to carry out an in-depth characterization study on the impact of climate change on Nigerian agriculture with the aim to isolate specific areas of agriculture most prone to the devastating effects of the change and to evolve adaptive and mitigation strategies in the short and long term.

Human capacity building and computational capacity development to expand available database: Greater expertise has to be developed in agricultural climatology and instrumentation to handle the highly sophisticated instruments for computation and accurate predictions of weather/climate and effects on agriculture and agric-related businesses in both the short and long term.

.A carefully **planned program for strategic research** (breeding for resistance/tolerance to drought, new emerging pests and diseases, development of production systems necessary to cope with a rapidly changing environment,etc.) along with dedicated funding, is needed to develop solutions to cope with the impact of global warming on crops, livestock, fish, soil etc.

Conducting a capacity survey of National Agricultural Research Systems This is for the purpose of identifying the institutions with relatively higher comparative advantage in handling specific components of climate change as they affect agriculture. We recommend that deforestation, reckless land clearing practices, unorthodox and careless use of agricultural chemicals must be curtailed to preserve the natural environment as an adaptive strategy to also halt the effects of climate change. Government at all levels (federal, state, local) must be deliberate about this.

Political will on climate change should take cue from other countries that are infusing a substantial percentage of their annual budget to make for adaptation/mitigation of the adverse effects of climate change. Public enlightenment on climate change Intensification of public enlightenment on climate change at the local and state levels require urgency.

National Action Committee on Climate Change **(NACCC)**.Climate change could be as devastating as HIV/AIDS, if not more. There is therefore an urgent need for a National Action Committee on Climate Change to be set up to serve as the Technical Committee on climate in Nigeria.

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