BRITISH COUNCIL

Future Proofing Agricultural Production Against Environmental Change.

PRIFYSGOL ABERYSTWYTH UNIVERSITY

UNIVERSITY OF UYO NIGERIA

Pictured (l to r).

Prof. Kirk Semple (Lancaster University); Dr. Edu Inam (Uyo University); Prof. Okon Ansa (Uyo University); Ahmed Mohammed, (Director Partnerships. British Council, Nigeria), Dr. Akanimo Odon (Envirofly Consulting); Prof. Gabriel Umoh (Uyo University); Prof. Luis A. J. Mur (Aberystwyth University)

Forward

Agricultural science is now entering a crucial period when the potential offered through recent advances in the field must be brought to fruition. New developments are required to secure crop production in the face of climate change, spiralling growth in the human populations and in, some cases, the impact of increased pollution. These challenges, although differing in their relative degree, are relevant as much to the UK as Nigeria. Crucially, there
are new advances in crop production, methods of dealing with pollution and means of improving the distribution of produce under adverse conditions ("supply change management") that need to be brought together in order to meet what has been called the "food security" agenda.

In responses to such opportunities the British Council has kindly funded a UK-Nigerian workshop which brings together leaders and mentors in crop production, soil-pollution remediation and supply chain optimisation. This workshop was seen as very much the beginning of a process whereby invitees could begin to build an extensive Nigerian-UK academic network through expertise and resources could be used address very important agricultural questions. With the close involvement of early stage scientists from both nations the workshop aims to deliver long-term research programmes that will be of substantial benefit to both nations.

This document represents a summary of the workshop discussions and presentations. It is intended to act both as a record but also as an encouragement to the attendees to continue developing their collaborations. We would also be very happy for non-invitees to join in with our efforts to have a significant impact on agricultural practice in its many forms.

Prof Luis A. J. Mur
Averystwyth University, UK`

Prof. Gabriel Umoh
Uyo University, Nigeria

Acknowledgements:

Firstly, the organisers wish to express their gratitude to the British Council in Nigeria for funding and supporting this workshop. We hope that the emergence of a functioning UK-Nigerian academic network focusing on food security; arising directly as a result of the workshop, will an appropriate testimony of their support.

Organising such a work involving delegates from different continents would be neigh on impossible. Therefore, the workshop co-ordinators wish to thank the Abuja-based British Council Organisers - Anthony Chukwuma, Abidemi Kolawole, and. Especially thanks must also go to Dr. Akanimo Odon (Envirofly Consulting) whose tireless efforts played a major role in bring this workshop about.

Prof Luis A. J. Mur
Averystwyth University, UK`

Prof. Gabriel Umoh
Uyo University, Nigeria

ORIGINAL WORKSHOP PROGRAMME

FUTUREPROOFING AGRICULTURAL PRODUCTION AGAINST ENVIRONMENTAL CHANGE

Programme Schedule

VENUE: *DENNIS HOTEL, ABUJA, MALABO STREET, WUSE 2, ABUJA*

DAY 1: *THURSDAY 22ND JANUARY 2015*

Morning Session

07.30 – 09.00 Breakfast

09.00 – 09.45 Arrival, Registration, Tea/Coffee

09.45 – 09.50 Welcome, Nigerian National Anthem; House Keeping

09:50 – 10.00 Welcome Addresses from a Representative of the British Council.

10.00 –10.20 Overview of the University of Uyo – **Prof. (Mrs) Comfort Ekpo,** Vice Chancellor, University of Uyo.

10.20 – 10.40 Overview of the Institute of Biological, Environmental and Rural Sciences (IBERS) Aberystwyth University, - **Prof. Luis Mur**

10.40 – 11.10 Collaborative Research and Development (Nigeria and UK); Innovation and Capacity Building Opportunities PART 1– **Dr. Akanimo Odon** (Lancaster University)

11.10 – 11.40 TEA/COFFEE BREAK

11.40 – 12.20 Participants Expectations and Feedback – Led by **Prof. Gabriel Umoh**

Afternoon Working Session

Session 1: Modern Breeding Approaches to Secure Yield

Chair: Prof. Luis Mur + Prof. Nyaudoh Ndaeyo

Sub-Theme I - Crop Responses to Stress

	SPEAKER AND TOPIC
12.20 – 12.40	*'Translating from models to crop species to improve stress tolerance"*– **Prof. Luis Mur,** IBERS, Aberystwyth University
12.40 – 13.00	*'Sustainable Method of Ameliorating Drought Stress on Crop Production'* – **Adejumo Sifau**
13.00 – 13.20	*'Examining Yield Sensitivity of Different Types of Crops to Changes in Climatic Factors: Implications for Adoption of Maize Breeds amidst Climate Change in Nigeria'* – **Mkpado Mmaduabuchukwu**
13.20 – 14.20	**LUNCH BREAK**

Sub-Theme II - Tapping the Potentials of Germplasm Variation Using Genomic Approaches

	SPEAKER AND TOPIC
14.20 – 14. 50	'*Tapping the Potentials of Germplasm Variation Using Genomic and Post-Genomic Approaches'* – **Rhys Kelly**
14.50 – 15.10	'*Breeding for Resistance against Climate Change-Induced Crop Diseases: An Experiment with Taro (Cocoyam) Leaf Blight in a Tropical Environment'* - **Emmanuel Essien**
15.10 – 15.30	'*Assessment of Impact of Climate Change Adaptation Strategies on Sorghum Production Among Small Scale Farmers in Kwara State, Nigeria'* – **Muhammad-Lawal, A.**
15.30 – 15.50	'*Utilization of Climate Change Agricultural Mitigation Technologies in Rural Communities of Akwa Ibom State'* – **Kesit Nkeme**

Evening Session

15.50 – 16.50 Group Discussions on Session One' sub-themes:
16.50 – 17.00 Final Comments and Conclusions

18.00 – 20.00 **DINNER**

DAY 2: FRIDAY 23RD JANUARY 2015

Morning Session

07.30 – 08.30 Breakfast

08.30 – 09.30 Arrival, Registration for "speed dating" session, Tea/Coffee

09.30 – 09.35 House Keeping: Anthony Chukwuma (British Council)

09:35 – 10.00 Recap of Day I – **Prof. Luis Mur**, IBERS, Aberystwyth University.

10.00 – 10.20 Collaborative Research and Development (Nigeria and UK); Innovation and Capacity Building Opportunities PART 2– **Dr. Akanimo Odon** (Lancaster University)

10.20 – 10.40 Enhancing Agricultural Research using sensor-based technology – **Blessing Obinaju**, Lancaster University

10.40 – 11.00 **TEA/COFFEE BREAK**

Session 2: Maintaining and Improving Soil Quality

Chairs: Prof. Anthony Eneji (University of Calabar & Dr. John Scullion (Aberystwyth University), Prof. Kirk Semple (Lancaster University)

Sub-Theme I - Remedying Contaminated Agricultural Soils and Maintaining Soil Quality in the presence of Climate Change

	SPEAKER AND TOPIC
11.00 – 11.30	'*Organic amendments and soil quality: application to agricultural and polluted soils'* – **Prof. Kirk T. Semple** (Lancaster University)
11.30 – 11.50	'*Total Petroleum Hydrocarbon and Heavy Metal Remediation with Jatropha curcas L. Seedlings Grown on Spent Oil Polluted Soil'* – **Oluyole Idowu**
11.50 – 12.10	*'Biodegradation of Hydrocarbons in a Tropical Ultisol by Legumes Planted Organic Manure'* – **Bassey Udom**
12.10 – 12.30	*'Management of Meloidogyne Incognita and salinity on pepper with different Arbuscular Mycorhizal Fungi Species'* – **Dr. Aniefiok Uko**
12.30 – 13.30	**LUNCH BREAK**

Sub-Theme II – Indigenous Approaches to Tropical Soils Management under Changing Climate.

	SPEAKER AND TOPIC
13.30 – 13.50	*Analysis of Choice of Indigenous Soil Management Technologies among Arable Crop Farmers in Akwa Ibom State, Nigeria'* – **Dr. Brownson Akpan**
13.50 – 14:20	'*Remediating polluted soils.* **Dr. John Scullion** (Aberystwyth University)

14-20 – 15.00 – Group Discussions on Session 2 subthemes

Session 3: Supply Chain Management under Environmental Stress

Chairs: Prof. Joseph Essien & Dr. Edu Inam (International Centre for Energy and Environmental Sustainability Research, University of Uyo)

Sub-Theme I – Modelling of Supply Chains, which are functional with environmental changes.

	SPEAKER AND TOPIC
14.30 – 15.00	*'Modelling of Supply Chains which are functional with environmental Changes'* – **Dr. Nishikant Mishra**, Aberystwyth University Talk given in absentia by Prof. Luis Mur , Aberystwyth University
15.00 – 15.30	*'Vulnerability of Farming Households to Environmental Change in oil rich region'* – **Prof. Gabriel Umoh** (University of Uyo)
15.30 – 15.50	*Vulnerability Assessment of Climatic Hazards in Coastal Ghana: A Livelihoods Approach*- **Dr. Eno Anwana** (University of Uyo)

Sub-Theme II – Overcoming institutional barriers to efficient Supply Chain Management

	SPEAKER AND TOPIC
15.50 – 16.10	*'Barriers to Efficient Value Chain Management in the Broiler Industry in Akwa Ibom State, Nigeria'* – **Chindinma Egwuonwu**
16-10 – 16.30	*'WE are Farmers! Enhancing the Agricultural Supply Chain using Collective Intelligence and Crowdsourcing'*- **Obinna Ajuruchi** (Lincoln University)

Session 4: "Speed Dating" Session

16.30 – 17.30 Networking Session

17.30 – 18.00 Closing Discussion: The Way Forward

18.00 – 20.00 DINNER

Workshop attendees and contact details

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Table of contents

PART 1 : Workshop Mentor Overviews

Overview of University of Uyo, Uyo, Akwa Ibom State, Nigeria

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VICE CHANCELLOR
Professor (Mrs.) Comfort Memfin Ekpo
BLS, Ed. M.Ed.(Zaria) Ph.D(Wales)

The University of Uyo was established on October 1, 1991 by the Federal Government of Nigeria. The University inherited students, staff, academic programmes and the entire facilities of erstwhile University of Cross River State, Uyo, established by the then State Government in 1983. Academic activities commenced in 1991/92 session.

Location: The University is located in the heart of Uyo, capital of Akwa Ibom State, Nigeria. Akwa Ibom is the largest oil producing states in Nigeria. Uyo is easily accessible by road and there are two international airports within 100 km radius, Margaret Ekpo International airport, Calabar, and Ibom International airport, Uyo. Currently, the University operates from five campuses: the Town Campus as well as Town Campus Annexe and the Main Campus. The Town Campus with its Annexe, the Main Campus, the Ine Umanah Campus and the College of Health Science all within 10km from the city centre.

OUR CORE VALUES

Faith in God
Academic Excellence in Teaching and Research
Institutional Autonomy
Peer and Professional Review
Qualitative Service Delivery
Strong Work Ethics
Equal Opportunity
Creativity and Innovation
Integrity
Transparency and Accountability
Peace and Orderliness

OUR MISSION
To diligently pursue scholarship and deploy its output for human capacity development and economic growth in the society, with active participation in Information and Communication Technology, sensitivity to Nigeria's rich cultural heritage and responsiveness to global environmental changes

Population: The University of Uyo has One thousand four hundred and six (1,406) academic staff of which one hundred and twenty five (125) are full professors. The number of senior non-academic staff is one thousand one hundred and seventy-five (1,175) while one thousand one hundred and sixty (1,160) are junior non-teaching staff. The university has a total student population of eighteen thousand seven hundred and twenty-four (18,724) comprising of two thousand four hundred and forty (2,440) post graduate students and sixteen thousand two hundred and eighty four undergraduate students.

Academic and Research Directorates:

Academic Planning; Centre for Wetlands and Waste Management Studies; Clement Isong Centre for Development Studies; Centre for Skills Acquisition and Rural Development; Centre for Cultural Studies; Centre for Entrepreneurial Development; Centre for Research & Development Studies; Centre for Gender and Women Studies; General Studies Directorate; Directorate of Pre-degree Studies

New Research Initiatives: International Centre for Energy and Environmental Sustainability Research (ICEESR), Institute for Biomedical Research and Innovation, and Institute for Agricultural Research and Innovation.

List of Faculties: The University of Uyo has a total of Sixty Six (66) full accredited programmes housed within twelve (12) faculties including Agriculture, Arts, Basic Medical Science, Business Administration, Clinical Science, Education, Engineering, Environmental Studies, Law, Pharmacy, Science, and Social Sciences

Academic Programmes: The University of Uyo runs the following programmes:

- Regular Undergraduate programmes
- Regular Postgraduate programme
- Part-time diplomas and degrees coordinated by the School of Continuing Education in

OUR VISION
To be a center of academic excellence by utilizing the available human and technological resources for teaching, research, community service and sustainable development

collaboration with the Postgraduate School

- Sandwich and undergraduate long vocation programmes strictly for Teachers already in Employment and coordinated by the Institute of Education in collaboration with the School of Continuing Education
- Pre-degree Programmes strictly for science students in the Faculties of Sciences, Agriculture and Education
- Basic studies programmes which prepares students for Advanced Level Examinations Papers through Cambridge/IJMB Examination bodies

Uyo: A dynamic and forward thinking University

Strides:

- One of the Nine Federal Universities in Nigeria selected for e-learning by the Federal Government of Nigeria
- The 10th most preferred university out of the 124 universities in the country by UTME Candidates. About 45,000 candidate choose UNIUYO as 1st Choice University
- One of the two universities in Nigeria selected for the study of Space Technology
- The only Nigerian University where Computational Language Documentation and Technology is studied at Masters and Doctorate degree levels in conjunction with Bielefield University, Germany.
- Has the largest number of programmes with full accreditation
- Honoured as the Information Technology School of the year 2012
- UNIUYO is a Fulbright affiliated institution visited by the AMERICAN Ambassador to Nigeria, Mr. Terence McCulley and parades six Fulbright scholars at the moment

The International Centre for Energy and Environmental Sustainability Research (ICEESR), University of Uyo, Uyo

The International Centre for Energy and Environmental Sustainability Research is a newly created R & D centre in the University of Uyo, Uyo, Akwa Ibom State, Nigeria dedicated to generation and transfer of knowledge, strengthening individual and institutional capacities in furtherance of the mission and vision of the University of Uyo. ICEESR is a model research centre for international technological cooperation to be affiliated with renowned International Research Centers (including the Massachusetts Institute of Technology's Media Laboratory, USA; Strategic Energy Institute, Georgia Institute of Technology, USA and the International Environmental Research Centre at Gwangju Institute of Science and Technology, South Korea), and at the same time bringing in private ownership through a consortium of local, national and international businesses and governments.

CONTACT INFORMATION:

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PRIFYSGOL ABERYSTWYTH UNIVERSITY

An introduction to Abersytwyth University and the Institute of Environmental and Rural Science (IBERS).

Luis A. J. Mur: lum@aber.ac.uk

Fig.1 Students in front of the "Old College" Aberystwyth University

Aberystwyth University is the oldest University in Wales which is one of the four constituent nations of the United Kingdom. Aberystwyth University was established through the efforts of a small group of London-based Welshmen in the 1850. Led by Hugh Owen, they worked to secure sufficient finances through public and private subscriptions to found this University in 1872. The first university building was a half-finished hotel building on the sea front in Aberystwyth. This building is still in use by the University and is known as "Old College" (Fig. 1).

The first intake of the University was 26 students which were taught by 3 members of staff. After some initial difficulties the University has continued to grow over the years and now has a student population of ~10,000 and a teaching staff of 2,000.

Currently the University is grouped around seven institutes: Biological, Environmental and Rural Sciences (IBERS); Literature, Languages & Creative Arts; Geography, History & Politics; Human Sciences; Management, Law & Information Science; Mathematics, Physics & Computer Science; Education, Graduate & Professional Development.

In its mission statement Aberystwyth University makes clear its aims to maintain its place as to be a first-class teaching and research University. This involves providing students with learning opportunities to the highest academic standards with a distinctive flavour given the University's location and culture. It aims to respond to the needs of society for research and for skilled and educated graduates. In its research Aberystwyth plays a full part in the international research scene through collaboration with contacts in Britain, Europe and the wider world. Equally, the

University has a special responsibility for the needs of Wales its role in sustaining the culture of Wales and the Welsh language.

The Institute of Biological, Environmental and Rural Science (IBERS).

IBERS was created in 2008 when the former BBSRC Institute of Grassland & Environmental research merged with the institutes of rural Sciences and of Biological Science. This represented a substantial pooling of teaching and research expertise as well as infrastructure so that IBERS has from its inception, strived to make major impacts in a range of areas.

IBERS is the largest Institute within Aberystwyth University with 360 members of staff. It is a highly active teaching and research organization. IBERS is spread across two University Campuses, the Gogerddan Campus which is primarily research orientated and the Penglais Campus which is both teaching and research focused. Recently, IBERS has considerable infrastructure development which is most obviously seen in the completion of two new buildings (Fig. 2)

Figure In 2012 two new buildings were opened at IBERS – an investment of £25million

IBERS Gogerddan Campus

IBERS Penglais Campus

IBERS also manages are series of farms in and around Aberystwyth extend to a total of some 1000 hectares. These farms are involved in beef rearing and sheep production, the latter including both commercial lowland sheep and performance-recorded pedigree flocks (Texel, Suffolk, Bluefaced Leicester and Beulah Speckled Face breeds) that sell high genetic merit rams to commercial producers. Other farms provide land for plant breeding purposes. IBERS commitment to farming is demonstrated by it being on one of the two founding partners of Farming Futures (formerly the Centre of Excellence for UK Farming and Food Supply). Farming Futures is a research consortium with very close links with industry that aims to help farmers and the food industry address key challenges and achieve a balance between increased productivity and more efficient use of resources.

IBERS core interests as a premier research organization is demonstrated by its population of over 1350 undergraduate students and more than 150 postgraduate students. Its undergraduate degree schemes cover a range of topics which are designed to integrate with our considerable research interests and also equip our students with the knowledge and skills to become successful graduates. Our courses include

C100 Biology
C164 Marine & Freshwater Biology
C500 Microbiology
C200 Plant Biology
C300 Zoology
CC35 Zoology & Microbiology
C990 Life Sciences
C700 Biochemistry
CC47 Genetics & Biochemistry
D322 Equine Science
D334 Equine and Veterinary Bioscience
D444 BSc Agriculture with Countryside Management
D447 BSc Countryside Conservation
D455 BSc Countryside Management
C180 BSc Ecology
C600 Sport and Exercise Science

Our teaching has been classified as excellent and has recently figured highly in student satisfaction surveys. The UK University course comparison site "Unistats" has suggested that around 80% of our students are in work or studying within 6 months of completing their degree (Fig. 3).

Figure 3. Our latest tranche of successful graduates.

IBERS also leads innovative and novel interdisciplinary postgraduate teaching that links to the global "grand challenges" of: Living with climate change; Conserving biodiversity & natural resources; Renewable energy; Global food and water security;

and Animal and plant diseases. Our taught post-graduate portfolio includes courses in the following.

MRes (Masters of Research) in Biosciences
MSc Statistics for Computational Biology
MSc Green Biotechnology and Innovation Management
MSc in Food and Water Security
MSc Equine Science
MSc Animal Sciences
MSc Livestock Science
MSc Managing the Environment: Environmental Sustainability
MSc Managing the Environment: Marine and Freshwater Systems
MSc Managing the Environment: Bioenergy and Environmental Change
MSc Managing the Environment: Habitat Restoration and Conservation

IBERS is rightly proud its internationally recognised research which, in one of its aims, seeks to underpin its teaching. More widely, research in IBERS is focused on meeting its aspiration to be one of the top three University departments in the World whose interests are primarily environmental, ecological or agricultural. . In order to realise this vision the institute conducts fundamental and applied biological research to tackle four of the most important challenges facing humanity:

- living with climate change;
- renewable energy;
- global food and water security
- animal and plant diseases.

To address these challenges, IBERS has organised its research along three broad areas of research:

- Animal and microbial sciences consists of five research groups, including: animal systems; diet and health; herbivore gut ecosystems; microbiology; and parasitology and epidemiology;
- Environmental impact consists of five research groups, including: abiotic stress resistance and nutrient use efficiency; bioconversion and biorefining; ecology; energy crop biology; and energy crop breeding and modelling;
- Genome diversity consists of four research groups: public good plant breeding; breeding methodologies; plant genome and chromosome biology; aquatic, behavioural and evolutionary biology.

The research undertaken at IBERS generates various outputs including new seed varieties; novel applications for plant based products and improved understanding of biological and land-based systems. In order for these research outputs to generate economic impact, the knowledge embedded within them is transferred from IBERS into industry. One of the main ways in which IBERS transfers knowledge into industry is through its students. This process occurs either before students graduate, through the completion of work experience placements or participation in knowledge transfer programmes (Fig. 4).

Fig, 4: Students are an integral part of our research and outreach activities

The success of research at IBERS is demonstrated by our excellent record in winning awards. IBERS Awards include the Times Higher Education Award 2013 for Outstanding Contribution to Innovation and Technology and The Queen's Anniversary Prize for Higher Education 2009 for International Leadership in Public Good Plant Breeding. IBERS was awarded a BBSRC Excellence With Impact Award in 2011.

IBERS research is an ever expanding part of its activities. IBERS is home to the National Plant Phenomics Centre which funded by the BBSRC for use by researchers from academia and industry (Fig. 5).

Figure 5: The National Phenomics Centre is a £6.8 Million National Capability.

This is a state-of-the-art phenotyping platform which aims to deliver integrated phenotyping solutions for key crop and model species. The Centre employs a multidisciplinary approach, bringing together computer scientists and engineers to work with biologists to address how genetics and environment interact to give rise to the characteristics (or phenotype) of the individual organism. DNA sequencing technologies are now scalable at reasonable cost so that the genomes of whole populations can be defined at molecular detail, but phenotypic analysis remains relatively expensive. Understanding how phenotypic diversity emerges from the underlying genetic code, therefore, requires new approaches to capturing and measuring traits

IBERS also is the nerve center for BEACON; A Centre of Excellence for Biorefining. This is a £20 million partnership between Aberystwyth Bangor and Swansea Universities. BEACON will build on research already underway at IBERS to produce fuels from energy crops such as high-sugar grasses like rye. It is enabling Swansea University to develop their expertise in using bacteria and fungi to digest, or ferment, plant matter within the bio-refining process. Bangor University is developing new materials from plants which can be used to develop innovative products.

The University is now investing over £100m in new facilities. A key element of this programme is the development of the new £35m Aberystwyth Innovation and Enterprise Campus (AIEC) at Gogerddan, where much of the research undertaken by IBERS is based.

Fig. 6: IBERS Gogerddan; the future site of the AIEC.

Once complete the AIEC will enable IBERS to:

- Increase investment in commercial R&D from around £800,000 to £850,000/year
- Create 150 new jobs
- Increase income from joint projects with industry to £3.3 million/year
- Develop 25 new processes, products, technologies or services
- Assist 300 SMEs and commercial partners

In summary: IBERS is a near unique amalgam of teaching organisation with research the ranges from lab-based research to the development of a commercially relevant products or environmental interventions. It uses innovative approaches to use its various human and infrastructure resources to make real economic and social impact.

IBERS Groups Represented at the Abuja British Council Workshop.

Crop Responses to Stress: Prof. Luis A. J. Mur is investigating in plant responses to abiotic and biotic stress and is heavily involved in a range of food security projects in the UK and internationally. His research uses genomic and post-genomic technologies to translating discoveries made in the laboratory into field situations. He is currently sequencing the genomes of key pathogens from Brazil (*Moniliophthora crinipellis*) and India (*Xanthomonas axonopodis*) to identify key virulence determinants. He is using metabolomics-approaches to target key stress tolerance mechanism for drought, heat and pathogen stress in tea, rice and wheat in India. In the UK, he leads a BBSRC-DEFRA link project which is determining the costs (in terms of yield) of field-resistance to disease in wheat.

http://www.aber.ac.uk/en/ibers/staff/lum/
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Remediating contaminated soils: Dr. John Scullion is an expert on soil ecological relationships to soil function, with a particular interest in the impacts of climate change on soil quality and in the reclamation of degraded land, including former coal mine sites. His research interests also focus on exploiting the potential of phytoremediation for reducing soil metal and hydrocarbon concentrations, and on the biological treatment of wastewaters. He also has a long-standing interest in soil C dynamics and impacts of various land use and broader environmental factors on soil C stocks

http://www.aber.ac.uk/en/ibers/staff/jos/
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Public good plant breeding group: This group aims at crop potential of genetic improvement, using advanced scientific approaches, to support multifunctional land-use and alleviate environmental impacts as well as coping with problems associated with climate change. The Group includes scientists and plant breeders developing new varieties of forage and amenity species, cereals and energy crops. The group develops innovative grass, clover, oat and

Miscanthus varieties that have a significant impact in the market and on end use. By combining conventional and molecular approaches to plant breeding with high throughput phenotyping the group aims to develop improved plant varieties that are marketed by our commercial partners.
Current projects aim to generate new varieties can make to reduce the environmental footprint of UK agriculture. In particular, productive new grass and legume varieties are being produced that can help to reduce diffuse pollution to air and water by increasing the efficiency of nitrogen and phosphorus use through the soil-plant –animal system.
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Part II: Modern Breeding Approaches to Secure Yield

TAPPING THE POTENTIALS OF GERMPLASM VARIATION USING GENOMIC AND POST-GENOMIC APPROACHES

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ABSTRACT

The aim of the breeding methodologies team is to introduce genomics assisted methods to the breeding of improved forage crops. The purpose is to help to increase the genetic gain per unit time and cost. Secondly, using the genomics and phenotypic data to help to dissect traits genetically, and to discover genes governing some of the agronomically important traits.

Acknowledgements:
Charlotte Jones, Sarah Palmer, David Lloyd, Matt Hegarty, Tina Blackmore, Ross King.

Introduction

Grassland is an important component of agriculture in the UK, occupying over 60% of the total area used for crop production. There are three principal types of grassland:

Rough grazing is uncultivated grassland that is found on the mountains, hills, moors and heaths of the UK. It accounts for 4-5Mha in the UK. For the most part it is "uninmproved" receiving no fertiliser and suffering from difficulties such as poor drainage, steep slopes and physical obstructions. It is usually characterised by low productivity of livestock.

Permanent grassland (or pasture) is grassland that is maintained perpetually without reseeding, however grassland that is at least five years old is often defined as "permanent" as well. In the UK most of the truly permanent grassland (5.8 Mha) has been created through the gradual "improvement" of rough grazing over the centuries, for example by drainage and the application of fertiliser.

Rotational grass is grass which is sown every few years as part of an arable crop rotation where it is often known as a grass ley. Although grass leys are expensive to establish they are very productive in their early life and play an important role in a mixed farm by returning organic matter to the arable rotation. The IBERS based perennial ryegrass breeding programme is principally concerened with developing varieties for rotational grass systems. (1)

Most important forage crops in temperate grasslands are outbreeding, and very heterozygous. Genetic improvement usually happens via recurrent selection in populations, whereby the frequency of beneficial alleles at loci is increased over the generations. This is based on phenotypic selection. The traits of importance for achieving the best success for livestock feed are biomass yield, persistency, digestibility, energy content (water soluble carbohydrates and lipids) and protein content. Of course it is also necessary to achieve a reasonable seed yield to make it worthwhile for the seed growers.

Lolium perenne breeding programme

IBERS is the only university department in the UK with active breeding programmes. Perennial ryegrass is the most important of the forage crops, and IBERS breeding programme is described in Fig 1. It is separate from most other grass breeding programmes by not using mass selection. At any given generation a paced plant nursery with 1000 plants from each of 4-6 families. Four hundred plants from each family are selected based on winter survival, stature and growth habit, disease resistance to go forward for polycrossing in pollen proof chambers. 100 of the best seed yielding motherplants are selected for plot trials (4 reps of 1 m2 plots) for 3 years. Biomass yield and other traits are recorded in the period. The results are used

to decide on 4-6 parents to go forward for a polycross programme to generate a synthetic population, which provides the basis for variety trials. The phenotypic traits will also inform the selection of the 4-6 plants with 1000 plants each to forward for the next generation of spaced nursery trials. This is based on various visible traits as well.

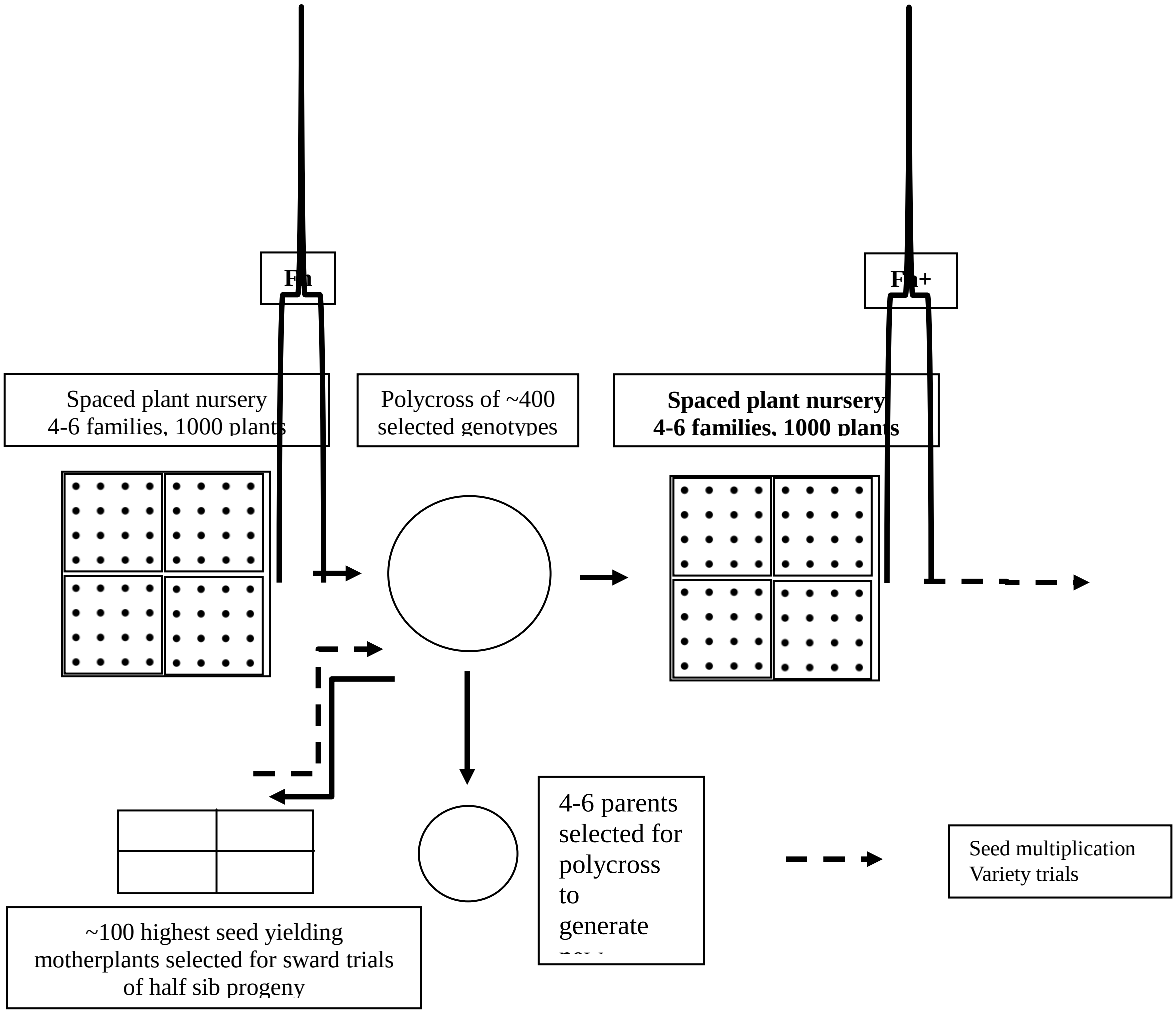

Fig 1 – Breakdown of the *Lolium perenne* breeding programme.

The breeders equation: **$\Delta G = i r \sigma_g / L$,** describes the genetic gains that can be made in phenotype by selection (where **i** represents selection intensity; **r** the accuracy of breeding value; **σ_g** is the genetic SD (standard deviation) and **L** the length of breeding cycle**.** This important equation shows which factors can be influential on the amount of genetic gain made. The selection pressure is easily controlled, but given a certain value for that, the genetic variance or standard deviation and the length of the breeding cycle are important for genetic gain. If the available genetic variance could be increased the genetic gain would improve.

The amount of genetic variance that can be exploited in half sib progeny family evaluations accounts for only a quarter of the between family genetic variance. This is assuming that only the motherplant is known, and that the pollen donor is unknown. Three quarters of the genetic variance is left on the plots. In half sib progeny test breeding we are basically leaving 75% of the potential variance in the field. If the pollen donor is known the usable amount of genetic variance can be doubled; the within family variance is accounting for the rest. Knowing the pollen donor can be achieved with a few microsatellite markers and is one of the cheapest ways of increasing genetic gain in population based plant breeding. If the pollen donor is known the usable amount of genetic variance can be doubled. Consequently, fifteen simple sequence repeat (SSR) based markers were employed to establish the paternity of the half sib progeny, in the most recent generations of the *Lolium perenne* breeding programme, with the intention of instituting such testing as routine for all subsequent generations.

There are two other stages of the breeding cycle where we would like to make improvements in the genetic gain achieved per unit time. One is the 3 year period of the plot trials. And the other is the selection of plant families for the next generation of spaced plant nursery. The phenotypic data and the paternity data then feeds back into the selection of mother plants for the next generation. The most obvious candidate for improvement would appear to be the length of the breeding cycle. If it can be halved then the accuracy of the breeding value can be almost halved in order to achieve improved genetic gain.

Genomic Selection

Genomic selection was first proposed in 2001 by Meuwissen et al. (2) It has been taken up in animal breeding over the last decade, particularly with the arrival of next generation high throughput sequencing and genotyping platforms. Determining the simultaneous effects of many genome wide markers rather looking at a handful of markers associated with a single trait.Benefits include: a faster selection of candidates for the production of synthetic varities; an increase the number of recombinations per unit time and hopefully an improvement of the efficiency of introgression of beneficial trait from donor to breeding population and a reduction of the cost of phenotyping.

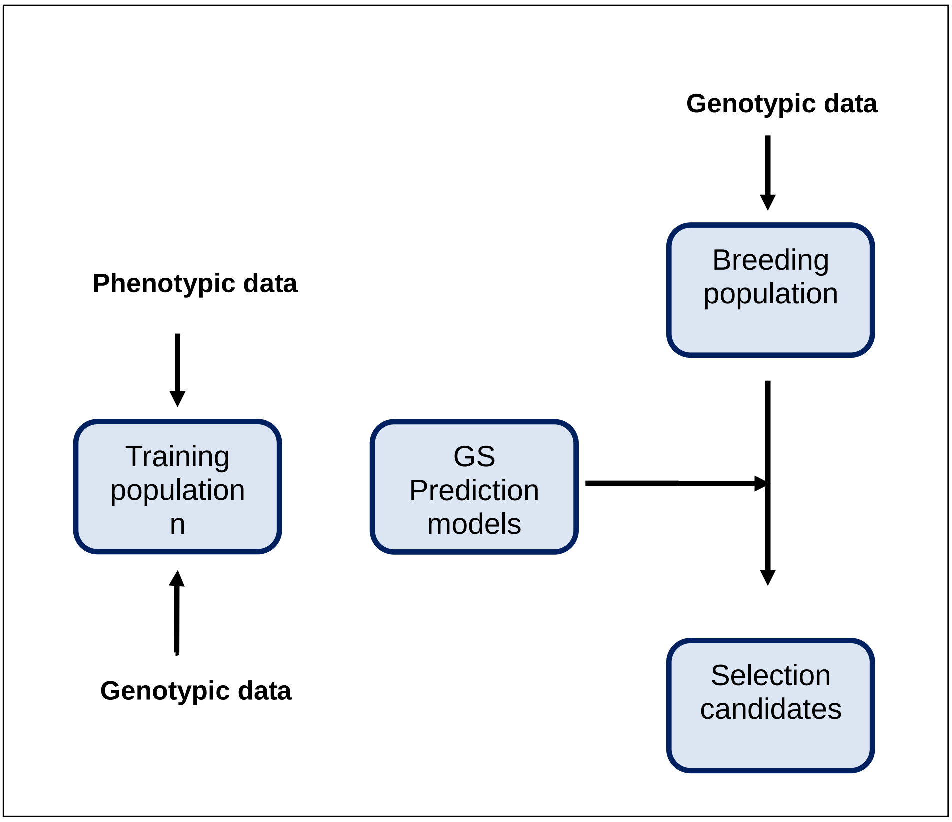

Fig 2 – The principal of genomic selection

A training population needs to be established which is both phenotyped and genotyped (see Fig 2). The data from this training population are used to estimate the effect of all the markers, and this is converted to genomically estimated breeding values (GEBVs). The model for determining this is then used to predict the GEBVs of a breeding population from which it is desired to identify selection candidates.

Genomic selection is affected by the proximity of each marker to a QTL of an agronomic traits is one factor. This is in turn dependent upon linkage disequilibrium (LD). This property is determined by the breeding habit of the crop species in question. An outbreeding species is characterised by low LD (in general), while inbreeding species tend to have higher genome-wide LD. The size of the training population is another important factor. The larger the training population the better. Another factor which we have found to be important is the relationship between training population and test population. The more closely related the better. Heritability also tends to influence the accuracy of predictions. The number of QTL is also important, but is not easy to manipulate.

Continued update of the training Population

The programme has two breeding populations in perennial ryegrass, separated by their difference in flowering time, which is an important factor determining digestibility and other quality traits. We have gradually increase the size of the intermediate flowering population to include more and more historical generations. We are currently at the 14th generation, but have data going back to the 11th. In addition we have a late flowering population, but have fewer generations to work with in our training set. We use a 4K Infinium array SNP CHIP for genotyping. This is probably on the low side, but we are working on expanding the numbers in the near future. The traits we are working with are ground cover, biomass yield, digestibility, water soluble carbohydrate and nitrogen content.

Intermediate flowering generations – F11, F12, F13, F14 (370 genotypes)
Late flowering – F5 (170 genotypes)]

The two methods we have tried for the prediction models include the traditional ridge regression BLUP (Best Linear Unbiased Predictor) and a machine learning (ML) method called random forest.

The way in which we measure the accuracy of the models are by correlating the genomically predicted breeding values to the actual phenotypic values using cross validation. See also Table 1.

Population	Ground Cover	Yield year1	Yield year2	DMD	WSC	N
Intermediate Flowering F13	0.22	0.71	0.67	0.82	0.73	0.67
Late Flowering F5	0.15	0.08	0.57	0.39	0.61	0.51

Table 1 – Broad sense heritabilities for the F13 and F5 of the intermediate and late flowering (respectively) populations in the *Lolium perenne* breeding programme. DMD stands for: dry matter digestibility; WSC for: water soluble carbohydrate and N for Nitrogen content.

Principal component analysis of the breeding populations (Fig 3) showed a divergence between the late and intermediate populations are rather different, and that the 11th generation of the intermediate separated out from the later generations of the intermediate. The structure has an effect on prediction accuracy where the closely related training population to the test pop is more accurate Fig 5 shows accuracies for the 14th generation using the total population: the late and the all the intermediate generations as training population on top. Fig 4 shows the same predictions on F14 but using only intermediate populations as the training set. Even though the latter training population is smaller, its closer relationship with the test population increases the accuracy.

Analysis of LD in *L. perenne* (Fig 6) show that LD decays rapidly with increased pairwise distance between markers. This would indicate that increased marker coverage would potentially help to improve accuracy.

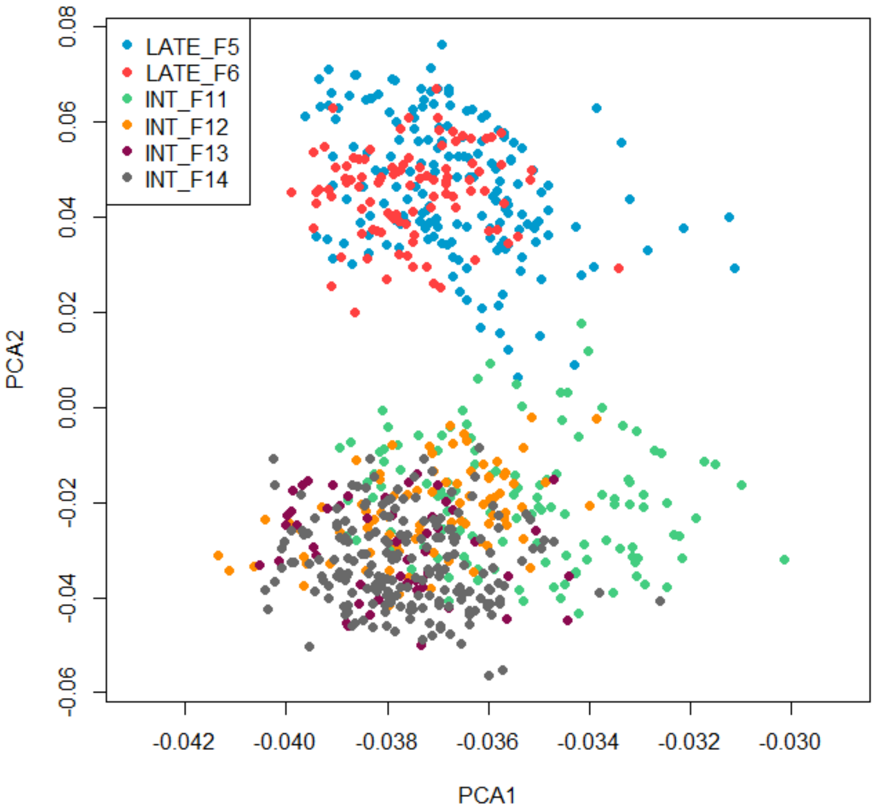

Fig 3 – Principal component analysis of perennial ryegrass breeding populations. Showing the late flowering F5 and F6; and the F11 through to F14 of the intermediate flowering population.

Fig 4

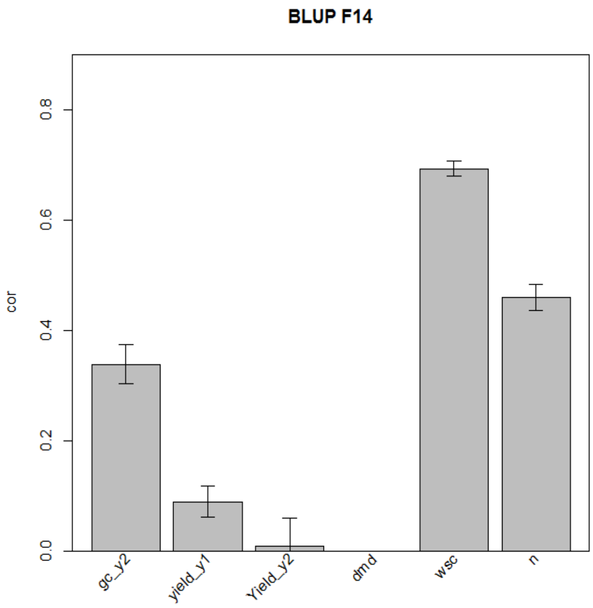

Fig 5

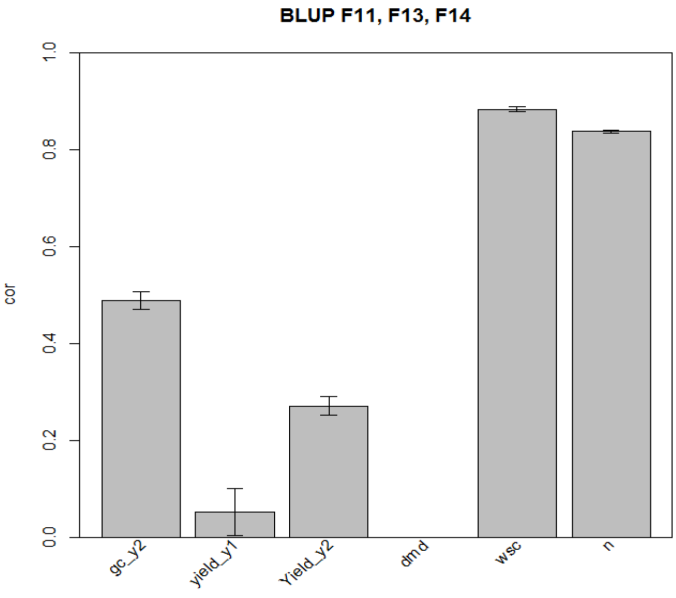

Fig 4 (left) - Broad sense heritabilities of the F14 of the intermediate flowering population.
Fig 5 (right) – Broad sense heritabilities of the F11, F13 and F14 training populations.

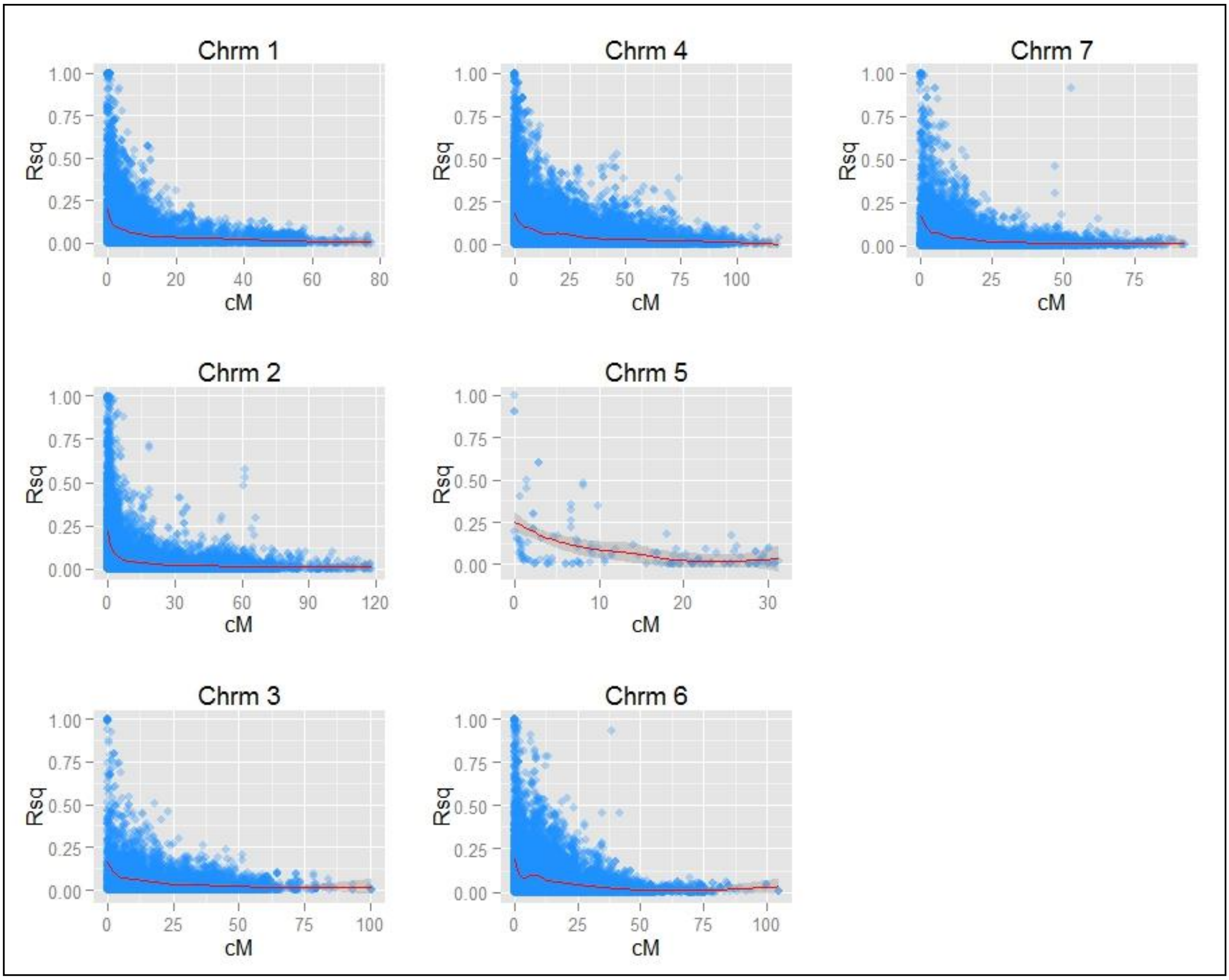

Fig 6 – Linkage disequilibrium in *L. perenne*.

Conclusions

These studies show that a close relationship between training and test population, and the size of the training populations both improves correlation. That traits related to forage quality perform better than yield and ground cover. For these populations rrBLUP performed as well as or better than ML methods, though it is possible that very large training populations will improve performance of ML.

Future work will include, further SSR based pollen donor testing for the F11 and F12 generation of the intermediate flowering half sibs, and extension of routine paternity testing to all subsequent breeding populations. The results obtained so far for GEBVs are very promising with respect to obtaining reasonable accuracies. The next step will be to test the method out by selecting the 4 parents for generation of a synthetic populations based on GEBVs.

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Part III: Maintaining agricultural production under conditions of environmental change.

MANAGEMENT OF *MELOIDOGYNE INCOGNITA* AND SALINITY ON PEPPER WITH DIFFERENT ARBUSCULAR MYCORRHIZAL FUNGI SPECIES.

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ABSTRACT

A greenhouse experiment was conducted to evaluate the efficacy of three arbuscular mycorrhizal fungi (AMF) in alleviating the adverse effects of salinity and root-knot nematode on sweet pepper (*Capsicum annum.L*) plants. The experiment was a 2x3x4 factorial laid out in a completely randomized design (CRD) with three replications. The treatments involved 24 combinations of three mycorrhizal fungi (*Glomus mosseeae, Glomus deserticola, Gigaspora gigantea*), plus an uninoculated control, different salinity levels (0.08, 2.00 and 4.00 ds/m) and inoculation with or without 5,000 eggs of *M. incognita*. The pepper seedlings were inoculated with AMF at the nursery stage. Data were collected on number of galls per root system, gall index (0-5 scale), number of egg masses, plant height, fresh root weight and shoot dry weight per plant. The results obtained indicated that the pepper variety "Tatese" was highly susceptible to *M. incognita* infection with heavy galls on non-mycorrhizal plants. Nematode inoculation significantly ($P \leq 0.05$) inhibited growth and dry matter production in pepper relative to the uninoculated plants. Increase in salinity level significantly ($P \leq 0.05$) inhibited root galling, growth and dry matter accumulation in pepper .AMF inoculation significantly ($p<0.05$) reduced root galling compared with the non-mycorrhizal plants. Arbuscular mycorrhizal fungi inoculation significantly ($P \leq 0.05$) enhanced growth and dry matter yield of pepper in the presence or absence of nematode infection at all salinity levels relative to the non-mycorrhizal plants. Among the AMF species, *G. deserticola* was the most efficient in ameliorating the injurious effects of salt and *M. incognita* followed by *G. mosseae*.

Keywords : Salinity, Arbuscular mycorrhizal fungi, Pepper, *Meloidogyne incognita,* Stress amelioration.

Introduction

The cultivated and wild pepper belongs to the family Solanaceae and the genus *Capsicum.* The bell or sweet peppers (*C. annum L.*) and the pungent or "bird eye pepper" (*C. frutescens*) are the two widely grown species (Bosland and Votava, 2000). World production of pepper is estimated at 26,537 million tonnes with China leading with an output of 7.072 million tonnes representing 27% of the world production (FAOSTAT, 2010). In Africa, Algeria is the lead producer (317,500 tonnes) followed by Tunisia with 280,000 tonnes (FAOSTAT, 2010). Pepper is an important spice crop, highly cherished for its pungent flavour. Pungency is produced by the capsaicinoids, alkaloid compounds ($C_{18}H_{22}N0_3$) that are found only in the genus, *Capsicum* (Seleshi, 2011). Pepper fruits are rich in vitamins A and C, a good source of B_2, Potassium, Phosphorus and Calcium (Bosland and Votava, 2000). They are used industrially as an ingredient of many products, e.g. hot sauces, canned fish, ginger beer as well as some pharmaceutical products. The red pigment extracted from the ripe fruit is used as a natural colouring agent for food and cosmetics.

Pepper production in sub-saharan Africa is hindered by a number of biotic and abiotic factors. The adverse effects of these factors on the crop are further aggravated by climate change. In Nigeria, the bulk of the crop is produced in the semi-arid region of the country under irrigation in which drought and salinity are potential production constraints. Pepper is a salt-sensitive crop (Chartzoulakis and Klapaki, 2000). Salt may originate from several sources such as sea water and the salt strata. In the arid and semi-arid regions, it originates from surface run-off and capillary movement. Poor source/quality of irrigation water may also constitute a source. Excess salt in the root zone inhibits water and nutrient absorption by the plant and may induce toxic effects (Mitter, 2002). Some saline soils contain sufficient salts that can suppress plant growth by upsetting osmotic potential and enzyme activities in plants (He *et al*., 2007; Shiyab *et al*., 2013).

The best management option for the production of crops under saline condition has been the use of salt-tolerant varieties (Chartzoulakis and Klapaki, 2000; Udo *et al*., 2006). Of recent however, researches have shown that arbuscular mycorrhizal fungi (AMF) are effective in alleviating the stress induced by salts on plants in saline soils (Al-karaki, 2000; Al-karaki, 2006; Giri and Mukerji, 2004; Kaya et al., 2009; Abdel Latef and Chaoxing, 2011). The physiological and biochemical mechanisms involved in ameliorating salt stress by AMF are still topical. Improved nutrient acquisition especially immobile elements such as P, Cu, Zn (Al-karaki, 2000; Kaya et al., 2009) has been attributed in part to the induced salt-tolerance by AMF-colonized plants. In recent studies, other potential mechanisms have been advocated, which include, greater osmotic adjustment, reduced oxidative damage, selective toxic ion absorption like Na^+, vacuolar compartmentalization of toxic ions, increased production of antioxidative enzymes, etc (Ruiz-Lozano, 2003; Mashide et al., 2008; He et al., 2007; Abdel -Latef and Chaoxing, 2011). In spite of the substantial scientific evidence that AMF colonization alleviates salt stress, some researchers have explicitly stated that salt has negative effects on AMF (Juniper and Abbott, 2006; Hirrel, 1981). Apart from salinity, root-knot nematode (*Meloidogyne* spp) is a serious threat to pepper production in the tropics (Judy *et al*., 2002; Udo *et al*., 2005; Sowley *et al*., 2014). The control of nematodes with chemical nematicides is the most effective method but the environmental and health concerns associated with it are serious drawbacks. Recently, many authors have reported the effectiveness of AMF in the management of root-knot disease on several crops (Zhang *et al*., 2009; Odeyemi *et al*., 2010; Udo *et al*., 2013). The mechanisms involved in nematode suppression by AMF are still topical (Gera Hol and Cook, 2005). However, induced systemic resistance/tolerance, histological, physiological morphological and biochemical changes associated with AMF inoculation have been implicated in nematode control and improved crop growth (Umesh *et al*., 1988; Singh *et al*, 1990). Galling of plant roots by root-knot nematodes under saline condition could lead to severe growth and yield impairment if not checked (Edongali and Ferris, 1982). There is paucity of information on the salt ameliorating ability and root-knot disease control by AMF with both stress factors occurring simultaneously. The objectives of this work were to: (i) evaluate the efficacy of arbuscular mycorrhizal fungi (AMF) in the management of *Meloidogyne incognita* on pepper and (ii) assess the salinity ameliorating ability of different AMF species in salt-stressed pepper.

Materials and Methods

Experimental site

The study was carried out in the Screenhouse of Faculty of Agriculture, University of Calabar from January to July, 2013. Calabar lies in the tropical high rainforest agroecology of the Equatorial Climatic belt of Nigeria (Latitude 5^o00' and 5^o40'N, Longitude 8^o04' and 8^o62'E) and about 70m above sea level.

Source of Materials

The pepper seeds (Capsicum annum cv. "Tatase") used in the experiment were obtained from crop germplasm collection of Crop Science Department, University of Nigeria, Nsukka. The pepper cultivar is susceptible to *M. incognita* (Udo *et al*., 2005). The starter culture of AMF species; *Glomus mosseae, Glomus deserticola* and *Gigaspora gigantea* were obtained from soil Microbiology Unit of Agronomy Department, University of Ibadan, Ibadan, Oyo State, Nigeria. The salts used for the trial were sodium chloride (NaCl) and Calcium Chloride ($CaCl_2$) and were bought from a chemical shop in Calabar.

Soil Sample Collection and Analysis

A composite surface soil (0-15cm) was collected from University of Calabar Teaching and Research Farm and was analysed for its physicochemical properties. The soil from this farm was used to fill plastic pots which served as the growth medium for the pepper plants.

Multiplication of Starter Culture of AMF and *M. incognita inoculum*

The starter culture of each AMF made up of chopped roots of the trapping plant, spores, chlamydospores and soil was multiplied in a sterlised soil, planted with maize and irrigated with Hogland's solution (half strength low in phosphorus) for three months. The spore density of AMF incoculum ranged from 48 to 51 spores/10g of soil, as estimated by the method of Gerdemann and Nicolson (1963). Indigenous population of *M. incognita* maintained on *Talinum fruticosum* (water leaf) in the vicinity of the *Screenhouse* was multiplied in *Celosia agentea* (Cock's comb) in a sterilized soil. It served as an inoculum source.

Preparation of nematode inoculum

Heavily galled roots of *C. agentea* were uprooted and washed gently with water to remove the adhering soil particles. The galled roots were cut into 1-2cm segments for egg extraction using the method of Hussey and Barker (1973). This method involves shaking the galled root segments in 0.50% sodium hypochlorite solution in a 500ml conical flask covered tightly with a rubber bung for 4mins. The egg suspension obtained was then passed through a 200-mesh sieve nested over a 500-mesh sieve. The eggs were transferred into a beaker with the help of a wash bottle, and the inoculum density was adjusted as desired under stereoscopic microscope. The number of eggs in 1ml of the egg suspension was ascertained to be 500, average of three counts with a multiple tally counter in a nematode counting dish.

Raising of pepper seedling and inoculation with AMF.

The pepper plants were inoculated with the respective AMF species at the nursery stage. Sandy soil mixed with poultry manure in the ratio of 3:1 by volume was steam-sterilized. Two and half kilograms of the steam-sterilized soil mixture was used to fill plastic baskets to which 150g of the arbuscular mycorrhizal fugus inoculum was added to the top 5-cm layer. The pepper seeds were surface sterilized with 0.5% of NaOCl solution (household bleach) and rinsed three times in distilled water. The seeds were drilled in each basket and seedlings thinned to 25 per basket after emergence. Seedlings raised in basket without AMF served as the control. The seedlings were watered appropriately. This method of inoculation follows the procedure of Oyekanmi *et al.* (2007).

Inoculation of pepper seedlings with *M. incognita* and irrigation with saline water.

Five-week-old pepper seedlings were transplanted in the evening and inoculated with the root-knot nematode species. Seventy-two (72) plastic pots were used for the experiment. The pots were perforated at the bottom to allow for easy drainage. Pots were labeled appropriately for easy identification and treatment application. Each of the labeled pots was filled with 2.5kg of sterilized soil. The pepper seedlings were transplanted and inoculated by making 3 holes around each seedling and pouring 10ml of the inoculum suspension containing 5000 eggs. Uninoculated seedlings served as the control. Salinity level of 2.00 ds/m was obtained by dissolving 10.41g each of NaCl and $CaCl_2$ in 18 litres of tap water, while 4.00 ds/m was obtained by dissolving 20.82 g of each salt in 18 litres of tap water. The electrical conductivity of the saline irrigation (EC_w) was measured with an electrical conductivity meter. Irrigation with saline water (150 ml/plant) commenced two weeks after transplanting. The control plants were irrigated with tap water with electrical conductivity(EC_w) of 0.08 ds/m.

Experimental design

The experiment was laid out as a 2x3x4 factorial in completely randomized design (CRD) with three replications. The first factor was nematode inoculation, with uninoculated plants serving as control. This factor was combined with the three salt levels and the three AMF species inoculation plus non-mycorrhizal plants as control. Thus there were 24 treatment combinations with three replications amounting to 72 experimental units (Pots).

Data Collection and Statistical Analysis

Data were collected on number of leaves and plant height (cm)/plant at seven weeks after transplanting. At seven weeks after transplanting, each plant was uprooted and roots washed thoroughly with flowing water. Number of galls and egg masses per root system were counted. Root gall index was determined on a 0-5 scale rating according to Taylor and Sasser (1978); 0=0, 1=1-2, 2=3-10, 3=11-30, 4=31-100 and 5 = more than 100 galls per root system. For egg mass count, fresh root was stained with phloxine B(0.15g/l) for 15 minutes (Daykin and Hussey, 1985). The root system was separated from the shoot system; fresh root weight was obtained by weighting with an electronic balance, while the dry shoot weight was obtained after oven drying in an envelope at 70 ^{o}C for 48hrs.

Data collected were subjected to statistical analysis of variance (ANOVA) for a 3 factor factorial experiment in CRD with Gen Stat 10th Release Version Statistical Software. Means were separated by Fisher's Least Significant Difference (F-LSD) at 5% level of probability. Before analysis, data on gall and egg mass counts were transformed using square root transformation ($\sqrt{x + 0.50}$) as there were zero counts.

Results

The results of the physicochemical properties analysis of the soil used for the trial showed that the soil was loamy-sand in texture, strongly acidic (pH = 5.80), electrical conductivity of the extract (ECe) = 0.13 ds/m, low in total N, exchangeable cations, ECEC, medium in available P (24.63 mg/kg) and with a very high base saturation. The results of the effects of arbuscular mycorrhizal (AMF) inoculation on gall index per root system of pepper inoculated with *Meloidogyne incognita* and exposed to different levels of salinity are presented in Table 1. Mycorrhizal inoculation significantly ($P<0.05$) reduced the severity of galling compared with the non-mycorrhizal plants. However, among the AMF species, *G.deserticola* had the lowest gall rating followed by *G. mosseae*. Successive increase in salinity level significantly ($P\leq 0.05$) reduced the gall ratings. Nematode inoculation significantly ($P\leq 0.05$) increased gall rating compared with the uninoculated plants. Interaction between mycorrhiza and salinity was significant ($P<0.05$). For the non-mycorrhizal plants, application of salt significantly reduced gall rating compared with the non-saline water treatment. However, there were no significant ($P>0.05$) differences among the salinity levels with *G. mosseae* inoculation. For *G. deserticola*, the highest salt level significantly reduced gall index relative to other salt levels. The interaction between mycorrhiza and nematode was significant. In both mycorrhizal and non-mycorrhizal plants, *M. incognita* inoculation caused a significant increase in gall rating. Mycorrhizal inoculated plants at salinity level of 0.08 ds/m in the presence of *M. incognita* had lower gall ratings compared with the non-mycorrhizal plants. At 4.00 ds/m salinity level, with *M. incoginta* inoculation, *G. deserticola* inoculated plants had the lowest gall index of 3.00.

The results of the effects of AMF inoculation on egg mass production by *M. incognita* on pepper exposed to different levels of salinity are presented in Table 2. Mycorrhizal inoculation significantly ($P< 0.05$) inhibited egg mass production by the nematode species compared with the non-mycorrhizal plant. *G.deserticola* inoculated plants had significantly the lowest number of egg masses in their roots. Successive increase in salt concentration significantly inhibited egg mass production.

The interaction among the three factors was significant (P≤0.05). Generally, inoculation of pepper plants with AMF significantly reduced egg mass production by *M. incognita* compared with the non-mycorrhizal plants. In both mycorrhizal and non-mycorrhizal plants, increase in salinity level in the presence of *M.incognita* significantly reduced egg mass production. The lowest number of egg mass was observed in plants irrigated with 4.00 ds/m saline water and inoculated with *G. deserticola* in the presence of *M. incognita* infection. This was closely followed by *G. mosseae* inoculated plants.

The results of the effects of arbuscular mycorrhizal fungi (AMF) inoculation on fresh root weight of pepper inoculated with *Meloidogyne incognita* and exposed to different levels of salinity are presented in Table 3. Mycorrhizal inoculation significantly (p≤0.05) enhanced fresh root weight relative to the non-mycorrhizal plants. However, among the AMF species, *G. deserticola* produced plants with the highest fresh root weight followed by *G. mosseae.* Successive increase in salinity level significantly (p≤0.05) reduced fresh root weight. Nematode inoculation significantly (p≤0.05) reduced fresh root weight compared with the uninoculated. The interaction between mycorrhiza and salinity was significant (p≤0.05). In both mycorrhizal and non-mycorrhizal plants, increase in salinity level caused a significant decrease in fresh root weight. Similarly, interactions between mycorrhiza and nematode as well as between salinity and nematode were significant (p≤0.05). In both mycorrhizal inoculated and uninoculated plants, *M. incognita* inoculation caused a significant reduction in fresh root weight. Also, at all levels of salinity, inoculation of pepper seedlings with *M. incognita* reduced fresh root weight compared with the uninoculated control. The interaction among mycorrhiza, salinity and nematode was significant (p≤0.05). Relative to the non-mycorrhizal plants, plants inoculated with AMF at all salinity levels and with *M. incognita* inoculation had significantly (p≤0.05) higher root fresh weight except for *G. gigantea* at 2.00ds/m salt level. However, among the AMF species, *G. deserticola* inoculated plants had significantly (p≤0.05) the greatest fresh root weight at all salinity levels in the presence of *M. incognita* and followed by *G. mosseae*.

The result of the effects of arbuscular mycorrhizal fungi (AMF) inoculation on number of leaves per plant at seven (7) weeks after transplanting of pepper inoculated with *Meloidogyne incognita* and exposed to different levels of salinity are presented in Table 4. Mycorrhizal inoculation significantly ($p \leq 0.05$) increased number of leaves relative to the non-mycorrhizal plants. However, among the AMF species, *G. deserticola* produced plants with the highest number of leaves followed by *Glomus mosseae.* Successive increase in salinity level significantly ($p \leq 0.05$) reduced leaf production in pepper. Inoculation with *M. incognita* significantly ($p \leq 0.05$) reduced the number of leaves compared with the uninoculated. The interaction between mycorrhiza and salinity as well as between salinity and nematode were not significant. The interaction between mycorrhiza and nematode was significant ($p \leq 0.05$). In both mycorrhizal inoculated and uninoculated plants, *M. incognita* inoculation caused a significant reduction in the number of leaves. The interaction among mycorrhiza, salinity and nematode was not significant. However, leaf production was enhanced with mycorrhizal inoculation at all salt levels compared with the non-mycorrhizal plants with root knot nematode infection.

The results of the effect of arbuscular mycorrhizal fungi (AMF) inoculation on plant height at seven (7) weeks after transplanting of pepper inoculated with *Meloidogyne incognita* and exposed to different levels of salinity are presented in Table 5. Mycorrhizal inoculation significantly ($p \leq 0.05$) increased plant height in relation to the non-mycorrhizal plants. However, among the AMF species, *G. deserticola* produced the tallest plants, followed by *G. mosseae.* Successive increase in salinlity level significantly ($p < 0.05$) reduced plant growth. Inoculation of *M. incognita* significantly ($p < 0.05$) reduced plant height compared with the uninoculated. The interaction between mycorrhiza and salinity was significant ($p < 0.05$). In both mycorrhizal and non-mycorrhizal plants, increase in salinity level caused a significant decrease in plant height. Similarly, interactions between mycorrhiza and nematode as well as between salinity and nematode were significant ($p \leq 0.05$). In both mycorrhizal inoculated and uninoculated plants, *M. incognita* inoculation caused a significant reduction in plant height. Also, at all levels of salinity, inoculation of pepper seedlings with *M. incognita* caused a decrease in plant height. The interaction among mycorrhiza, salinity and nematode was significant ($p \leq 0.05$). Relative to the non-mycorrhizal plants, plants inoculated with AMF at all salinity levels and with *M. incognita* inoculation had significantly ($p < 0.05$) taller plants. However, among the AMF species, *G. deserticola* inoculated plants had significantly

($p<0.05$) the tallest plants at all salinity levels in the presence of *M. incognita.* This was followed by *G. mosseae.*

The results of the effect of arbuscular mycorrhizal fungi (AMF) inoculation on shoot dry weight of pepper inoculated with *M. incognita* and exposed to different levels of salinity are presented in Table 6. Mycorrhizal inoculation significantly ($p \leq 0.05$) enhanced shoot dry matter accumulation relative to the non-mycorrhizal plants. However, among the AMF species, *G. deserticola* produced plants with the highest shoot dry weight followed by *G. mosseae*. Successive increase in salinity level significantly ($p \leq 0.05$) reduced shoot dry weight. Nematode inoculation significantly ($p \leq 0.05$) reduced shoot dry matter compared with the uninoculated. The interaction between mycorrhiza and salinity was significant ($p \leq 0.05$). In both mycorrhizal and non-mycorrhizal plants, increase in salinity level caused a significant decrease in dry matter content of shoot. Similarly, interactions between salinity and nematode as well as between mycorrhiza and nematode were significant. At all levels of salinity, inoculation of pepper seedlings with *M. incognita* reduced shoot dry weight compared with the uninoculated control. Also, in both mycorrhizal inoculated and uninoculated plants, *M. incognita* inoculation caused a significant reduction in shoot dry matter accumulation. The interaction among mycorrhiza, salinity and nematode was significant ($p \leq 0.05$). Relative to the non-mycorrhizal plants, plants inoculated with AMF at all salinity levels and with *M. incognita* inoculation had significantly ($p \leq 0.05$) higher shoot dry matter content. However, among the AMF species, *G. deserticola* inoculated plants had significantly ($p \leq 0.05$) the greatest shoot dry weight at all salinity levels in the presence of *M. incognita.* This was followed by *G. mosseae.*

Table 1: Effects of AMF and salinity on gall index/root system of pepper inoculated with *M. incognita*

Mycorrhizal fungus		**Salinity Level (ds/m)**						**MN**	**N**	**M**
	M. incognita	*****S_O**	**S_O x N**	**S_1**	**S_1 x N**	**S_2**	**S_2 x N**			
M_O*	N_0**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.17
	N_1	5.00	4.33	4.00	4.00	4.00	3.75	4.33	4.03	
(M_O x S)		2.50		2.00		2.00				
M_1	N_0	0.00		0.00		0.00		0.00		2.00
	N_1	4.00		4.00		4.00		4.00		
(M_1 x S)		2.00		2.00		2.00				
M_2	N_0	0.00		0.00		0.00		0.00		1.83
	N_1	4.00		4.00		3.00		3.67		
(M_2 x S)		2.00		2.00		1.50				
M_3	N_0	0.00		0.00		0.00		0.00		2.06
	N_1	4.33		4.00		4.00		4.11		
(M_3 xS)		2.17		2.00		2.00				
S-mean		2.17		2.00		1.88				

*M_0 = control; M_1 = *G. mosseae*; M_2 = *G. deserticola*; M_3 = *G. giganteae*

**N_0 = uninoculated control; N_1 = nematode inoculated

***S_0 = 0.08ds/m; S_1 = 2.00ds/m; S_2 = 4.00ds/m

LSD(0.05) Mycorrhiza means(M) = 0.08
LSD(0.05) for salinity means(S)=0.07
LSD(0.05) for nematode means(N)=0.06
LSD(0.05) for (MxS) interaction means=0.14
LSD(0.05)for MxN) interaction means=0.11
LSD(0.05)for (SxN) interaction means=0.10
LSD(0.05)for(MxSxN) interaction means=0.19

Table 2: Effects of AMF and salinity on the number of egg masses/root system of pepper inoculated with *M. incognita*

Mycorrhizal fungus	*M. incognita*	Salinity Level (ds/m) ***S_O	S_O x N	S_1	S_1 x N	S_2	S_2 x N	MN	N	M
M_O*	N_0**	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	4.16
	N_1	9.33	7.49	7.15	5.97	6.34	4.65	7.61	6.04	
(M_O x S)		5.02		3.93		3.52				
M_1	N_0	0.71		0.71		0.71		0.71		3.03
	N_1	7.30		5.37		3.38		5.35		
(M_1 x S)		4.00		3.04		2.05				
M_2	N_0	0.71		0.71		0.71		0.71		2.58
	N_1	5.55		4.74		3.08		4.46		
(M_2 x S)		3.13		2.73		1.09				
M_3	N_0	0.71		0.71		0.71		0.71		3.72
	N_1	7.80		6.60		5.82		6.74		
(M_3 x S)		4.25		3.65		3.26				
S-mean		4.10		3.34		2.68				

*M_0 = control; M_1 = *G. mosseae*; M_2 = *G. deserticola*; M_3 = *G. giganteae*

**N_0 = uninoculated control; N_1 = nematode inoculated

***S_0 = 0.08ds/m; S_1 = 2.00ds/m; S_2 = 4.00ds/m

LSD(0.05) Mycorrhiza means(M) = 0.11
LSD(0.05) for salinity means(S)=0.09
LSD(0.05) for nematode means(N)=0.04
LSD(0.05) for (MxS) interaction means=0.10
LSD(0.05)for MxN) interaction means=0.09
LSD(0.05)for (SxN) interaction means=0.07
LSD(0.05)for(MxSxN) interaction means=0.15

Table 3: Effects of AMF and salinity on the fresh root weight (g/plant) of pepper inoculated with *M. incognita*

Mycorrhizal fungus		Salinity Level (ds/m)						MN	N	M
	M. incognita	$***S_O$	S_O x N	S_1	S_1 x N	S_2	S_2 x N			
M_O*	N_0**	2.73	3.08	1.54	1.98	0.89	1.19	1.72	2.08	1.37
	N_1	1.31	2.08	0.99	1.41	0.74	0.98	1.01	1.49	
(M_O x S)		2.02		1.27		0.81				
M_1	N_0	3.02		1.94		1.09		2.02		1.76
	N_1	2.08		1.42		0.98		1.49		
(M_1 x S)		2.55		1.68		1.04				
M_2	N_0	4.00		3.07		1.71		2.93		2.53
	N_1	3.11		2.10		1.16		2.12		
(M_2 x S)		3.56		2.59		1.43				
M_3	N_0	2.57		1.36		1.06		1.66		1.41
	N_1	1.84		1.14		1.02		1.33		
(M_3 x S)		2.21		1.25		1.04				
S-mean		2.58		1.61		1.08				

*M_0 = control　**N_0 = uninoculated control　***S_0 = 0.08ds/m　LSD(0.05) Mycorrhiza means(M) = 0.09
M_1 = *G. mosseae*　N_1 = nematode inoculated　S_1 = 2.00ds/m　(0.05) for salinity means(S)=0.08
M_2 = *G. deserticola*　S_2 = 4.00ds/m　LSD(0.05) for nematode means(N)=0.06
M_3 = *G. giganteae*　LSD(0.05) for (MxS) interaction means=0.16
LSD(0.05)for MxN) interaction means=0.13
LSD(0.05)for (SxN) interaction means=0.11
LSD(0.05)for(MxSxN) interaction means=0.22

Table 4: Effects of AMF and salinity on number of leaves/plant at seven weeks after transplanting of pepper inoculated with *M. incognita*

Mycorrhizal fungus	*M. incognita*	Salinity Level (ds/m)						MN	N	M
		***S_O	S_O x N	S_1	S_1 x N	S_2	S_2 x N			
M_O*	N_0**	22.33	28.92	19.33	25.50	16.67	22.92	19.44	25.78	18.50
	N_1	19.67	25.17	18.33	22.42	14.67	19.42	17.56	22.33	
(M_O x S)		21.00		18.83		15.67				
M_1	N_0	30.33		26.33		23.67		26.78		24.78
	N_1	26.00		22.33		20.00		22.78		
(M_1 x S)		28.17		24.33		21.83				
M_2	N_0	35.33		32.00		29.67		32.33		29.83
	N_1	31.00		27.33		23.67		27.33		
(M_2 x S)		33.17		29.67		26.67				
M_3	N_0	27.67		24.33		21.67		24.56		23.11
	N_1	24.00		21.67		19.33		21.67		
(M_3 xS)		25.83		23.00		20.50				
S-mean		27.04		23.96		21.17				

*M_0 = control **N_0 = uninoculated control ***S_0 = 0.08ds/m LSD(0.05) Mycorrhiza means(M) = 0.69
M_1 = *G. mosseae* N_1 = nematode inoculated S_1 = 2.00ds/m LSD(0.05) for salinity means(S)=0.51
M_2 = *G. deserticola* S_2 = 4.00ds/m LSD(0.05) for nematode means(N)=0.49
M_3 = *G. giganteae* LSD(0.05) for (MxS) interaction means=NS
LSD(0.05)for MxN) interaction means=0.97
LSD(0.05)for (SxN) interaction means=NS
LSD(0.05)for(MxSxN) interaction means=NS

Table 5: Effects of AMF and salinity on plant height at seven weeks after transplanting of pepper inoculated with *M. incognita*

Mycorrhizal fungus		Salinity Level (ds/m)						MN	N	M
	M. incognita	*****S_O**	**S_O x N**	**S_1**	**S_1 x N**	**S_2**	**S_2 x N**			
M_O*	N_0**	26.93	33.83	23.37	27.30	19.43	22.55	23.24	27.89	19.31
	N_1	18.37	26.35	15.10	22.50	12.67	18.37	15.38	22.41	
(M_O x S)		22.65		19.23		16.05				
M_1	N_0	34.83		26.17		22.27		27.76		25.25
	N_1	27.07		22.67		18.50		22.74		
(M_1 x S)		30.95		24.42		20.38				
M_2	N_0	45.20		36.00		28.83		36.68		33.76
	N_1	35.50		31.73		25.27		30.83		
(M_2 x S)		40.35		33.87		27.05				
M_3	N_0	28.37		23.67		19.67		23.90		22.28
	N_1	24.47		20.50		17.03		20.67		
(M_3 x S)		26.42		22.08		18.35				
S-mean		30.09		24.90		20.46				

*M_0 = control **N_0 = uninoculated control ***S_0 = 0.08ds/m LSD(0.05) Mycorrhiza means(M) = 0.75
M_1 = *G. mosseae* N_1 = nematode inoculated S_1 = 2.00ds/m LSD(0.05) for salinity means(S)=0.65
M_2 = *G. deserticola* S_2 = 4.00ds/m LSD(0.05) for nematode means(N)=0.53
M_3 = *G. giganteae* LSD(0.05) for (MxS) interaction means=1.21
LSD(0.05)for MxN) interaction means=1.06
LSD(0.05)for (SxN) interaction means=0.92
LSD(0.05)for(MxSxN) interaction means=1.83

Table 6: Effects of AMF and salinity on the shoot dry weight of pepper inoculated with *M. incognita*

Mycorrhizal fungus				Salinity Level (ds/m)				MN	N	M
	M. incognita	*****S_O**	**S_O x N**	**S_1**	**S_1 x N**	**S_2**	**S_2 x N**			
M_O*	N_0**	1.16	2.48	1.05	2.01	0.96	1.61	1.06	2.04	0.95
	N_1	0.96	1.87	0.90	1.61	0.68	1.21	0.85	1.62	
(M_O x S)		1.06		0.98		0.82				
M_1	N_0	2.27		2.03		1.81		2.04		1.81
	N_1	1.97		1.84		1.46		1.75		
(M_1 x S)		2.12		1.94		1.63				
M_2	N_0	4.47		3.08		2.62		2.39		3.04
	N_1	3.15		2.89		2.02		2.69		
(M_2 x S)		3.81		2.99		2.32				
M_3	N_0	2.04		1.89		1.05		1.66		1.43
	N_1	1.41		1.15		1.03		1.11		
(M_3 x S)		1.72		1.52		1.04				
S-mean		2.18		1.86		1.45				

*M_0 = control; **N_0 = uninoculated control; ***S_0 = 0.08ds/m; LSD(0.05) Mycorrhiza means(M) = 0.06

M_1 = *G. mosseae*; N_1 = nematode inoculated; S_1 = 2.00ds/m; LSD(0.05) for salinity means(S)=0.05

M_2 = *G. deserticola*; S_2 = 4.00ds/m; LSD(0.05) for nematode means(N)=0.04

M_3 = *G. giganteae*; LSD(0.05) for (MxS) interaction means=0.10

LSD(0.05)for MxN) interaction means=0.09

LSD(0.05)for (SxN) interaction means=0.07

LSD(0.05)for(MxSxN) interaction means=0.15

Discussion

Evidence from this study showed that salinity significantly reduced plant height, fresh root weight, shoot dry weight and number of leaves in pepper. These findings are in agreement with Abdel Latef and Chaoxing (2011), who reported that salinity stress significantly reduced the root, stem and leaf dry matter and leaf area of tomato compared with the control treatment. They attributed these to direct effects of ion toxicity or indirect effects of saline ions that cause soil/plant osmotic imbalance. Salinity reduces the growth and development of plants (Giri and Mukerji, 2004; Kaya *et al*., 2009). Salinity also affected nematode activities. Root galling was reduced at higher salt level. This could be due to the reduction of growth and development of the host plant which leads to failure of host tissue to keep pace with the nutritive demands of the nematode (Mote, 1988).

It was observed that where there was nematode inoculation, higher level of salt reduced nematode activities. Increase in salinity reduced the number of galls. This finding corroborates the report of Edongali and Ferris (1982) that increase in salinity decreased *M. incognita* reproduction and root galling in susceptible varieties of tomato. High levels of salinity suppressed root colonization by arbuscular mycorrhiza fungi. This is in agreement with the reports by several researchers (Hirrel, 1981; Juniper and Abbot,2006; Jahromi *et al*., 2008). They reported the negative effect of salinity stating that colonization capacity, spore germination and growth of hyphae of the fungus were impeded.

Inoculation of pepper seedlings with arbuscular mycorrhizal fungi (AMF) significantly reduced the effect of salts. This was obvious with the fact that the pepper plants inoculated with AMF had higher fresh root weight, shoot dry weight and were taller. This conforms to the report of several researchers who reported that AMF inoculated plants grew better than non-inoculated plants under salt stress. They stated that plants growth and biomass suffered a setback under salt stress suggesting that reasons may be the non-availability of nutrients and the expenditure of energy to counteract the toxic effects of NaCl (Al-karaki, 2000; Giri and Mukerji., 2004).

Inoculation of pepper seedlings with AMF reduced galling. This agrees with Borowicz (2001) findings where he listed various studies where a decrease in reproduction of sedentary nematodes occurred in the presence of AMF, suggesting that this reduction was due to physiological changes induced by the fungus in the root system. This could modify the attractiveness of the roots or induce a physical or chemical barrier, impairing nematode penetration. The reduction in number of galls observed on roots of the seedlings could be due to competition between the pathogen and the symbiont for infection sites, but other factors such as increase of lignin and phenols could be involved (Umesh *et al*., 1988). Zhang *et al*. (2009) recorded lower quantity of galls and egg masses in mycorrhizal cucumber plants than in non-mycorrhizal plants. This could be as a result of the reduction in the ability of the nematode to penetrate the root or of the presence of the AMF affecting the formation of giant cells and further development of the nematodes (Odeyemi *et al*., 2010, Flor-Peregrin *et al*., 2014)

However, among the AMF species, *G. deserticola* was the most effective in reducing root knot nematode infection and alleviation of salt stress in pepper plants. There are various reports on the variation in the efficacy of different AMF in nematode control and salinity amelioration (Udo *et al*., 2013). Generally, this trial has illustrated the possibility of managing the abiotic stress factor induced by salinity and the biotic factor caused by *M. incognita* on pepper production with the symbiont arbuscular mycorrhizal fungus.

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A SUSTAINABLE METHOD OF AMELIORATING DROUGHT STRESS IN CROP PRODUCTION

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ABSTRACT

Drought reduces agricultural productivity by 70-90% depending on the intensity. In this study, the ability of organic amendments in ameliorating stress on cowpea exposed to different water regimes (100, 50 and 0% field capacity) in response to different rates (0, 10 and 15t/ha) of compost was investigated. Compost was applied as single and double dose(s) at different times (two weeks before and after planting of cowpea seeds) during one cropping season. The results showed that though water stress adversely affected cowpea fresh and dry weights, compost application increased the growth and yield parameters of cowpea. Variations were also observed based on time of compost application with application before planting and repeated application (Two weeks Before and After planting) performing better than application after planting. Cowpea dry matter yields were increased by 98, 110, 153 and 223 % in C1B+C1A, C1B + C2A, C2B +C1A and C2B +C2A compared with control ($P<0.05$). Chlorophyll, Carotenoid content and Stomata density of Cowpea under water stress were also enhanced compared with control ($P <0.05$). Application of compost both before and after planting therefore enhanced cowpea growth and yield under water stress.

INTRODUCTION

Abiotic stresses on crops pose serious threats to food security because it causes significant yield loss. These include drought, salinity, excessive light and heat, heavy metal contamination etc. The most prominent of these is drought. It is estimated that 10 billion people in the world will be hungry and malnourished by the end of this century because of drought (AATF, 2012). The research focus must therefore be channelled towards enhancing the survival of plants during the period of drought.

Though drought stress reduces the ability of plants to absorb nutrients due to low solubility the adverse effect of drought on plant is reduced in well nourished soil (Singh and Singh, 2004). The physiological responses of plants to water stress is said to depend on soil nutrient supply/availability and interaction occurring at the root soil interface (Guiterrez-Boem & Thomas, 1999). This is because plant grown on fertile soil will have enough nutrients in its tissue to adjust its osmotic status in the time of drought. Highly concentrated solute in plant tissue will increase the osmotic potential and the ability of such plant to draw water from its surrounding environment. It is well documented that essential plant nutrients regulate plant metabolism even in the plants exposed to stress by acting as cofactor or enzymes activators (Nicolas, 1975). Higher concentration of nutrients in plants also gives the plant a temporary succour by maintaining the turgidity under stress or at low water potential (Morgan and Condon 1986).

Unlike inorganic fertilizer, organic amendment is environment-friendly and has high water retention capacity which could be an added advantage in the period of drought (Sahs and Lesoing 1985; Atiyeh *et al*., 2002). For instance, compost made from plant residues most especially Mexican sunflower when applied on land increases soil organic matter and supplies plant nutrients (Akanbi and Togun, 2002; Abou El-Magd *et al*., 2006; Adejumo et al., 2011). The application of humic substances has been shown to ameliorate the effect of water stress in crop by increasing antioxidant and phyto-hormonal activities of the organically fertilized crop (Xu, 2000). Sahs and Lesoing, (1985) also reported that organically fertilized crops performed better than inorganically fertilized crop under drought stress condition. Plant's tolerance to water stress has been reportedly enhanced in response to organic amendment through increase in soil water holding capacity (Zhang and Ervin, 2004). This was attributed to increase in soil-water tension as a result of binding of soil micro-aggregates by humic acid in organic amendments (Elsharawy *et al*., 2003; Newman *et al*., 2005). However, it has been reported that the effectiveness of organic amendment is dose-dependent (Akanbi and Togun, 2002; Adejumo *et al*., 2010). The time of application and effect of repeated application (Double doses) on the performance of compost most especially under stress have not been well focused. This study was therefore carried out to assess the effect of different rates and time of application as well as repetition of compost application on the physiology, growth and yield of cowpea under water stress conditions. It was hypothesized that the use of compost will ameliorate the effects of drought and help in increasing cowpea production under stress while increasing soil fertility.

Materials and methods

The experiment was conducted in a Greenhouse at the Department of Crop Protection and Environmental Biology, University of Ibadan, Ibadan, Nigeria. A total of 108 pots were used, and 5kg soil was weighed into each pot. Compost used for the experiment was prepared from Mexican sunflower and poultry manure in ratio 3:1 using PACT method (Adejumo *et al*., 2011). Treatments include, different rates of compost (0, 10 t/ha and 15t/ha) designated as CO, C1 and C2 respectively. Application of compost was done two weeks before planting (CB) and after planting (CA) as well as double application of compost before and after planting (CB + CA). The pots were laid out in a Completely Randomised Design with 3 replicates. At 6WAP the plants were subjected to the following watering regimes for two weeks; W_1 → Watering to field capacity every other day ; W_2→ Watering to 50% field capacity every other day W_3→ Watering to 25% field capacity every other day; W_4→ No watering

Data collection

Data were collected on plant growth and yield parameters, stomata density, carotenoid and Chlorophyll contents. Chlorophyll contents were obtained using the method described by Sarropoulou *et al.,* (2012) and the total chlorophyll contents were estimated from this equation.

Chlorophyll (a+b)= $(6.10\times A_{665}+20.04\times A_{649})\times 15\div 1000/FW$(mg/g FW)

The absorption peak of Carotenoid was measured at 440nm, Carotenoid were estimated using this equation. $(4.69\times A_{440}-1.96\times A_{665}-4.47\times A_{649})\times 15\times 0.1$

At harvesting, dry matter yield were determined.

Statistical analysis

Statistical analysis of the data collected was carried using analysis of variance (ANOVA) while Least Significant Difference (LSD) was used to separate the means.

RESULTS

Effect of different rates and time of compost application on vegetative parameters under water stress

Effect of water stress was significant on leaf area production. Compost application both before and after planting performed better than control. Repeated application before and after planting also enhanced Cowpea leaf area production more than other compost treatments. Cowpea plant treated with C2B+C2A under 100% FC had the highest mean leaf area while treatments with 0%FC had the lowest mean. At 8WAP, there was reduction in the leaf area in all the treatments under water stress (Table 1). Similar trend was observed for the number of leaf. (Table 2).

Effect of different rates and time of compost application on fresh weight and dry matter accumulation/partitioning of cowpea under water stress

Water stress adversely affected cowpea fresh weight. Treatment with 100%FC and with the two rates of compost recorded highest value while treatments with 0%FC recorded the lowest value (Fig 1). The dry matter accumulation in the stressed plants were also reduced compared to those grown under 100% field capacity. Application of compost however increased dry matter accumulation in compost treated cowpea under water stress compared to control. Though, there was no significant difference between treatments C1B+C2A and C2B+C1A when compared with each other but they outperformed other compost treatments. Significant difference was observed in the dry matter accumulation of cowpea that received compost before planting compared to those that received compost after planting with higher rate being superior (Fig 2).

TABLE 1. Effect of different rates and time of compost application on Leaf area (cm^2) under water stress at 4WAP and 8WAP

TRTS	4WAP	8WAP	4WAP	8WAP	4WAP	8WAP	4WAP	8WAP
	100%FC		50%FC		25%FC		0%FC	
C0	30.9	43.4	30.2	42.2	31.1	35.0	30.5	32.4
C1B	40.4	48.9	40.9	47.2	39.8	41.9	40.1	45.4
C2B	63.1	66.9	62.7	64.6	60.3	61.1	60.3	58.3
C1A	39.6	48.4	40.2	45.3	39.7	41.7	40.2	37.1
C2A	40.6	49.5	40.8	45.4	40.3	42.0	40.9	49.2
. B+C1A	54.4	60.5	53.7	57.5	50.3	54.1	49.5	50.9
C1B+C2A	57.6	66.5	57.3	65.4	56.6	62.5	55.1	55.0
C2B+C1A	70.2	76.8	69.5	74.3	68.1	66.1	67.2	62.7
C2B+C2A	74.8	79.1	75.1	76.4	74.3	71.7	73.3	67.0
LSD	0.86	0.65	0.99	1.15	0.44	1.37	0.32	1.34

C1 and C2 = Compost rate 1 and 2. B= before planting, A = After planting. C0 = Control. Different watering regimes; 100, 50, 25 and 0 Field capacity

TABLE 2: Effect of different rates and time of compost application on number of leaf under water stress at 4WAP and 8WAP

TRTS	4WAP	8WAP	4WAP	8WAP	4WAP	8WAP	4WAP	8WAP
	100%FC		50%FC		25%FC		0%FC	
CO	3.2	3.0	3.0	3.0	3.2	2.7	3.0	2.0
C1B	3.3	3.7	3.3	3.5	3.3	2.8	3.3	2.5
C2B	4.7	4.7	4.7	4.7	4.7	4.2	4.7	3.5
C1A	3.3	3.3	3.7	3.2	3.3	2.7	3.7	2.8
C2A	3.3	3.3	4.2	4.2	3.3	3.0	4.0	2.3
C1B+ C1A	3.5	3.5	3.8	3.2	3.7	3.0	4.0	2.5
C1B+ C2A	3.8	4.2	4.0	4.0	3.8	3.3	3.7	3.2
C2B+ C1A	4.5	4.7	4.3	4.3	4.8	4.0	4.0	3.7
C2B+ C2A	5.3	5.3	5.2	5.2	5.0	4.8	4.8	4.3
LSD	0.25	0.21	0.28	0.27	0.32	0.24	0.32	0.22

C1 and C2 = Compost rate 1 and 2. B= before planting, A = After planting. C0 = Control. Different watering regimes; 100, 50, 25 and 0 Field capacity

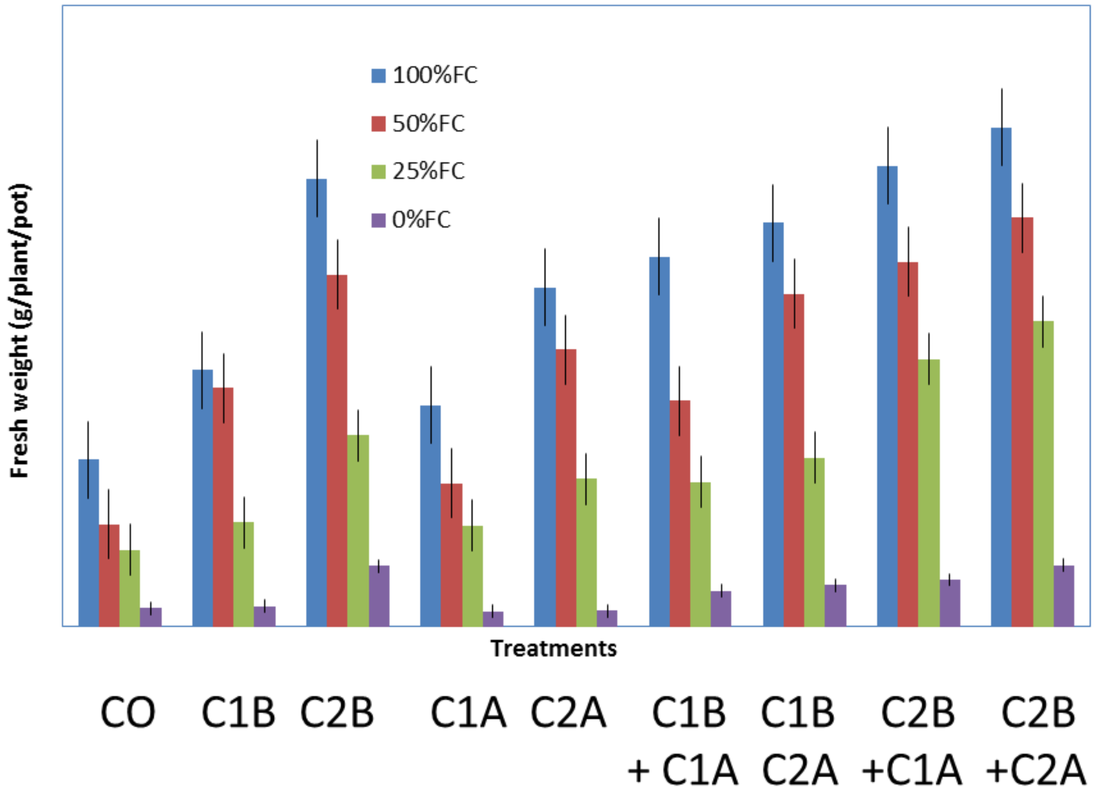

Fig 1. Effect of different rates and time of compost application on dry weight (g) accumulation of Cowpea under water stress.
C1 and C2 = Compost rate 1 and 2. B= before planting, A = After planting. C0 = Control. Different watering regimes; 100, 50, 25 and 0 Field capacity

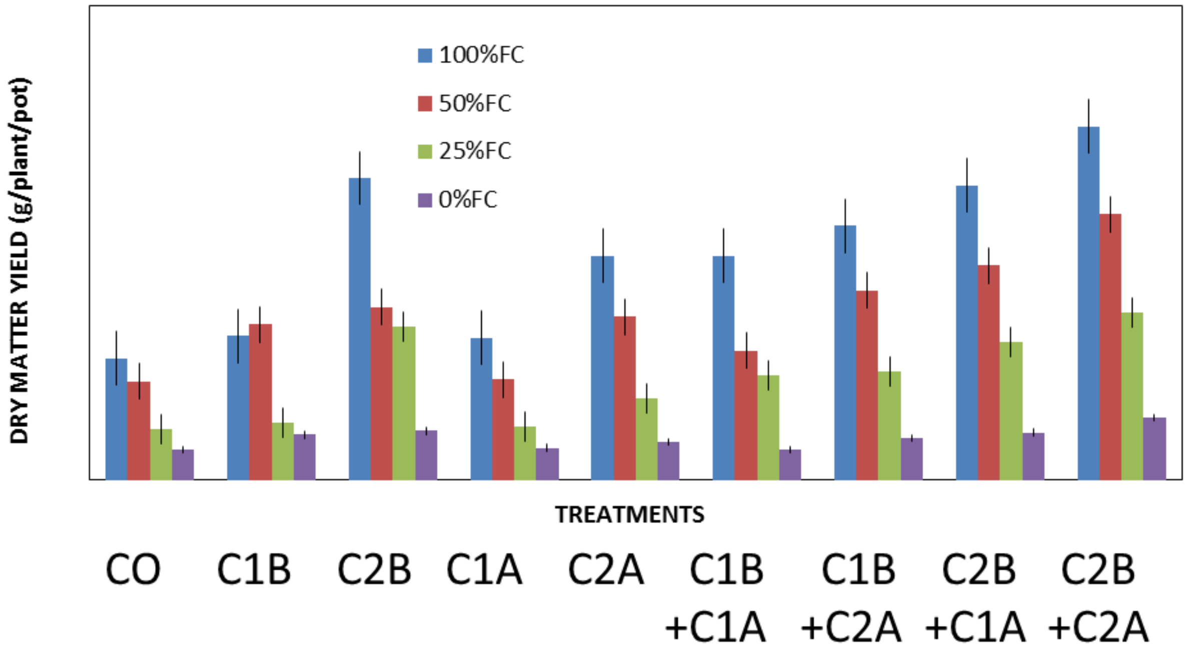

Fig 2. Effect of different rates and time of compost application on fresh weight (g) of Cowpea under water stress.

C1 and C2 = Compost rate 1 and 2. B= before planting, A = After planting. C0 = Control. Different watering regimes; 100, 50, 25 and 0 Field capacity

Effect of different rates and time of compost application on Chlorophyll, Carotenoid content and Stomata density of Cowpea under water stress

Cowpea plant grown on soil amended with higher rate of compost both before and after planting (C2B+C2A) had the highest chlorophyll content while control, C1A, and C2A recorded the lowest chlorophyll content and were not significantly different from control. For Carotenoid, as observed for chlorophyll, there were significant differences among the treatments. Compost amendments also increased carotenoid contents of cowpea leaf. Double application of higher rate of compost before and after planting also performed better than other compost treatments while the lowest value was recorded in the control. Treatment with C2B+C2A however had the highest carotenoid content compared to its counterparts. Those that received compost after planting (C1A, and C2A) recorded the lowest value compared to those that received compost before planting. The stomata density was also affected by compost application. Though compost treatments almost had equal amount of stomata but C2B+C2A, C2B+C1A, C1B+C2A recorded the highest level of stomata density and they were all better than control which had the lowest (Fig 3).

DISCUSSION

Water stress generally decreased biomass accumulation as a result of reduction in nutrient and water uptake by plant (Singh and Singh, 2004). This in turn affects different physiological processes most especially photosynthesis where water serves as one of the reactants. The reduction in leaf area and leaf number which was observed in all the water stressed treatments at 8WAP.agreed with the finding of Summerfield *et al* (1979) that stress during vegetative stage irreversibly reduced leaf area and leaf number thereby causing significant yield loss. However, the ability of compost to supply the required nutrients for plants growth at any rate made the compost treated cowpea to perform better than the control (Akanbi and Togun, 2002; Premsekhar and Rajashree, 2009; Adejumo *et al.,* 2011). Availability of nutrients in the growing medium has also been reported to enhance nitrogen fixation capability

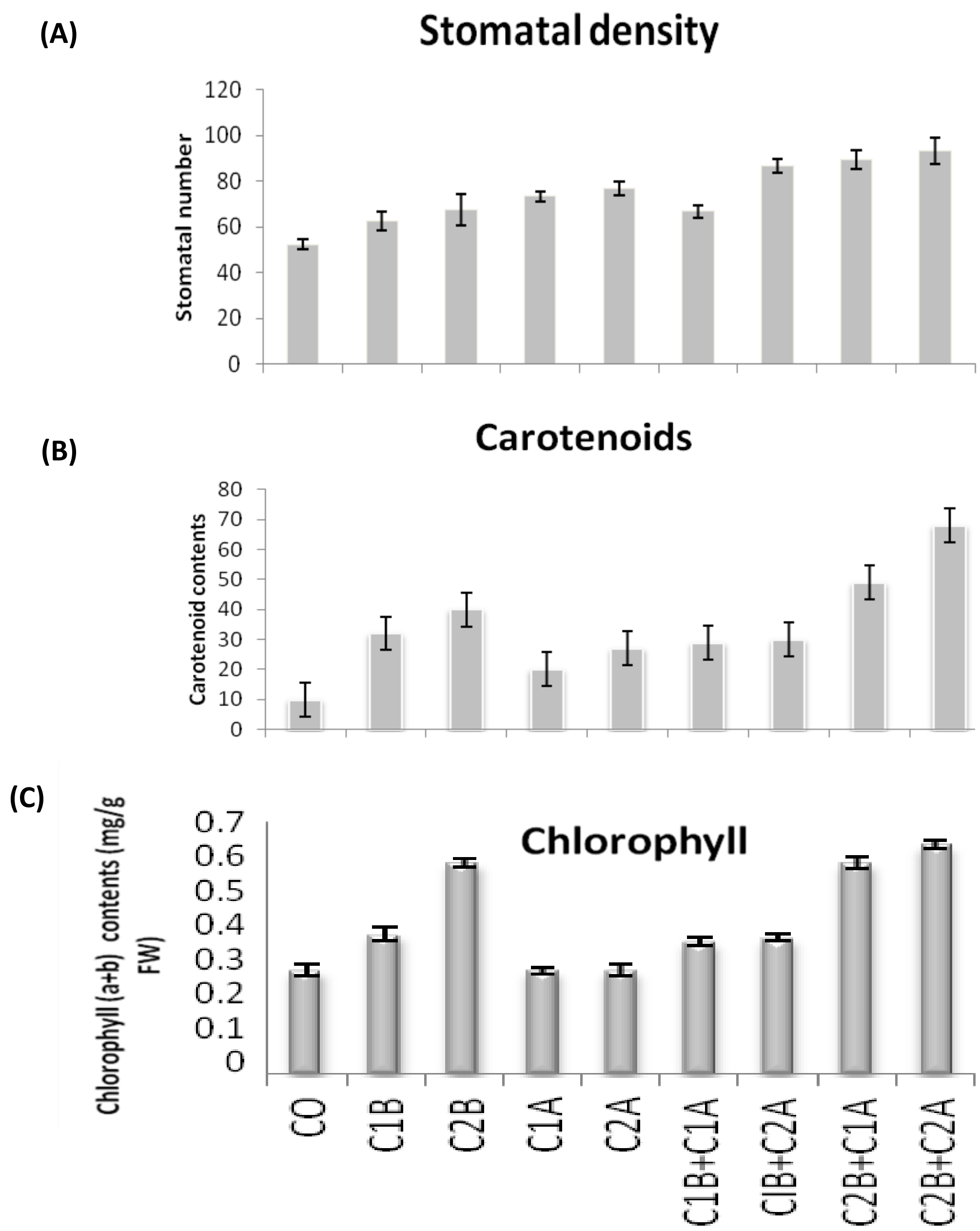

Fig 3: Effect of different rates and time of compost application on (A) stomatal density, (B) carotenoid and (C) chlorophyll contents of Cowpea under water stress

; C1 and C2 = Compost rate 1 and 2. B= before planting, A = After planting. C0 = Control. Different watering regimes; 100, 50, 25 and 0 Field capacity of cowpea (Hafner *et al*.,1992) which in turn would have contributed to yield

Application of compost before and after planting most especially, C2B+C2A increased the dry matter accumulation in cowpea more than other compost treatments. Similarly, soil that received higher rate of compost was able to supply enough nutrients to crop compared to the lower rate.. Though previous reports had it that compost or organic amendments generally last longer in the soil more than inorganic fertilizers that are proned to leaching (Adediran *et al*., 2004), but repeated application of compost (both before and after planting) ensured continuous supply of nutrients to crop thereby making room for the replacement of nutrients that might have leached out.

Different rates and time of compost application also had significant effect on Chlorophyll and Carotenoid contents of Cowpea compared to control. This could also be attributed to the availability of major nutrients most especially Mg and Fe which are the major constituents of photosynthetic pigments. Increase in chlorophyll and carotenoid contents in plants enhanced light trapping and increased photosynthesis (Moore *et al*., 2003). Nutrients availability also enhances the activity of most metabolic enzymes most especially, those enzymes that use different metals as cofactors. It has also been reported that organic amendment increases soil phosphorus content and plant available phosphorus which are considered as limiting nutrients in cowpea production (Eghball *et al*., 2004). This in-turn will increase the physiological processes and consequently increase dry matter production. Xu (2000), also reported higher photosynthetic rates in maize grown on organically treated soil.

The stomata density was also affected by compost application with C2B+C2A, C2B+C1A, C1B+C2A giving the highest number of stomata. The effect of all these culminated in increased dry matter production recorded in these treatments. The more the number of stomata, most especially in water stressed plant, the more effective the plant is in trapping of atmospheric CO_2 and water vapour which are the major requirements for photosynthesis. This agreed with previous report where stomatal conductance was enhanced following foliar application of humic substances to drought stressed wheat (Mladenova *et al*., 1998).

The better performance observed in cowpea treated with higher rate of compost and those that received repeated application could be due to increase in water retention in this soil. Organic amendment has been reported to increase water holding capacity at higher rate (ShengoGao and Lei, 2004). Though not determined in this study, but increase in water holding capacity between 0.03 and 1.5MPa is said to be beneficial to crop growth and has been attributed to increase in crop yield observed in organically amended soil (Curtis and Claasen, 2005).

CONCLUSION

It could be concluded that though, water stress had adverse effects on growth and yield parameters when comparing stressed and unstressed cowpea but those treated with compost were able to compare favourably with unstressed ones in terms of growth and yield parameters. Higher compost rate applied two weeks before planting followed by another application at two weeks after planting enhanced cowpea growth and dry matter yield under water stress. Using compost helps in reducing drought stress in plants and adapting to climate change thereby ensuring long-term agricultural production under unpredictable weather conditions.

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BREEDING FOR RESISTANCE AGAINST CLIMATE CHANGE INDUCED CROP DISEASE: AN EXPERIMENT WITH TARO (*COLOCASIA ESCULENTA*(L) SCHOTT) LEAF BLIGHT IN A TROPICAL ENVIRONMENT.

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ABSTRACT

Discussions were held with the rural cocoyam farmers in four Local Government Areas of Akwa Ibom State, Nigeria (Abak, Ibiono Ibom, Itu and Uyo) to obtain and assemble baseline information on cocoyam blight disease status and its effects on rural economy. *Colocasia esculenta* germplasm were collected from six cocoyam growing communities in Akwa Ibom State: (Ayadehe, Ikot Ada Idem, Ikot Ekang, Oku Abak, Midim and Afaha Oku) for growth, yield and blight disease tolerance evaluation in the four local government areas for both screen house and field. This was with a view to identifying or/ developing resistant cultivars for the rural farmers who have depended on taro for food and income to meet their needs. Results in the screen house experiment indicated no apparent symptoms of cocoyam blight disease. Evaluation of growth characteristics and yield components demonstrated promising results. The reverse was the case for the field evaluation as severe symptoms of the disease were observed with some germplasm than others. The germplasm were therefore characterized into four accessions (Ce-Uy-1, Ce-Uy-2, Ce-Uy-3 and Ce-Uy-4) based on morphological characteristics, yield and resistance to the disease. Severe blight disease effects were observed for both the leaves and tubers of Ce-Uy-1, while Ce-Uy-2 had severe effect on leaves alone with no apparent effect on the tubers. The leaves and tubers of Ce-Uy-3 and Ce-Uy-4 showed some degree of tolerance and resistance respectively to the disease and

therefore have potentials to be selected for multi-location trials and genetic and agronomic improvement/evaluation.

Keywords: *Colocasia esculenta, cocoyam leaf blight disease, Akwa Ibom State, screen house, field evaluation.*

INTRODUCTION

Colocasia esculenta and *Xanthosoma sagittifolium* are two important species of cocoyam in *Araceae* family cultivated in southeastern and southwestern agro-ecologies of Nigeria (Pacumbab *et al*., 1992). Cocoyam constitutes an important staple for over 150 million people in developing countries (Chukwu *et al.,* 2009). Nutritionally cocoyam is superior to cassava, yam and sweet potato based on its fibre content, digestibility, crude protein, minerals and vitamins, particularly vitamins B_6 and E (Lewu *et al.,* 2010).

Medically, cocoyam is particularly suitable for stomach regulation, prevention of diabetes, cancer, heart and kidney diseases. It is low in calorie, fat and sodium and thus makes it ideal food for preventing hardening of arteries which is caused by foods rich in cholesterol (Onwueme, 1987).

Cocoyam in its fresh state stores better than yam, cassava and potato and it is available in reasonable quantities throughout the year, ensuring regular supply of food and income for resource poor farmers (Sagoe *et al.,* 2001). Cocoyam can also be processed into several food products and industrial materials similar to those of potato in the western world. It may be processed into such products as *fufu*, soup thickener, flour for baking bread, biscuit, cake, chips, beverage powder, porridge and special foods for people with gastro-intestinal disorders and the convalescents (Onwuka *et al.,* 2002). In Akwa Ibom and Cross River States, the popular local delicacies – Ekpang Nkukwo and Ekpang are prepared with taro (Udoh *et al.,* 2010).

Of all the different kinds of cocoyam, taro (C*olocasia esculenta*) stands out due among others to high corm and cormel yields, early maturity, high palatability and ease of cooking. It had indeed served as food for many households, but since 1974, taro production in Nigeria had suddenly declined (Arene and Okpala, 1981) partly due to climate change and poor resource allocation for research, compared to cassava and yam (Okoye *et al*., 2000). In addition, the use of poor yielding cultivars and decreased cropping areas (Udoh *et al.,* 2010), as well as cocoyam leaf and root rot blight complex (Mbanaso *et al.,* 2008) have affected both growth and yield of the crop in the humid topics (Udoh *et al., 2010*). In recent years, several farmlands have been devastated by leaf blight resulting in the disappearance of the crop from the

Nigeria markets (Adofo, 2004) and hence food table of the rural poor in particular. Besides, the livelihood of many rural farmers who depended on it for income either as occupation or for commerce purpose has been greatly affected. Wide spread of the disease has been reported in many West African countries (Adofo, 2004).

Many concerned individuals and stakeholders have more or less implicated climate change as being responsible for the development of strains of pathogenic organism which now break through the resistance of cocoyam resulting in the blight disease. It has also been stated that because of this, there is less time for optimum natural selection and adaptation of the crop hence the devastation widely reported about taro (Fischer *et al., 2002*). The crop is also fragile and environmental stress sensitive. Sudden climate change has resulted in evolution of new races or strains of pathogenic organisms with different parasite capabilities which the hitherto resistant taro cultivar has succumbed (Fischer *et al., 2002*). Development of new varieties through conventional genetic improvement method is not yielding meaningful result, for now (Udoh *et al., 2010*). Breeding efforts to improve taro is compounded in that flowering scarcely occurs and when induced, viable seeds are rarely set (Mbanaso and Nwachukwu, 2009). Worse still, the crop has very narrow genetic diversity suggesting that with the severity of the blight incidence if positive steps are not taken, the crop might face extinction with the rural-poor's situation worsening.

The objectives of this study were first to assess the occurrence and severity of the taro blight disease in Akwa Ibom State, Nigeria. Secondly, to collect and characterize taro germplasm in Akwa Ibom State, evaluate and select the germplasm against the blight diseases using both screen house, laboratory and field experiments. Thirdly, to determine the level of resistance to the disease and identify superior genotypes based on high yield and resistance to the disease as indices of adaptation to climate smart change in Akwa Ibom State, Nigeria.

MATERIALS AND METHODS

Survey of incidence of the taro blight disease

Cocoyam farmers in four cocoyam growing Local Government Areas of Akwa Ibom State were visited and interviews and groups discussions held to determine the extent of devastation of cocoyam farms by the cocoyam leaf blight and root rot disease and their effect on their livelihoods. The on-farm visitation, discussion and collection of cocoyam (taro) cultivars in the areas called for immediate rescue effort to prevent extinction of the cultivars. Information obtained though not part of this presentation, showed that the people could no longer cultivate the crop due to the diseases that usually strike at the critical stage of the crop development.

EVALUATION OF THE GERMPLASM COLLECTED

1. Screen House Evaluation

The germplasm collected from farmers' plots in the four local government areas: Abak, Ibiono Ibom, Itu and Uyo were cleaned and placed in a cool dry place for screen house evaluation. Polythene bags were filled with sterilized top soil and the samples planted at 1m x 1m using a complete randomized design with three replications on 16th October, 2013. There were 72 plants and each genotype consisted of four plants, giving 24 plants per replicate. A prototype experiment was simultaneously carried out of the screen house as a check. The crops were watered in the morning every two days using clean water and administered at the base of the crop. Other data collected were height, leaf area, number of leaves per plant, number of cormels per plant, length of corms, girth of corms, fresh weight of corms and disease incidence. No fertilizer or agrochemical against pests was administered. The plants were harvested on 16th April, 2014, about six months after planting. Three plants per genotype were tagged for data collection and their means subjected to analysis of variance and separated with the Least Significance Difference at 5% probability level.

FIELD EVALUATION

The taro germplasm from the screen house evaluation were cleaned and stored in a cool dry place in readiness for field planting at the University of Uyo Teaching and Research Farm, Use Offot, Uyo, Nigeria. The land was mechanically ploughed and harrowed and planting carried out on 23rd April, 2014. The plants were spaced at 1m x 1m apart giving 10,000 plants per hectare. The experiment occupied a land area of 35m x 23m and was laid out in a randomized complete block design with four replications. The experiment was rain fed and no fertilizer and agrochemical was applied for pest or disease control. The agronomic practices, characters studied and method of data analysis were similar to that of screen house evaluation. Four cocoyam genotypes with distinct morphological characters were distinguished and tagged per plot for growth, yield and blight disease data collection.

Separate data were taken on each of the categories and labeled as Ce-Uy-1 for *Congoma*. Similarly, another type with the accession Ce-Uy-2, designated as Favourite was identified. Also, Ce-Uy-3 which was identified as the oldest genotype among them was designated as Uyo local. The last genotype was Ce-Uy-4, classified as Nkenge, an intermediate between Ce-Uy-2 and Ce-Uy-3. Analysis of variance was conducted for each character and the means separated with the Duncan Multiple Range Test (DMRT) at 5% probability level.

The accessions were evaluated for resistance to cocoyam blight disease following the procedure of Stather *et. al.* (2003) and Williams (1989). Percentage of leaves or tubers per accession affected by the disease was determined using the formula:

$$\frac{\text{Total number of plant/ tuber affected per accession}}{\text{Total number of plants/ tuber per accession}} \times \frac{100}{1}$$

The scale and descriptor used to categorize the observed variations into classes of resistance and susceptibility were:

1. No apparent damage to plants (shoot) or tuber – high resistance.
2. Very little damage – resistance (1-25% of shoots or tubers affected by cocoyam blight disease)
3. Moderate damage – weak susceptibility (26 – 50% damaged by the disease to either shoot or tuber)
4. Considerable damage – susceptibility (51 – 75% damaged by the disease)
5. Severe damage – high susceptibility (76 – 100% of plant part(s) affected by cocoyam blight disease

RESULTS AND DISCUSSION

Screen House Evaluation

Significant differences (P≤0.05) were observed among the taro accessions for all the characters studied (Table 1). The accession Oku Abak exhibited superior performance in four characters, namely height, number of leaves, leaf area and number of cormels per plant, followed by Itu-Ayadehe in one character (fresh weight of corms) and Ikot Ekang for length of corms. However, while Ikot Ada Idem recorded the lowest value for height, Midim was the lowest for number of leaves. Similarly, the lowest number of cormels per plant was given by Ayadehe. No pathogenic symptom of cocoyam blight was observed among the cocoyam germplasm (accessions). A dusty white appearance on the upper surface of the leaves was diagnosed to be *Basitetospora*, a common fungus considered to be non-pathogenic to known crops. The appearance of the organism was however indicative of poor resistance by the cocoyam genotypes. But when some of the cocoyam genotypes were taken out of the screen house, the dusty white appearance gradually disappeared.

FIELD EVALUATION

Significant differences (P0≤05) were observed among the cocoyam germplasm for all the characters studied, with Ikot Ekang and Oku Abak each leading in three characters (Table 2). The lowest performance was observed for Afaha Oku and Ikot Ada Idem, although both accessions showed superiority in resistance to cocoyam leaf blight disease. Three genotypes (Ayadehe, Ikot Ada Idem and Afaha Oku) were earlier introduced cultivars which have been cultivated for decades, while those obtained from Abak Local Government Area were probably cultivars with higher yields released later (*Congoma*) to replace the adapted cultivars hence, their poor resistance status. Kulkarni and Chopra (2005) noted that resistance may be found in locally adapted cultivars. Although the three germplasm (accessions) are not high yielding as their counterparts from Abak, they could be selected for tolerance (Politowski and Browning, 1978). Colocasia is vegetative propagated and do not produce flowers, and when induced, the seeds are not usually viable, this makes it difficult to improve the genetic constitution of cocoyam using the conventional breeding methods. However, there is need to maintain all the cocoyam germplasm and continually screen them for tolerance or resistance to the diseases.

To further understand the behaviour of the cocoyam, the accessions were characterized based on differences in morphological traits in addition to disease resistance. Four distinct types were identified based on size of corm, alignment of cormels and size of cormels. First cultivar was Ce-Uy-1 (*Congoma*) which possesses long corms with long cormels. The cormels grew away from the corm, constituting a circle around the corm. The cormels were slender or tapered towards points of attachment to the corm while the corms constitute the edible portions; about 8-10 cormels were borne by one corm. Similary, Ce-Uy-2, designated “Favourite” consisted of very large corms with 14-30 cormels some of which were very large in size. The cormels congregated or clustered about the corm. This particular cultivar showed high prolificacy of cormels. They provided the best yields.

The accession, Ce-Uy-3 locally called *Panya* which has been cultivated for several decades consists of small corms and small cormels. They are more adaptable to the high humid environment than the other accessions. Similarly, the Ce-Uy-4 accession has moderate corm and cormels. The arrangement of cormels fell between *Congoma* and Favorite. The cormels distanced from the corm about 5-10cm in the field, though not so wide as in *Congoma*. The result revealed Ce-Uy-1 and Ce-Uy-2 as the most susceptible accessions to blight disease, although for Ce-Uy-2 the tuber was not affected by the disease. The other accessions, Ce-Uy-3 and Ce-Uy-4 had moderate resistance to the disease and could be considered as possible candidates for further breeding purpose, although their yields were lower (Table 3). Visual assessment revealed that the disease symptoms increased with increase in rainfall and could be so correlated, such that by July the susceptible ones were completely devastated in the field (Plate 1).

Table 1: Taro height, number of leaves per plant, leaf area, fresh weight of corms, number of cormels and blight disease tolerance as influenced by different germplasm.

Cocoyam Accession/Location	Plant height (cm)	Number of leaves per plant	Leaf area (cm^2)	Fresh weight of corm per plant (g)	Number of cormels per plant	Length of corms (cm)	Girth corms (cm)	Disease score	
								Leaves	Tuber
Itu-Ayadehe	66.3^c	4.3^e	293.9	244.2^a	3.4^f	4.0^d	4.2^d	1	1
Abak-Ikot Ekang	68.3^b	5.4^b	319.5	226.4^b	4.7^b	6.1^a	4.6^b	1	1
Abak-Basin	79.6^a	6.1^a	385.1	218.3^c	6.4^a	5.2^b	5.6^a	1	1
Abak-Midim	65.6^c	4.2^f	266.4	206.8^d	3.8^e	4.6^c	4.4^c	1	1
Ibiono-Ikot Ada Idem	46.3^e	4.5^d	305.4	199.4^e	4.0^d	3.2^f	3.8^e	1	1
Uyo-Afaha Oku	60.7^d	5.0^c	286.4	184.4^f	4.2^c	3.6^e	3.6^f	1	1
LSD ($P< 0.05$)	1.02	0.06	7.32	6.74	0.07	0.06	0.06	NA	NA

- NA = Not Applicable

Table 2: Growth and yield characteristics of *colocasia* germplasm evaluated under field conditions at Use-Offot, Uyo, Nigeria.

Cocoyam accession /locations	Plant height (cm)	No. of leaves per Plant	Leaf area (cm^2)	Fresh wt. of Corms per plant (g)	Number of cormels Per plant	Length of corms (cm)	Girth of corms (cm)	Length of cormels (cm)	Girth of cormels (cm)	Disease Score Leaves	Disease Score Tubers
Itu-Ayadehe	66.4^d	16.3^d	305.8c	378.4^e	6.3^f	6.7^d	12.6^e	6.2^e	4.3^d	4	2
Abak-Ikot Ekang	78.6^a	26.6^a	358.7a	2240.7^a	16.8^a	17.6^a	28.4^a	15.2^a	8.8^a	5	2
Abak-Basin	73.4^b	24.1^b	320.2b	2106.4^b	12.2^b	14.0^b	27.6^b	12.0^b	6.3^b	5	2
Abak-Midim	69.2^c	20.4^c	301.4^c	2041.5^c	11.0^c	12.4^c	21.6^c	10.3^c	4.3^e	5	2
Ibiono-Ikot Ada Idem	63.4^e	14.2^e	279.6^d	464.6^d	6.8^e	6.8^d	14.6^d	7.2^d	5.6^c	3	1
Uyo-Afaha Oku	64.2^e	15.4^e	272.4^e	365.8^f	8.9^d	5.6^e	12.8^e	7.6^d	4.4^d	3	1

Mean with the same superscripts are not significantly different according to DMRT ($P<0.05$)

Table 3: Classification of *Colocasia esculenta* cultivars collected from Akwa Ibom State, Nigeria.

Cocoyam accession	Plant height (cm)	No. of leaves	Leaf area (cm^2)	Length of corm	Girth of corms (cm)	No. of cormels corm	Length of cormels (cm)	Girth of corms (cm)	Fresh wt of corm and cormels (g)	Salable cormels	Disease score	
											Leaves	Tubers
Ce-uy-1	76.9a	17.4c	466.7a	14.0a	27.3b	8.6c	15.2a	8.5c	589.2b	0d	5	3
Ce-uy-2	73.2b	28.6a	412.1b	12.4b	36.0a	18.4a	12.2b	15.3a	2112.7a	5.4a	5	1
Ce-uy-3	64.4c	14.8d	259.8d	4.2d	9.6d	9.3b	7..0d	10.2b	357.6d	1.8b	3	1
Ce-uy-4	57.3d	20.1b	302.8d	5.8c	16.5c	6.2d	8.5c	6.1d	426.5c	0.6c	4	1
LSD ($p<0.05$)	3.02	1.06	6.86	0.08	1.07	0.16	0.24	0.72	9.76	0.006	NA	NA

CONCLUSION

Farmers no longer cultivate *Colocasia esculenta* in Akwa Ibom State, Nigeria due to the devastating cocoyam root rot and leaf blight disease. The rural economy depended so much on the crop due to its early maturity, promising yields, high nutritional value, quick return to investment and low content of calcium oxalate and acridity, longer shelf life compared to other cocoyam species. Some cultivars in this study have been identified with tolerance to the diseases, although their yields are not very high compared to highly susceptible ones with high yield. There is hope that with continuous evaluation and appropriate breeding and agronomic strategies development of resistant cultivars in the nearest future will be possible. Mixed cropping and early planting could be some of the keys to unlock solution to the disease. The research is on-going and positive results are on sight.

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UTILIZATION OF CLIMATE CHANGE AGRICULTURAL MITIGATION STRATEGIES IN RURAL COMMUNITIES OF AKWA IBOM STATE, NIGERIA

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ABSTRACT

Climatic change in the form of rainfall fluctuations, rise in temperature, gully erosion, flooding and desertification has had devastating effect on the quality of soil which in turn results in reduction of agricultural production. Available evidence from historical texts shows that communities that can protect their natural resources are able to achieve sustainable agricultural development. This study investigated the utilization of climate change agricultural mitigation technologies by farmers in Akwa Ibom State. The specific objectives included sources of information, knowledge level, ways of ameliorating the effect of climate change and extent of utilization of the agricultural mitigation technologies. Data were collected from a sample of 120 farmers participating in the Agricultural Development Programme (ADP) in the study area. Focus Groups Discussions (FGDs) and in-depth interviews (IDIs) were conducted to validate agricultural mitigation technologies used in the study area. Data were elicited from structured interview schedule while descriptive statistics and likert scale techniques were used to analyze the data. Correlation analysis was used to show the relationship between knowledge level of farmers and utilization of agricultural mitigation technologies. The study revealed that knowledge level of climate change among the farmers was high. The findings revealed that out of the twenty-four (24) climate change agricultural mitigation technologies only four (4) recorded very high utilization level. The null hypothesis which states that there is no relationship between the knowledge level of farmers and utilization level of agricultural mitigation technologies was rejected while the alternative hypothesis was accepted. The study recommends that extension contact with farmers should be enhanced and that there should be sustained enlightenment campaigns.

Keywords: Utilization, Farmers' knowledge level, climatic change, agricultural mitigation technologies

INTRODUCTION

Agriculture remains one of the largest contributors to the economy of Nigeria. It accounts for over 88% of the non-oil foreign exchange earnings and produces jobs for over 70% of the active labour force and also contributes over 40% to the gross domestic product (GDP) of Nigeria (Akpabio, 2011).

Increasing frequency and severity of weather-related natural disasters such as heat stress, droughts, bush fires, sandstorms, cyclones and floods, are contemporary signals that all is not well with our climate. Meanwhile, climate occupies a central place in the determination of animal species in an environment and in the selection, growth and yield of crops. It influences the productive capacity of crops that are grown in a particular crop ecological zone. The amount and distribution of rainfall together with temperature regime affects seed establishment, growth and yield of crops and subsequently, farmers' production and income level (Adejuwon, 2008). As climate changes, the habitats of plant, animal and man are affected. The detrimental impact of climate change on agriculture calls for its prompt arrest in order to mitigate its effect. This could be achieved through promoting effective utilization of mitigation strategies.

The earth's climate is rapidly changing. In Nigeria, farmers are experiencing the impacts of rising global temperatures on their communities, their livelihoods, the nature of the soil and the natural environment (Nhemachena and Hassan, 2007). Economic stability develops from good soil used intelligently and protected from erosion and unnecessary wastage of rainfall by excessive runoff (Taffa, 2002). The effect of climate change on soil is chronic and irreversible and as such threatens to undermine agricultural productivity. According to Eager et al (2004) about 24 billion tons of top soil are washed away with the wind every year.

Udosen (2008) reported that higher air temperature affects the soil while warmer conditions are likely to speed up the natural decomposition of organic matter and increase the rates of other soil processes that affect fertility. However, due to agricultural development and urbanization much of this has seriously been exposed, leading to leaching, loss of soil moisture and increased albedo of the surface, which according to Butler (2005), have the effect of altering the earth's radiation balance which in turn results in less heating and less rainfall in a region. Adejuwon (2008) stated that the mean global level of greenhouse gases in the atmosphere is increasing to a level that can trigger serious climate changes in air temperature and violent weather cycles. He further explained that agriculture can be one of many potential solutions to the problem of greenhouse gas emission through carbon sequestration. Additionally, adverse effects of climate change and environmental degradation could be mitigated through several agricultural technologies and environmental friendly practices which include mulching, relay cropping, agro-forestry, crop rotation, improving crop varieties, biological pest control, soil management, altering planting dates, mixed farming, irrigation, planting drought-resistant pastures, legumes application, and non-removal of crop residues. These agricultural conservation practices check and reduce the rate of soil erosion thereby leading to increased crop yield. For example, a return to crop rotation would substantially reduce soil erosion, water run-off and control weeds which results in improved soil quality. Also, irrigation could substitute for reduced rainfall, while mixed farming which is the strategy of planting different crops in the same plot or in different plots reduces the risk of complete crop failure as different crops are affected differently by climate events. This system of farming adds to and maintains soil texture.

Objectives of the study

The broad objective of this study was to investigate farmers' utilization of climate change agricultural mitigation strategies in rural communities of Akwa Ibom State. It specifically examined the socio-economic and demographic characteristics of the farmers in the study area, identified the sources of information, established the perceived knowledge level, identified mitigation strategies presently in use by the farmers and examined the perceived constraints of the farmers in the use of climate change agricultural mitigation technologies.

Hypothesis of the Study

There is no relationship between the knowledge level of farmers and utilization level of agricultural mitigation technologies.

Methodology

Akwa Ibom State is one of the oil rich states in the Niger Delta Region of Nigeria. It is located in the southeastern coast of the country.

Itu Local Government Area with a high population of farmers was purposively selected for this study. Itu shares boundaries with Ini, Ibiono-Ibom, Uyo and Uruan Local Government Areas. It is about 20 kilometers from Uyo, the capital of Akwa Ibom State. The climate in Itu is characterized by two seasons: rainy season (March to November) and dry season (December to February). The area has an estimated mean annual rainfall of about 2000 and a temperature range of about 26^{o}c to 30^{o}c. It has an undulating topography and it is a community that is severely prone to erosion. The vegetation is tropical rain forest where rainfall is torrential, erratic and destructive to the fragile soil of Itu. The people of Itu practice farming and fishing, and concentrate mostly in the production of food crops such as yam, cassava, vegetables, cocoyam, banana, maize, among others.

Sampling Technique and Sampling Size

One hundred and twenty (120) farmers were selected by a multi-stage random sampling technique. Eight (8) extension cells were selected randomly from the two (2) extension blocks that are in the area, according to Akwa Ibom Agricultural Development Programme (AKADEP) grouping. Five (5) cells were selected out of the cells in Ntiat block and three (3) selected out of six cells in Ikot Ada Idem. Fifteen (15) farmers were randomly selected from the list of farmers in each of the circles with the aid of extension agents working in each of the selected extension circles. Structured questionnaire and oral interview were used to collect the primary data used for this analysis.

Analytical Technique

Descriptive statistics such as frequency count and percentage were used to achieve socio-economic characteristics, sources of information and climate change agricultural mitigation strategies utilized. A 4-point rating scale of strongly disagree = 1, disagree = 2, agree = 3, strongly agree = 4 with a mean of 2.5 was used to assess the farmers' level of knowledge of climate change. The null hypothesis which states that there is no significant relationship between the knowledge level of farmers and utilization level of mitigation strategies was realized using Pearson's product moment correlation (r).

Results and Discussions

Table 1 shows the results of the socio-economic characteristics of farmers in Itu Local Government Area of Akwa Ibom State. From the table, most (78.34%) of the farmers were between the ages of 31 and 50 years and were women (81.67%). This corroborates the findings of Akpabio (2005) that females dominate the present farming population in the study area. A large proportion (65.83%) of them were married. 64.8% of them had household size of 5 to 8 persons. About 55.0% of the respondents accepted having no formal education while 41.7% of them had formal education. This low level of education of the respondents implies low level of innovative information flow and consequently, low level of utilization of improved technologies. 60.0% of the respondents had 11-30 years experience in farming, implying that these farmers are well knowledgeable on farming activities.

The results of the farmers' monthly income showed that majority (48%) of them were low income farmers. Only 5.33% of the farmers had earned N40,000.00 monthly from the sales of their farm produce. This revealed that farming in the study area was practiced at a subsistence level. Most (71.67%) of the respondents did not belong to co-operative societies. In this study, a sizeable number of the respondents were visited once in a month by the extension agents. This may be attributed to the many circles that one extension agent needs to cover.

Distribution of Respondents by Information Sources

Table 3 shows that most (40%) of the farmers had access to information on agricultural climate change mitigation technologies through relatives, extension agents (35%) and friends (25%). This finding is in line with Davies and Davies (2009) earlier findings that the source of information to farmers is mostly through interpersonal communication which occurs from day to day interactions and activities among families, relatives and friends.

Table I: Socio-Economic Characteristics of the Respondents

Variable	Frequency	Percentage (%)
Age		
Below 30	17	14.17
31-40	50	41.67
41-50	44	36.67
51-60	9	7.50
Above 60	0	00.00
Sex		
Female	98	81.67
Male	22	18.33
Marital Status		
Single	18	15.00
Married	79	65.83
Divorced	9	7.50
Widowed	14	11.67
Household size		
1-4	11	9.26
5-8	77	64.27
More than 8	32	26.67
Educational level		
No formal education	66	55.1
Primary education	30	25.0
Secondary education	20	16.70
Tertiary education	4	3.33
Farming Experience		
0-10	47	39.20
11-20	72	60.00
21-30	01	00.80
Monthly income (Naira)		
5,000	12	10.00
5001-10,000	17	14.17
11,000-20,000	58	48.33
21,000 – 30,000	26	
31,000	7	
Members of co-operative societies		
Yes	34	28.33
No	86	71.67
Extension Contacts (monthly)		
None	34	28.33
Once	69	57.56
Twice	13	10.83
Thrice	4	3.40
Total	**120**	**100.00**

Source: Field Survey, 2014

Table 3: Distribution of Respondents by Information Sources on Climate Change Mitigation Technologies

Sources of Information	Yes Frequency	%	No Frequency	%	Total %
Radio	-		-		
Television					
Friends	30	25.00	90	75.00	120
Relatives	48	40.00	72	60.00	120
Extension agents	42	35.00	78	65.00	120

Source: Field Survey, 2014

Mean Distribution of Respondents According to Level of Knowledge of Climate Change

Result from table 4 shows that majority (x=3.42) of the respondents agreed knowing the risk of rainfall irregularities. (x=3.31) of them claimed experiencing poor and unpredictable yield.

Other variables included increasing pests and diseases (x=3.28), occurrences of drought (x=2.36), crop logging attributable to excessive flooding (x=2.91), noticeable increased temperature in my locality (x=2.76) and moisture stress causes severe damages (x=3.16). This result implies that farmers sampled for the study had variation in their responses due to their varying degrees of knowledge about climate change.

Climate Change Agricultural Mitigation Technologies Utilized by Farmers

Table 3 reveals the results of climate change mitigation technologies in use by the farmers in the study area. Very high utilization level was observed for homestead garden and planting fruit trees which provided good income for the home while legume application served as weed control and safeguarded the farm investment. This implies that expected economic benefits or returns accruing from these This agrees with the findings of Kenga (2003) who observed that economic consideration was of primary importance in determining which technologies farmers practiced.

Tables 4: Mean Distribution of Respondents According to their Level of Knowledge

Statement	SD	D	A	SA	Teach	Decision
Poor and unpredictable yield	12 (6.22)	26 (13.47)	59 (30.57)	96 (49.74)	3.31	Accept
Knowing the risk of rainfall irregularities	9 (7.5)	12 (10.4)	40 (33.33)	59 (49.0)	3.42	Accept
Noticeable increased temperature in my locality	8 (6.7)	13 (11.0)	29 (24.17)	69 (57.5)	2.76	Accept
Increasing pests and diseases	4 (3.3)	12 (10.4)	24 (20.0)	80 (66.67)	3.28	Accept
Crop logging attributed to excessive flooding	2 (1.67)	18 (15.0)	28 (23.0)	72 (60)	2.9	Accept
Occurrences of drought	60 (50.0)	38 (31.7)	17 (14.17)	5 (4.17)	2.36	Accept
Moisture stress causes severe damages	30 (25.0)	20 (16.7)	65 (54.1)	5 (4.2)	2.16	

Grand mean score Source: Field Survey, 2014

Distribution of Respondents According to Technology used in Mitigating Climate Change Effects

	Mitigation Technologies	Frequency	(%) Percentages
1	Less use of fuel wood	9	7.50
2	Alley cropping	0	0.00
3	Non removal of crop residues	0	0
4	Prevention of bush burning	4	3.33
5	Control of felling trees	11	9.00
6	Legumes application	98	81.67
7	Planting wind break	81	67.50
8	Forest recreation/fallowing	16	13.33
9	Tree planting	47	39.26
10	Agricsilviculture	3	2.50
11	Home stead garden	112	93.00
12	Establishment of fire break	71	59.31
13	Pump-powered irrigation	0	00.0
14	Taungya system	0	0.0
15	Mulching	72	60.00
16	Planting of fruits trees	102	85.00
17	Terrace hedge planting	30	25.00
18	Erosion control	67	55.80
19	Organic manuring	78	64.65
20	Crop rotation	87	72.50
21	Contour ridging	28	23.30
22	Drought vehicles	18	15.00
23	Establishment of botanical garden	0	0
24	Plantation	3	2.14

Source: Field Survey 2014

Constraints Perceived by Farmers in Practicing Mitigation Technologies

The problems encountered by the respondents in their bid to adapt to climatic changes are shown in Table 5 with the farmers' lack of information concerning climate change, forecasting and lack of knowledge of soil conservation techniques identified as their most pressing problems. Other problems identified by the respondents were in this order, lack of improved and drought varieties, lack of storage facilities, insufficient land, scarce labourers, high cost of transportation and lack of capital. Most of these problems were associated with lack of information and poverty. For instance, lack of information on appropriate climate change mitigation strategies contributed to the respondents in the study area to abandoning farming activities to other businesses. Lack of capital/credit facilities hindered farmers from getting the necessary resources and technologies that facilitate adapting to climate change. Insufficient land was associated with fragmentation of lands and high population pressure which force farmers to intensively farm a small plot of land which makes them unable to prevent further damage by using practices such as continuous cropping which affect soil quality and maintenance.

Table 6 shows the Pearson product moment correlation (PPMC) analysis of the relationship between farmers knowledge level and utilization of mitigation technologies. The result of correlation analysis shows a significant relationship between knowledge level of farmers' and utilization of climate change mitigation technologies. Therefore, the null hypothesis was rejected while the alternative hypothesis was accepted ($r=0.141$, $p=0.001$). This result is in agreement with Jones and Henessy (2000). Hassan and Nhemachana, (2008) and Sangotebe (2011) that better knowledge on climate information help farmers' to make proper decision on

Table 5: Perceived Constraints to Climate Change Mitigation Strategies by Farmers in the Study Area

Constraints	Major	Minor	Not a Constraint
Lack of information	110(91.67)	10(8.3)	0(0.00)
Lack of knowledge of mitigation techniques	96(80)	24(20)	0(0.00)
Lack of improved and drought varieties	86(71.9)	27(22.5)	7(5.8)
Lack of storage facilities	74(61.67)	26(21.67)	20(16.7)
Insufficient land	80(66.6)	30(25.0)	10(8.33)
Labourers are scarce	60(50.0)	22(18.3)	38(31.7)
High cost of transportation	82(68.2)	11(9.7)	27(22.1)
Lack of capital/credit	98(81.67)	22(18.33)	0(0.0)

Percentages in parenthesis

Source: Field Survey, 2014

the utilization of climate change mitigation technologies. There was also a significant relationship (r=0.094, p=0.07) between climate change mitigation technologies and knowledge level of climate change. This infers that the simplicity and clarity of all the identified climate change mitigation technologies collectively have a direct bearing on the knowledge level of the respondents. This result is line with Agbongiarhuoji et al (2013) that simplicity of climate change innovation aids better understanding of such innovation.

Table 6: Pearson Product Moment Correlation (PPMC) showing relationship between farmers' knowledge level of climate change and utilization of climate change mitigation technologies

Variables	r-values	p-value
Knowledge level of climate change	0.141	0.001
Utilization of climate change mitigation technologies	0.94	0.07

Conclusion

This study revealed that extension delivery services have not sufficiently educated the farmers to understand the importance of adopting mitigation strategies to maintain and improve their soil texture. This implies that if the climate change mitigation strategies are practiced, the effect of climate change on agricultural production will greatly be mitigated and soil fertility will be greatly enhanced.

It is recommended that extension agents of Akwa Ibom State Agricultural Development Programme (AKPAEP) should launch enlightenment campaigns to sensitize farmers on the benefits of adopting agricultural climate change mitigation technologies. Farmers should form or join associations or co-operative societies that will organize and disseminate essential information on agricultural climate change mitigation strategies in the study area.

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EXAMINING YIELD SENSITIVITY OF DIFFERENT TYPES OF CROPS TO CHANGES IN CLIMATIC FACTORS: IMPLICATIONS FOR ADOPTION OF MAIZE BREEDS AMIDST CLIMATE CHANGE IN NIGERIA

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ABSTRACT

Crops resilience and resistance to climate change varies from different ecological systems. The paper attempts to explore the sensitivity of yield of different stable crops in Nigerian ecosystem to changes in climatic variables and recommend ways toward cropping with the most sensitive crop. Secondary data were sourced from FAO statistics, Nigeria Bureau of statistics and Nigerian Meteorological stations, UNCTAD data base for 1970-2012. Descriptive statistics and regression analysis were employed to examine the sensitivity of cereals, tubers and perennial crops to climatic factors. The results showed that maize as a cereal was the most sensitive crop to all climatic variables such as temperature, humidity and rainfall; while yam as a tuber was more sensitive than cocoa tree as a perennial crop. The paper discusses potentials and strategies for using early maize and extra early maize varieties by farmers in overcoming climate change effects on maize production. It further examined timeliness of using the varieties for planning lucrative enterprises to meet early and late maize markets in Nigeria. The paper was optimistic that with the proper use of improved breeds, farmers can stomach effects of climate change on maize production. It recommends among others multiple phase cropping of maize in a growing season.

Key words: Extra Early Maize, Rainfall, Humidity, Temperature, Food Security, Enterprise

Introduction

Agriculture and food security is undoubtedly adversely affected by climate change. The biological nature of agriculture makes it easily susceptible to environmental hazards. Agribusiness in developing economy like Nigeria is very much under the effects of environmental factors unlike those in developed world where advanced and most efficient production, processing, storage and marketing facilities abound. For instance sub Saharan Africa has only about 3.8 percent of her arable land equipped with some irrigation facilities from 1990 to 2009; while Asia had 44.8 and the World average was 20.5 for the same period (Mkpado, 2013). The same trend goes for fertilizer use in Africa as Nigeria had one of the least rates of fertilizer use in rice production (Ogundele and Okoruwa, 2006).

The climate change could cause an estimated loss of about 25–42 percent of species habitats; negatively affect food and non-food crops (McClean *et al*., 2005). In developing countries especially African countries, climate change can adversely affect about 11 percent of arable land which will lead to a reduction in cereal production and about 16 percent loss in agricultural GDP for about 65 countries (FAO, 2005 in Mkpado, 2012). The ability of ecosystems to stomach shocks may be exceeded the increasing climate change and associated disturbances. Temperature increase from 1°C to 3°C can result in higher crop productivity at mid to high latitudes for only certain types of crops while production of majority of other crops can reduce (Bates, et al 2008, IPCC, 2007).

The mode at which climate change can affect agriculture and food security include reduction in value of available arable land due to drought and desertification, increasing temperature and pollution which can reduce photosynthetic ability of green crops, reduced rain fall duration and intensity which reduces natural growing season in rain fed agriculture. The impacts of climate change depend on a range of the climate parameters and on a country's social, cultural, geographical and economic background (Nzeh and Eboh, 2011). The building of resilience in capacity to cope with climate change is related to the level of innovation/technological adaptation and mitigation processes. Agriculture and food security situations of many societies with the same climatic stress can differ because of infrastructure, innovations and management systems in place. Improved breeds and farming system are integral aspect of innovation and technological adaptation for mitigating and adapting to climate change. Maturity period of a crop has an important role to play with respect to number of time it can be planted in a growing season. Strategies towards improved agriculture and food security amidst climate change today are dealing with the art of managing available resources such as land, water, fertilizers, labour, breeds and innovative farming systems to achieve a target.

What do the dynamics of climatic factors' threat on food security hold for Nigerian agriculture among cereals, root and tubers and plantation crops? What are the options for improving agricultural production and food security with the available resources in Nigeria? The paper aimed at examining the trend in yield of few crops from the classes of cereals, plantation crops as well as roots and tubers. Also estimate the responsiveness of the crops yield to climatic factors and recommend a strategy for improved food production.

Methodology

The study focused on Nigeria. Secondary data were gathered from Nigeria Bureau of statistics and augmented with FAO statistics for agricultural production, other sources are, Nigerian Meteorological stations, and UNCTAD for 1970 to 2012. Descriptive statistics and regression analysis were employed. The model is presented as:

$$Y_{is} = a + b_1 AGE_1 + b_2 FDI_2 + b_3 FT_3 + b_4 HUM_4 + b_5 RAIN_5 + b_6 TEM_6 + b_7 TLEP_7 + e$$

Where: Y_{is} refers respectively to the yield in Kg. of yam (YAM), cocoa beans (COCOA) and Maize (MAIZE) respectively

AGE = aggregate government Expenditure in agriculture

FDI = foreign direct investment inflows

FT= fertilize used in kg

HUM= relative humidity

RAIN=rainfall in mm

TEM= atmospheric Temperature in ^oC

TLEP= total labour employment in Agriculture

e=error term

a is the intercept while bs are the coefficients

Results and Discussion

Descriptive Statistics Results: Considering the yield of maize, cocoa beans and yams showed that yam took the lead among the crops. It had a mean yield of 98622.27kg from 1970-2012 while cocoa bean had 3219.98kg and maize had 13,617.14kg. (see Table 1). The yield of yam appeared to be impressive, considering its lengthy growing period of about 7-8 months, it is certain that it can only have one phase during a growing season. Cocoa as a plantation crop will require consistent managed long term strategic plan in order to change the ugly trend. Maize with a relatively short maturity period of about three months can be a variable for improving food security. The graphic presentation of the trend is presented in Fig.1.

Table 1: Descriptive statistics of the yield in Kg. of selected crops from 1970-2012

Statistics	Maize Yield	Cocoa Beans Yield	Yams Yield
Mean	13617.14	3219.98	98622.27
Mini	5731.00	2000.00	56284.00
Max	21961.00	4980.00	131034.00
Std	3364.53	783.60	21789.95

Source: Authors' computation

Figure 1 showed that from 1980 1988 the yield of Yam was lowest but did increase after wards. Mkpado and Arene (2012) showed that price advantage enjoyed by yam help to increase its cultivation. The price advantage is as a result of the preference enjoyed by yam in a number of ceremonies in Nigeria. Maize yield just like yam have not maintained linear curve. It is evident that a number of factors such as agronomic including edaphic features, environmental factors and management strategies have affected the yields leading to such curves.

Descriptive statistics of climatic and some variables capable of affecting yield is presented in Table 2. It showed that rain fall had a mean of 131.73mm with a standard deviation of 19.47. Temperature had a mean of 29.48 ^{o}C with a standard deviation of 1.04 while the relative humidity had a mean of 72.18 with a standard deviation of 3.26. It is apparent that certain profound changes are associated with the climatic variables as their standard deviations were more than one.

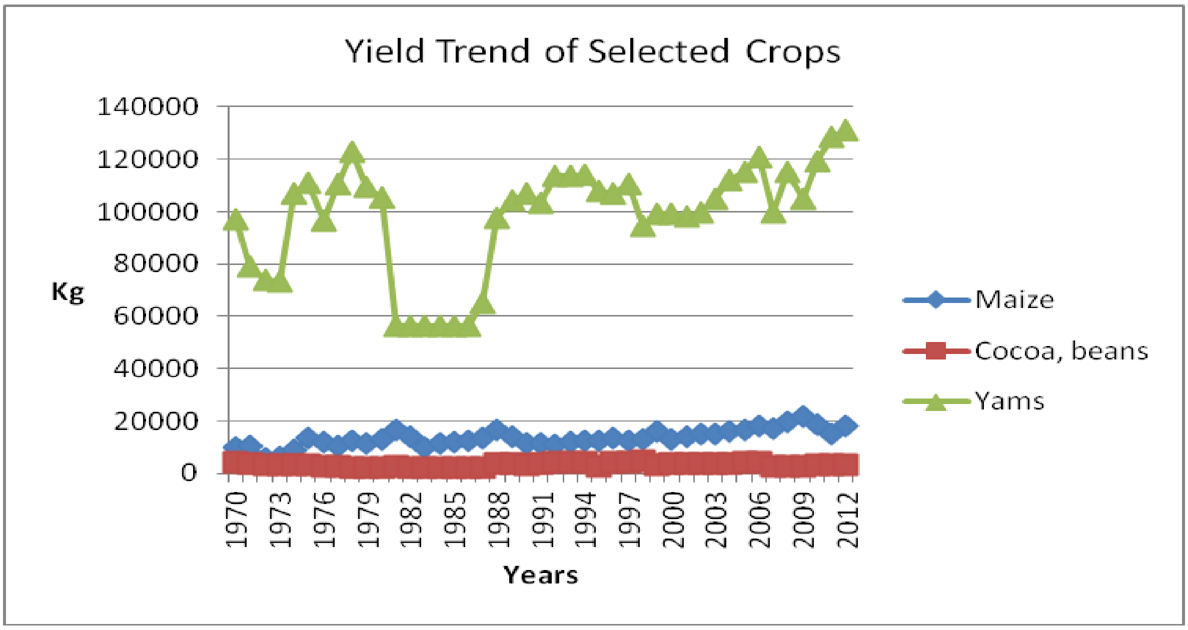


Fig.1: Yield trend of selected Crops; **Source:** Authors' computation

Table 2: Statistics of Climatic and Some Variables Affecting Yield from 1970-2012

Statistics	RAIN	TEM	HUM	FT	FDI	AGE	TLEP
Mean	131.73	29.48116	72.18326	41621.3	7667.256	4359.86	12271.37
Mini	74.93	28.27	68.77	150.96	6001	4165	11489
Max	159.29	32.8	78.99	190023.4	8356	4997	12583
Std	19.47008	1.040948	3.258515	49318.67	730.9687	208.4069	313.0488

Source: Authors' computation

Fertilizer usage, foreign direct investment inflows, aggregate government expenditure and total labour employment in agriculture in Nigerian had experienced lots of variations over the years.

Estimated Results

Estimating impact of environmental factors on yield of crops using times series data required among other things examining time series properties of the variables and testing for coinegrataion. The stationarity of the variables was tested using Augmented Dickey –Fuller (ADF) test. The results of the ADF test on Table 3 showed that the variables were of the same order of stationarity at first difference. This is an indication of possible cointegrataion among the dependent and independent variables. In order to make a good decision Johansen Co integration Test was employed.

Table 3: Time series properties of the variable at first difference Order I(0)

Variable	ADF Value	Remarks
Aggregate government expenditure (AGE)	-3.393382	Sig at 1 %
Maize yield	-7.532655	Sig at 1 %
Yam yield	-7.215498	Sig at 1 %
Cocoa yield	-6.231742	Sig at 1 %
Foreign direct investment (FDI)	-5.829468	Sig at 1 %
Fertilize (FT)	-9.388070	Sig at 1 %
Relative Humidity (HUM)	-12.36062	Sig at 1 %
Rainfall in mm (RAIN)	-7.732818	Sig at 1 %
Temperature ^{o}C (TEM)	-7.906909	Sig at 1 %
Total labour force in agriculture (TLEP)	-6.130416	Sig at 1 %

Critical ADF values at 1% probability = -3.605593; at 5% probability = -2.936942;
Source: Authors' computation

The Johansen Co integration Test was reported on table 4. There is conflicting result by number of Johansen relations r. The two types of test statistics usually reported are the trace statistics and the maximum eigenvalue statistics. The first column is the number of Johansen relations under the null hypothesis and second column is the ordered eigenvalues of the $\prod$ matrix (Johansen and Katarina 1990). It is because of absence of one conintegrataing relations in the Trace statistics and Max-Eigen statistics that it can be concluded that weak cointegtaion exists (see Table 4). Thus, error correction mechanisms were not included in the analysis as this may lead to poor conclusion.

Table 4: Johansen Co integration Test

Dependent variable	No of cointegrating vectors	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.
Cocoa beans	r=0	0.812468	188.4925	159.5297	0.0005*	0.812468	66.95233	52.36261	0.0009*
	r= 1	0.566028	121.5402	125.6154	0.0863	0.566028	33.39097	46.23142	0.5654
	r= 2	0.527910	88.14923	95.75366	0.1487	0.527910	30.02345	40.07757	0.4223
	r=3	0.396832	58.12578	69.81889	0.2974	0.396832	20.22235	33.87687	0.7411
Yam	r=0	0.853340	219.6641	9.5297	0.0000*	0.853340	76.78552	52.36261	0.0000*
	r= 1	0.636015	142.8786	125.6154	0.0029*	0.636015	40.42570	46.23142	0.1834
	r= 2	0.572543	102.4529	95.75366	0.0160*	0.572543	33.99605	40.07757	0.2063
	r=3	0.500508	68.45686	69.81889	0.0639	0.500508	27.76657	33.87687	0.2245
Maize	r=0	0.824102	213.3409	159.5297	0.0000*	0.824102	69.51396	52.36261	0.0004*
	r= 1	0.598990	143.8270	125.6154	0.0024*	0.598990	36.55077	46.23142	0.3657
	r= 2	0.574869	107.2762	95.75366	0.0064*	0.574869	34.21428	40.07757	0.1973
	r=3	0.507757	73.06194	69.81889	0.0269*	0.507757	28.35132	33.87687	0.1978
	r= 4	0.401365	44.71062	47.85613	0.0958	0.401365	20.52413	27.58434	0.3060

Source: Authors' computation

Estimated Regression Results

The estimations of impact of climatic variables on Nigerian agricultural supply chain are acceptable because of high coefficient of determination(R-squared), low standard error of regression and significant F-statistics (Table 5).

Relative humidity had a negative and significant relationship with yield of yams. It means that higher relative humidity leads to lower yam yield. High humidity leads to decay of yam leaves on the ground thus, reducing the number of leaves for photosynthesis. This accounts for the reason why yam farmers in rainforest and guinea savannah zones that experience higher humidity to stake their yam crops. On the other hand high rainfall is required for higher yield. This is rain fall have positive and significant relationship with yam yield. The Yam as a heavy feeder crop requires much rainfall to dissolve soil nutrients and the relatively large leaves requires such heavy rainfall to keep the transpiration pull working. This accounts for why higher rain fall is desirable for yam yield.

Relative humidity had negative and significant impact on maize yield. High humidity can lead to rot and decay of maize fruits in the field or undergoing sun drying as high humidity can encourage growth of moulds. Rain fall has negative and significant relationship maize yield. It means that the higher the rainfall intensity the lower will be maize yield. This is true in a rain fed system with only one phase cropping in which case mature maize cubs can get spoiled in the field by rain. Maize farmers thus need dryer where they can dry their crops during the rainy season. However, multiple phases cropping of maize can provide avenue where by the rain can be used for another phase cropping, thus possible doubling or tripling output. There are risk and uncertainty with heavy rain fall as high wind can damage growing maize crops. Whether based index insurance programme are designed to help farmers handle such; incidentally in Nigeria this type of insurance is still at initiation or incubation stage. Total labour employment in agriculture is negatively and significantly related to maize yield. This is apparently because of the mono phase cropping of maize in Nigeria. It is possible that with multiple phases cropping such experiences can be changed. Other variables that had positive and significant relationship with maize yield include aggregate government expenditure, foreign direct investment in flows and fertilizer usage. It is in line with expectations because FDI can help to develop breeds and other innovation for improved yield. Fertilizer is an input which can help maize yield. In fact maize is sensitive crop more than cassava as it cannot withstand environmental and nutritional stress as cassava (Mkpado and Arene, 2003). Aggregate government expenditure on agriculture can be used to provide incentives and subsidies to farmers thus, helping them to obtain necessary inputs or overcoming some production bottle necks with necessary information and technical guidance given by agricultural extension officers.

Table 5: Estimated Responsiveness of Selected Crops to Climatic Factors

	Yam		Cocoa bean		Maize	
Variables	Coefficient	t-value	coefficient	t-value	coefficient	t-value
AGE	0.003423	0.808828	2.77E-05	1.044928	0.008515	3.885091**
FDI	-0.000795	-0.260273	1.24E-05	0.645949	0.003603	2.278079**
_FT	8.37E-07	0.069522	3.88E-08	0.514424	1.3 E-05	2.103640**
HUM	-0.360941	-2.697588**	-0.000745	-0.888655	-0.142881	-2.062046**
RAIN	0.022267	1.392459	1.54E-05	0.142943	-0.015170	-1.700348**
TEM	-0.016135	-0.020438	0.005526	1.317617	0.245255	0.599884
TLEP	-0.000266	-0.038457	-3.48E-05	-0.804236	-0.008060	-2.251872**
C	29.56913	0.509293	0.107296	0.295060	42.23944	1.404856
R-squared	0.354987		0.307780		0.602927	
Adjusted R-squared	0.213890		0.156357		0.516068	
S.E. of regression	1.792854		0.011229		0.928454	
F-statistic	2.515915		2.032581		6.941398	
Prob(F-statistic)	0.035189		0.081307		0.000047	
Durbin-Watson stat.	1.68096		1.476118		1.592784	

***=significant at 10 %; **=significant at 5%; Source:** Authors' computation

The Maize Varieties for Climate Change Mitigation

Badu-Apraku et al (2013) noted that two maize varieties early (90-95 days to maturity) and extra-early maturing hybrids (80-85 days to maturity) with combined resistance/tolerance to Striga, drought, and low soil nitrogen have been released in Nigeria by the Institute of Agricultural Research and Training (IAR &T) in Nigeria.

The extra-early hybrids originally known as IITA Hybrid EEWH-21 and IITA Hybrid EEWH-26 and now designated as Ife Maizehyb-5 and Ife Maizehyb-6 were developed by IITA, and tested extensively in Nigeria in partnership with IAR & T, through the funding support of the Drought Tolerant Maize for Africa (DTMA) Project. The DTMA Project is executed by CIMMYT and IITA with funds provided by the Bill & Melinda Gates Foundation. Ife Maizehyb-5 and Ife Maizehyb-6, have the potential yield of 6.0 tonnes and 5.5 tonnes per hectare respectively compared with local varieties that yield about 1.5 tonnes per hectare (Agronigeria (2013).

The maize varieties can get to market early and attract higher prices to increase farmers' income. They can be grown with lower irrigation cost. They also have the ability to resist striga weeds and tolerate lower soils with lower nitrogen fertility thus helping farmers to reduce cost of fertilization.

Climatic Patterns Capable of Influencing Farming System for Increased Output

The maize production /productivity map of Nigeria (Fig.2) showed that maize does best within the derived savannah zone of Nigeria. It has lowest production rate at two extreme climatic areas of the country. That is where rainfall is highest (rainforest zone and Guinea savannah) and lowest (Sahel savannah) respectively. This is another indication of maize sensitivity to climatic variables as rain fall can influence humidity and temperature.

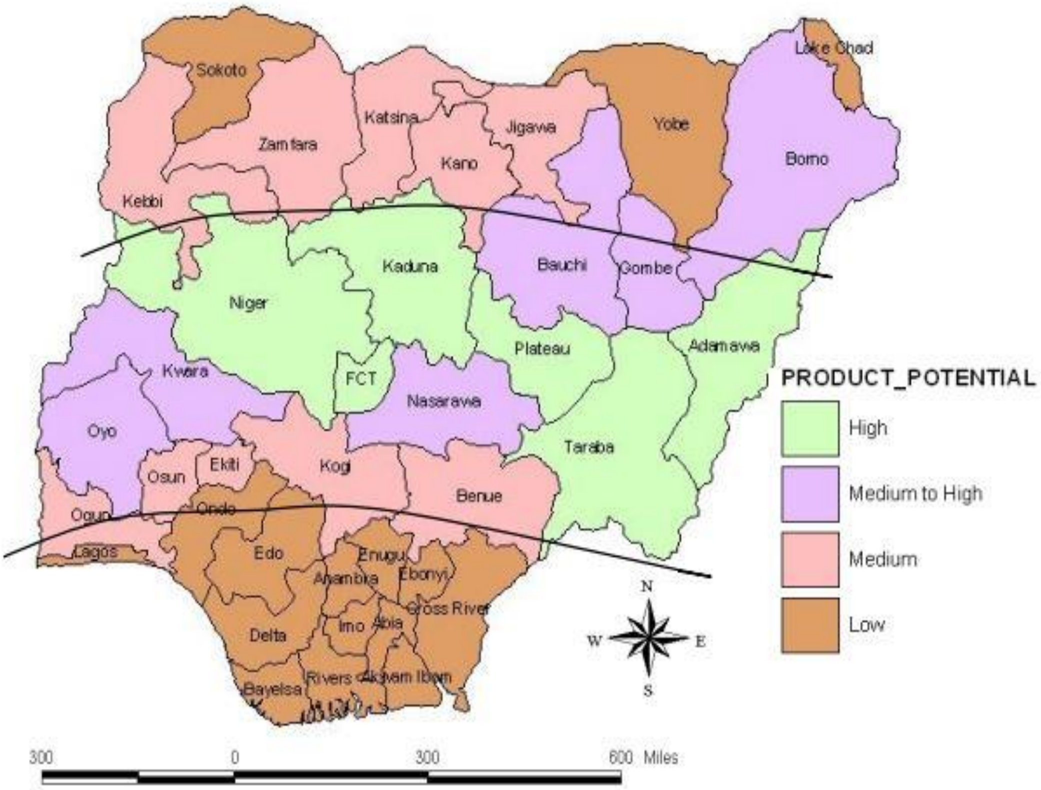
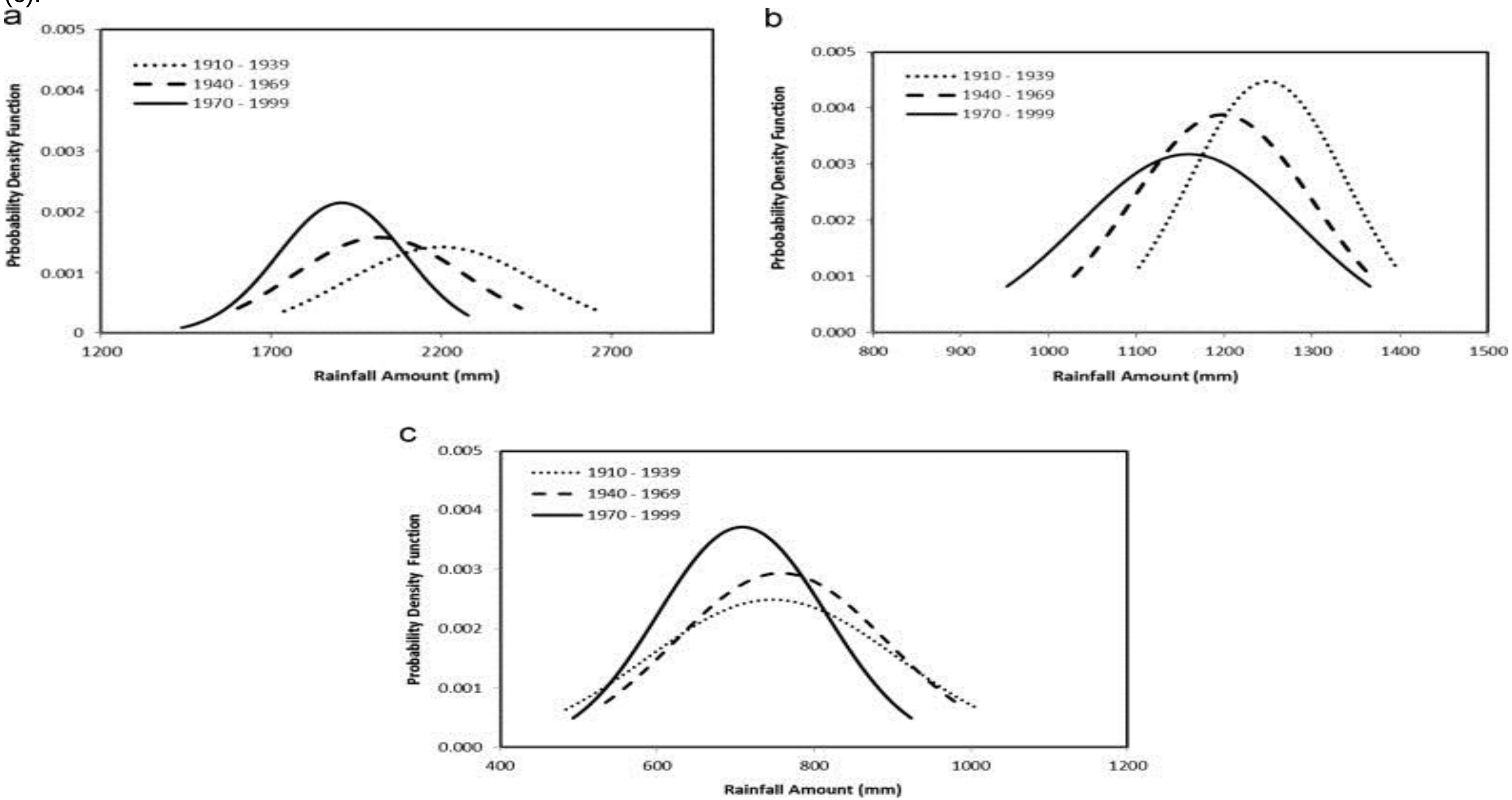


Fig. 2: Maize production /productivity map of Nigeria
Source: Plan for maize trainsformation(www.unaab.edu.ng)

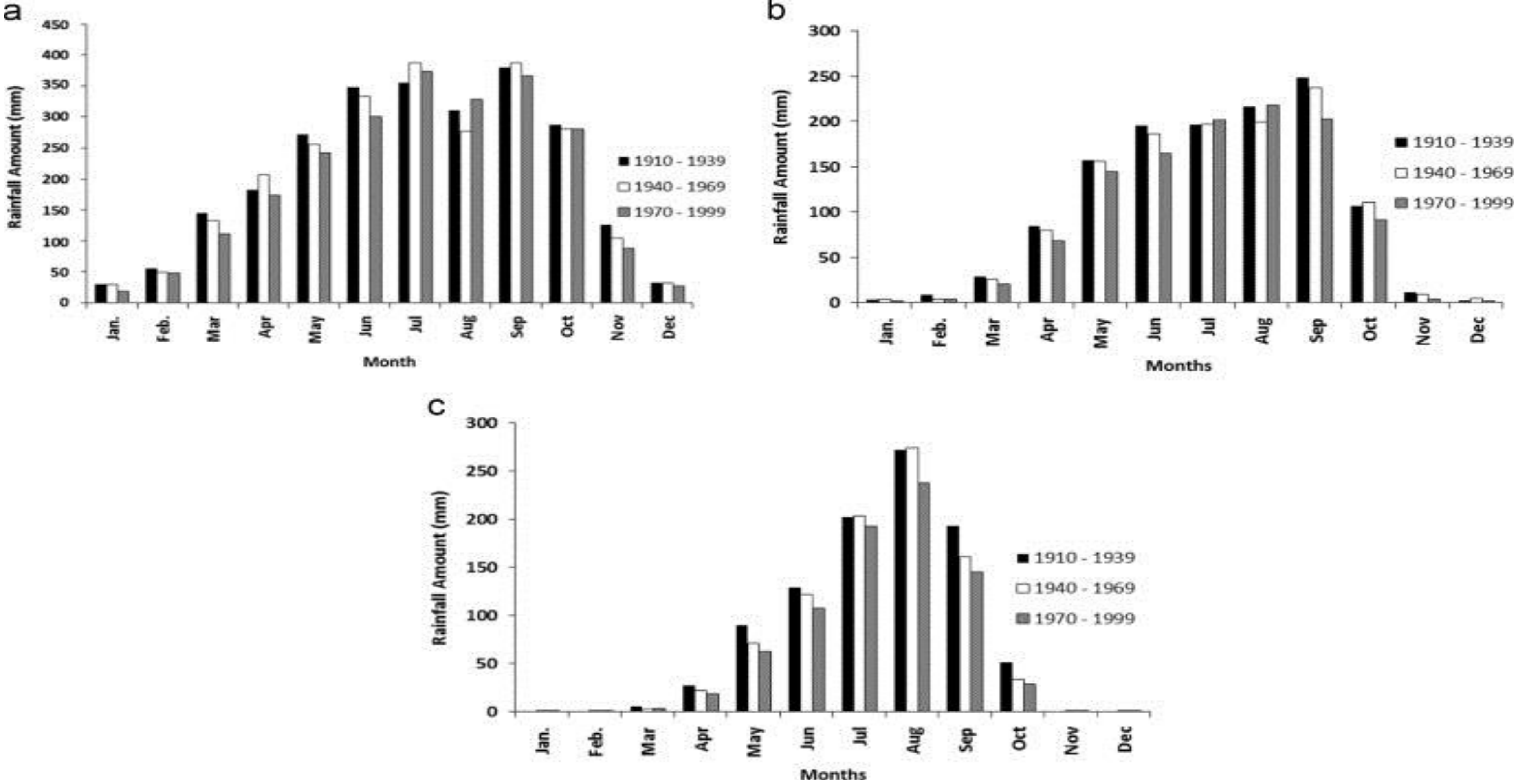
Available data indicates that there are variations in frequency and duration of rain fall across Nigeria major ecosystems (see Figures 3 and 4). This is in line with the experiences of changing climate. The task here is who can farmers use the available resources to optimize production.

Fig. 3 Mean annual rainfall distribution over Guinea (a), Savanna (b) and Sahel (c).



Source: Adopted from Stephen and Tobi, 2014.

Fig. 4 Comparison of mean monthly rainfalls over Guinea /rain forest (a), derived Savanna (b) and Sahel savannah (c)
Source: Adopted from Stephen and Tobi, 2014.



The Proposed Models for Cultivation of the new Improved Maize Varieties in Nigeria

It is assumed that the farmer has more than one portion of land for his/her farming activities at a time and or has a crop rotation system with at least one portion that is left to lay fallow. This will help in the control of pests and diseases associated with increasing intensity of cropping on a piece of land. The proposed model in Table 6 can double or even triple maize production in the country. When maize is grown two to three times in the country, domestic agro based industries using maize will get enough and excess can be exported to generate foreign exchange. Most important the food security situation of Nigerian households can be improved as the crop is fast becoming a major staple as it can be cooked with vegetables, with legumes, as pap with soybeans for baby food and used as snacks in a number of forms.

Table 6: Proposed Enterprise Models for new Improved Maize Varieties

Ecological zones	Phases of cropping		
	Phase 1	Phase 2	Phase 3
Guinea savannah and rainforest	April-June	August-October	
	March-May*	May –July	August-October
Derived savannah	April-June	August-October *	
	March-May*	May –July	August-October *
Sahel savannah	May-July	August-October *	
	April -June*	May –July	August-October *

* Supplementary Irrigation is required; **Source:** Authors' computation

Conclusion and Recommendations

It has been informative to examine yield sensitivity to different classes of crops in Nigeria. Maize as a cereal has proved to be the most sensitive. Improving food security of the nation has a lot to do with cultivation of cereals especially Maize and maintain a good record in cultivation of roots and tubers such as yams. Yam can have one phase during a growing season so it required optimum allocation of resources to sustain and even gain higher yield. Staking is to be encouraged especially in high humid zones of Nigeria as relative humidity had negative impact on its yield. Maize yield is very sensitive to climatic variables. Maize farmers thus need dryer where they can dry their crops during the rainy season as humidity and rainfall had negative impact on yield. The performance of plantation crops such as cocoa is not impressive, given the nature of the crop, long term strategy is required.

The paper thus recommends extension of the innovation of early and extra early maize breeds to farmers. Extension agents need to encourage maize farmers to adopt multiple phase cropping systems for maize as this can double or triple maize output and increase Nigerian's food security. Yam farmers need to continue staking especially in the humid areas as well as engage in optimum allocation of inputs to yam as the crop can be grown once in cropping season. Government expenditure in agriculture and foreign direct investment inflows in agriculture need to be encouraged as such funds can be very useful in developing breeds and providing necessary infrastructure including maize dyer and incentives for farmers.

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Part IV: The remediation of contaminated soils

BIODEGRADATION OF HYDROCARBONS IN A TROPICAL ULTISOL BY LEGUME PLANTS AND ORGANIC MANURE

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ABSTRACT

Global emphasis on food security and soil health should consider rehabilitation of degraded lands, especially where oil contamination limits the use of such lands. Three legume plants (*Gliricidia sepium*, *Leucaena leucocephala* and *Calapoconium caerulean*) alone or combination with 10 tons ha^{-1} poultry manure, were tested for their potentials to remove total hydrocarbons in a sandy soil contaminated with 5% (w/w) spent lubricating oil and grease. Results showed that significant high levels of residual total hydrocarbon content (THC) still persisted in the non-amended soils after 36 months. Total and net removal of THC after 3 months were 43 and 14% respectively, with degradation rate of 240 mg kg^{-1} day^{-1}, for soils planted with *Gliricidia* S. and *Leucaena luecocephala* combined with 10 tons ha^{-1} poultry manure. After 12 months, total and net removal of THC due to combination of 10 tons ha^{-1} poultry manure with *Gliricidia* S. or *Luecaena* L. were 69 and 31% respectively, with degradation rate of 127 mg kg^{-1} day^{-1}. At 18 months when additional 5% (w/w) spent oil load was applied, the total and net removal of THC were 80 and 11% for all the legume plants with 10 tons ha^{-1} poultry manure, and degradation rate of 142 mg kg^{-1} day^{-1}. Poultry manure or legume plants alone were not effective in THC removal. All the legume plants supplemented with 10 tons ha^{-1} poultry were effective in reducing THC in the contaminated soil to negligible levels within 208 days. These plants with 10 tons ha^{-1} of poultry are promising in clean-up of soils contaminated with oils and grease.

Key words: Contamination, oil and grease, degradation rate, poultry manure, legumes**.**

Introduction

Biodegradation of petroleum hydrocarbons is presumed to be based on the stimulation of microbial degradation in the rhizosphere. Effective soil treatment technologies require or suggest that residual total petroleum hydrocarbon (RTPH) concentration in soils be reduced to 1000 mg kg^{-1} or in some areas, below 100 mg kg^{-1} (Ram et al., 1993). Many of the standard treatment processes available for cleaning-up soils contaminated with petroleum hydrocarbons have been limited in their application, are prohibitively expensive, or may be only partially effective (Merkl et al., 2005). The high cost associated with a number of these methods, has been a major limitation to the sustainability of such methods (Van Gestel et al., 1992). Literature reports many examples in which both singular bacterial strains and microbial systems have been successfully utilized to reduce and/or transform selected pollutants in petroleum-contaminated soils under laboratory conditions (Gallizia et al., 2003, Harayama et al., 2004). The use of organic wastes, such as cow dung and pig droppings (Okurumeh and Okiemen, 1998) and rubber processing sludge (Okiemen and Okiemen, 2002), have also been reported to give positive results in *in situ* remediation of oil-contaminated soils. However, the use green plants to clean-up soils contaminated with petroleum hydrocarbons is a subject of scientific interest the require vigorous research (Merkl et al., 2005).

So far, major focus in the use of plants has been concentrated on heavy metal removal (Gallizia et al., 2003, Harayama et al., 2004). Information regarding the use of legume plants with organic manure to clean-up soils contaminated with petroleum hydrocarbons is limited, much so that the method is ecologically friendly (Mager and Hernandez-Valencia, 2003, Revera-Cruz et al., 2004). Plants can enhance microbial degradation of hydrocarbons by providing oxygen in the root area along root channels and loosened soil aggregates. Legumes are considered to be especially promising in this method, because of their nitrogen independence, which is of significance in oil-contaminated soils (Yeung et al., 1997). There is therefore the need for methods that are not only effective and economical, but which are also sustainable in terms of preserving and maintaining the environment. The biological method (biodegradation) is considered as a valuable alternative method because it is ecologically acceptable and rapidly deployable in a wide range of physical settings (Catallo and Portier, 1992, Kelly et al, 1992, Ram et al., 1993). Bioremediation is a managed process in which biological, especially microbial, catalysis act on contaminant compounds thereby eliminating environmental contamination (Revera-Cruz et al., 2004).

The indiscriminate discharge of petrol oils and grease into open vacant plots and farm lands is becoming an acute environmental problem in Nigeria, particularly, when large areas of agricultures are affected (Anoliefo & Vwioko, 1995). Spent indicating oil, otherwise called waste engine oil, is usually obtained after servicing and subsequent draining from automobile and generator engines by auto–repairers. It includes mono- and multi-grade crankcase oils from petrol engines with significant levels of hydrocarbons and other undesirable properties present in all petroleum products (Omoluobi, 1998). In this study, we evaluated the effectiveness of three tropical legume plants: *Gliricidia sepium* and *Leucaena leucocephala* and *Galapogonium caerulean* and poultry manure in cleaning up soil contaminated with petroleum hydrocarbons with a view to making it available for crop production. The study will also bridge the gap in current knowledge regarding the use of legume plant species and poultry manure for *in situ* biodegradation of petroleum hydrocarbons in soil.

Materials and Methods

Site Description and Application of Treatments

The study was carried out on 45 plots (each measuring 2.5 x 1.5m) at the University of Nigeria, Nsukka, Research Farm (Lat. $06^{o}52^{1}$N, and Long. $07^{o}24^{1}$E). The soil is sandy loam (*Typic Kandiustult*). Mean annual rainfall in the area is more than1700 mm with maximum temperature of 32^{o}C (Inyang, 1978). The plots were impacted with 5% (w/w) (equivalent of 50,000 mg kg^{-1}) mono- and multi-grade crankcase oils from petrol and diesel engines, together with gear oils and transmission fluids, in a single dose each for two years. By the second year, the plots had spent oil application load of 100,000 mg kg^{-1}, representing a total oil load of 10% (w/w). Biodegradation was enhanced using three (3) legume plants: *Gliricidia sepium*, *Leucaena leucocephala,* and *Galapogonim caerulean*, planted alone or combined with 10 tons ha^{-1} poultry manure. The selected legume plants are fast growing, have ability to generate high biomass, nitrogen-independent and encourage high population of hydrocarbon-degrading micro-organisms in the rhizosphere (Anderson et al., 1993). The experiment was arranged as a Randomized complete block design (RCBD), with nine (9) treatments in five replications viz: uncontaminated soil (Control) (C), spent oil only (A_5), spent oil + *Calapogonium spp* (A_5 +Ca), spent oil + *Gliricidia spp* (A_5 + Gl), spent oil + *Leucaena spp* (A_5 + Le), spent oil + poultry manure alone (A_5 + Pm), spent oil + *Calapogonium spp* + poultry manure (A5 + Ca +Pm), spent oil + Glirrcidia + poultry manure (A5 +Gl +Pm), and spent oil + *Leucaena spp* + poultry manure (A_5 + Le + Pm). The legume seeds and poultry manure were introduced to the plots seven days after the oil contamination. The second application of 5% (w/w) spent oil was done at 360 days after the first application.

Planting

The *Calapogonium caerulean* was planted at 30 x 90 cm spacing, giving density of 37,000 plants ha^{-1}, *Gliricidia sepium* and *Leucaena leucocephala* were planted at 1 m x 90 cm spacing, giving density of 11,100 plants ha^{-1}.

Sampling

Soil samples were collected from the 0-30 cm depth at 3, 6, 12, 18, 24 and 36 months after oil-contamination for laboratory studies.

Determination of total Hydrocarbon

Total Hydrocarbon (TH) at each sampling period was determined gravimetrically by toluene extraction (cold extraction) method described by Odu et al. (1989).

Biodegradation Rate of Total Hydrocarbon loss

Average biodegradation rates (mg kg^{-1} day^{-1}) of hydrocarbons were calculated according to the method of Yeung et al. (1997) as:

$$\Delta HL = (HC_{ini} – HC_{end} / Time_{inc} \quad (1)$$

Where: ∆HL is the average hydrocarbon content in the soil (mg kg^{-1}), HC_{ini} is the initial hydrocarbon content in the soil (mg kg^{-1}), HC_{end} is the hydrocarbon content when the experiment ended (mg kg^{-1}), and $Time_{inc}$ is the degradation time (d).

Data Analysis

Statistical analyses were carried out using the SAS Software (SAS Institute, 2001). Means were separated using the LSD (Fishers protected test) (Gomez & Gomez, 1984).

Results and Discussions

The soil is sandy loam. The mean sand, silt and clay contents are 820, 60 and 120 g kg^{-1} respectively (Table 1). Clay and silt contents are low, confirming highly weathered, soils of southern Nigeria. The soil also has low C.N. ratio and low water holding capacity (Table 1). The spent oil and poultry manure (Pm) have organic carbon of 31.5 and 28.6 g kg^{-1} respectively.

Residual Total Hydrocarbons

Mean value of the residual and total hydrocarbon (TH) content of the soil after 36 months were 2048 mg kg^{-1} (in control) and 35064 mg kg^{-1} (in contaminated soil) (Table 2). In 12 months, the residual TH for A_{5+} Gl + Pm, A_5+ Le + Pm and A_5 + Ca + Pm, were 15471, 15549 and 15816 mg $kg\text{-}^{1}$ respectively compared to high value of 30648 mg kg^{-1} found in the A_5 soil. When additional 5% (w/w) load of spent oil was added to the soil after 12 months, residual TH in the soil at 24 month were 31731 mg kg^{-1} for A_5 compared to 20416, 20544 and 20712 mg kg^{-1} found in A5 + Gl + Pm, A_5 + Le + Pm and A_5 + Ca + Pm soils, respectively. Treatments with either poultry manure (Pm) or legume plants alone, though able to remove total hydrocarbon, but the reduction not significant within a few months (Table 2). The ability of *Gliricidia spp*, *Leucaena spp* and *Calapogonium spp* to enhance biodegradation of TPH was higher when they were combined with 10 tons ha^{-1} of poultry manure.

Table 1: Some characteristics of the site, poultry manure and spent oil used in the experiment

Parameter	Unit	Soil	Poultry manure	Spent Oil
Sand (200-50 μm)	g kg^{-1}	820	-	-
Silt (50-2 μm)	g kg^{-1}	60	-	-
Clay (< 2μm)	-	120	-	-
Texture	g kg^{-1}	Sandy loam	-	-
Organic carbon	g kg^{-1}	6.84	28.6	31.5
Total N	g kg^{-1}	0.76	4.5	2.79
C:N	-	9	6	11
P^H (H_20)	-	4.7	6.5	-
Na	C mol kg^{-1}	0.10	1.94	-
Exchangeable acidity	C mol kg^{-1}	2.6	-	-
Saturated hydraulic conductivity	cm hr^{-1}	20.44	-	-
Bulk density	g cm^{-3}	1.52	-	-
Water holding capacity	cm^3 cm^{-3}	0.31	-	-
Total porosity	%	51.	-	-

Table 2: Changes in total hydrocarbon content (THC) of the soil as affected by treatment after
36 months

Treatments	THC (mg kg^{-1}) Months after oil application					
	3	12	18	24	36	Mean
A_5	35492	30648	41033	36416	31731	35064
A_5 +Gl	34784	17742	36617	29011	20619	27755
A_5 +Le	34652	17886	36214	29930	21174	27971
A_5 +Ca	33964	17421	36347	30662	24366	28552
A_5 +Pm	34011	16638	39118	31457	28694	29984
A_5 +Gl + Pm	28413	15471	35473	21974	20416	24349
A_5 +Le + Pm	28519	15549	35718	22603	20544	24587
A_5 +Ca + Pm	28944	15816	35736	23146	20712	24871
C	2390	2075	1964	19103	19004	2048
Mean	29018	16583	33136	25224	21128	-

LSD (0.05): Treatment = 9646, Mouth = 125.318, T x M = 594.437

Table 3: Degradation of total hydrocarbon content (THC) of the top 0-30cm soil as influenced by the treatments

Treatment	Spent oil loading (mg kg^{-1})	Total loss in THC (%)	Net loss due to amendment (%)	Degradation rate (mg kg^{-1} d^{-1})
		3rd month		
A_5	50000	29.0	-	161.2
A_5 +Gl	50000	30.4	1.4	169.1
A_5 +Le	50000	30.7	1.7	170.5
A_5 +Ca	50000	32.1	3.1	178.7
A_5 +Pm	50000	32.0	3.0	177.7
A_5 +Gl + Pm	50000	43.2	14.2	239.9
A_5 +Le + Pm	50000	43.0	14.0	238.7
A_5 +Ca + Pm	50000	42.1	13.1	234.0
		12th month		
A_5	50000	38.4	-	71.7
A_5 +Gl	50000	64.5	26.1	119.5
A_5 +Le	50000	64.2	25.8	118.9
A_5 +Ca	50000	65.2	26.8	20.7
A_5 +Pm	50000	66.7	28.3	123.6
A_5 +Gl + Pm	50000	69.1	30.7	127.9
A_5 +Le + Pm	50000	68.9	30.5	127.6
A_5 +Ca + Pm	50000	68.4	30.0	126.6
		18th month		
A_5	100000	59.0	-	327.6
A_5 +Gl	100000	63.4	4.4	352.1
A_5 +Le	100000	63.7	4.8	354.4
A_5 +Ca	100000	60.9	4.7	353.6
A_5 +Pm	100000	64.5	1.9	338.2
A_5 +Gl + Pm	100000	64.3	5.5	358.5
A_5 +Le + Pm	100000	64.3	5.3	357.1
A_5 +Ca + Pm	100000	64.3	5.3	357.0
		24th month		
A_5	100000	63.6	-	353.2
A_5 +Gl	100000	71.0	7.4	394.4
A_5 +Le	100000	70.1	6.5	389.3
A_5 +Ca	100000	69.3	5.7	385.2
A_5 +Pm	100000	68.5	4.9	380.8

A_5 +Gl + Pm	100000	78.0	14.4	443.5
A_5 +Le + Pm	100000	77.4	13.8	430.0
A_5 +Ca + Pm	100000	76.9	13.3	427.0
		36th month		
A_5	100000	68.3	-	379.3
A_5 +Gl	100000	79.4	11.1	441.0
A_5 +Le	100000	78.8	10.5	437.9
A_5 +Ca	100000	75.6	7.3	420.2
A_5 +Pm	100000	71.3	3.0	396.1
A_5 +Gl + Pm	100000	79.6	11.3	442.1
A_5 +Le + Pm	100000	79.5	11.2	441.4
A_5 +Ca + Pm	100000	79.3	11.0	440.5

Total loss (%) = [Spent oil loading - Residual THC (Treatment)/Spent oil loading] x 100

Net loss (%) = % loss in THC (Treatment) - % loss in spent oil (Control)

THC Degradation = initial THC – THC at the end, THC – total hydrocarbon content.

The significantly low residual TH obtained in soils amended with the combination of plants and poultry manure may have been possible due to enhanced positive changes in the physico-chemical conditions of the soils by the legume plants (Kirk et al., 2005). On the other hand, the plants may have participated in biodegradation of the petroleum hydrocarbon via their support of symbiotic root-associated micro-organisms. This is in agreement with Merkl et al., (2005), and Stamp et al., (1997) that different species of plants have varying effects on rhizosphere micro-organisms and their degradation activities. The *Gliricidia* and *Leucaena* showed better promise than *Calapogonium* ssp in cleaning up petroleum hydrocarbons in the soil.

Quantification of Total Hydrocarbon Degradation Rate.

At the end of 3 months when the soil was contaminated with 50,000 mg kg^{-1} (5% w/w) of spent oil, reductions in TH were 29%, 31%, 32%, 43%, 43% and 42% for A_5, A_5 + Gl, A_5 + Le, A_5 + Ca, A_5 + Pm, A_5 + Gl + Pm, A_5 + Le + Pm and A_5 + Ca + Pm, respectively, (Table 3). At 3 months, net loss of TH was 14% with degradation rate of 240 mg kg^{-1} day^{-1} for *Gliricidia* and *Leucaena spp* combined with 10 tons ha^{-1} poultry manure. The net loss of TH due to amendment with Gliricidia or Leucaena combined with poultry manure was 8-fold compared to values obtained for amendment with *Gliricidia* and *Leucaena* alone (Table 3). Absolutely, 21687, 21481 and 21058 mg kg^{-}

^{1} of TH were removed from the soil in 3 months by A_5 + Gl + Pm, A_5 + Le + Pm and A_5 + Ca + Pm, respectively (Table 2). It implies that with the degradation rate of 240 mg kg^{-1} day^{-1}, 50,000 mg kg $^{-1}$ spent oil would have been completed removed from the soil within 208 days (7 months) when the soil was treated with either *Gliricidia* or *Leucaena spp* with 10 tons ha^{-1} poultry manure..

Decreased in degradation rates during the 12 months may have been due to decreased in the number of hydrocarbon utilizing micro-organisms, which according to Molina-Barahona et al. (2004), are usually high in soil immediately and a few months after oil spills. In 18 months, reductions in TH of the soil due to A5 + Gl + Pm, A_5 + Le + Pm and A_5 + Ca + Pm amendments was 64%. It was found that about 38% of the TH was degraded naturally in 12 months, with degradation rate of 161 mg kg^{-1} day^{-1} in the first 3 months and 72 mg kg^{-1} day^{-1} in 9 months (Table 3). This implies that 50,000 mg kg^{-1} spent oil will degrade naturally from the 30 cm soil depth in more than 674 days under this site conditions. This result confirmed that indigenous micro-organisms in some tropical soils can degrade petroleum hydrocarbons by nature, as earlier reported by Wang and Bartha (1990) and Wilson and Jones (1992).

In 36 months, net loss of TH due to combination of *Gliricidia sepium* with poultry manure was 11.3% with mean TH degradation rate increasing to 442 mg kg^{-1} day^{-1}. It is believed that improvement in intrinsic properties of the soil by the legume plant residues may have acted as bulking agents and/or as bacterial biomass suppliers, which supported the high TH removal from soils treated with the legume plants with poultry manure.

4. Conclusion

Conclusions drawn from this study are that: 1. Contamination of the soil with spent lubricating oil increased the total and residual hydrocarbons which may have reduced water affinity to the soil aggregates. 2. High amounts of petroleum hydrocarbons persisted in the contaminated soils after 36 months. 3. Degradation rate of total hydrocarbon by indigenous micro-organisms under natural conditions was negligible. 4. Either *Gliricidia sepium* or *Leucaena leucocephala* with 10 tons ha^{-}

[1] poultry manure can remove 50,000 mg kg^{-1} of spent oil from the top soil 0-30 cm soil within 208 days. 5. The *Gliricidia sepium*, *Leucaena leucocephala* and Calapogonium *caerulean* are promising species for removal of total hydrocarbons in soils, but their effectiveness is enhanced when they are combined with 10 tons ha^{-1} poultry manure. 6. The *Gliricidia* and *Leucaena* showed better promise than *Calapogonium* ssp in cleaning up petroleum hydrocarbons in the soil.

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TOTAL PETROLEUM HYDROCARBON AND HEAVY METAL REMEDIATION WITH *JATROPHA CURCAS* L. SEEDLINGS GROWN ON SPENT OIL POLLUTED SOIL

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ABSTRACT

Soil contamination with Spent Lubricating Oil (SLO) from automobiles is a growing concern in many African countries including Nigeria. SLO has adverse environmental effect because of its highly toxic constituents including heavy metals such as Pb, Zn, Ni, Cr, Ar, Cd, Cu and Fe as well as complex mixtures of heavy Polycyclic Aromatic Hydrocarbons (PAHs). The presence of this wide range of toxic metals and compounds is responsible for its perceived adverse effect on flora and fauna in particular and the environment in general. Phytoremediation is a novel, environmentally friendly and cost effective approach used in restoring SLO polluted soils. This study, therefore, employed *Jatropha curcas* seedlings in phytoremediating organically amended and unamended soil contaminated with 0, 3 and 6% (w/w) SLO for 84 days. Total Petroleum Hydrocarbon (TPH) and heavy metal concentration of the phytoremediated soil were assessed every 28 days and at the beginning and the end of the experiment respectively. Phytoremediation with *J. curcas* seedlings was effective in the breakdown of TPH content of the polluted soil. At the end of the study, TPH reduction was higher in phytoremediated soil with up to 91.54% in amended soil and 84.81% in unamended soil at 3% level of pollution. For the three heavy metals investigated, there was a general reduction in their concentration at the end of the phytoremediation process in the order Pb>Cd>Fe. This study has shown that *J. curcas* seedlings together with organic soil amendment is a veritable tool for phytoremediation of SLO polluted soils.

Keywords: *Phytoremediation, Jatropha curcas, Heavy Metals, SLO, TPH*

INTRODUCTION

Spent oil contamination of soils is a devastating environmental problem plaguing Nigeria and other developing countries. The effect of such contamination and pollution is felt in agriculture, animal and human health as well as the general state of the environment. It is known that changes in soil properties associated with spent oil contamination often lead to water and oxygen deficit as well as shortage of available forms of Nitrogen and phosphorus (Wyszokowska and Kucharski, 2000). Contamination of soil environment can also limit soil protective functions, upset metabolic activities, functions and chemical characteristics as well as reduce fertility and ultimately affect plant production (Gang *et al.,* 1996).

The reason for the perceived dangerous effect of SLO is because it is a complex mixture of hydrocarbons and other organic compounds including some organometallics (Buttler and Mason, 1997). The Polycyclic Aromatic Hydrocarbons and heavy metals inherent in SLO are known to be among the most toxic and hazardous pollutants in the environment (Boochan *et al.,* 2000).

Uncontrolled and indiscriminate introduction of this category of pollutants into the environment in this part of the world, is eliciting great concern among scholars and environmentalists especially because of the insidious nature of SLO. Adegoroye (1997) reported that in Nigeria and some developing countries about 80 million litres of waste engine oil is generated annually from mechanic workshops and discharged carelessly into the environment. This renders the environment unsightly and constitutes a potential threat to humans, animals and vegetation (Adelowo *et al.,* 2006). The SLO eventually end up on the farmlands, fish ponds, rivers, lakes etc. Bamiro and Osibanjo (2004) gave a more comprehensive estimate of SLO generation in Nigeria. It was reported that up to 200 million litres of spent lubricating or used oil is generated annually mainly from the industrial and transportation sectors.

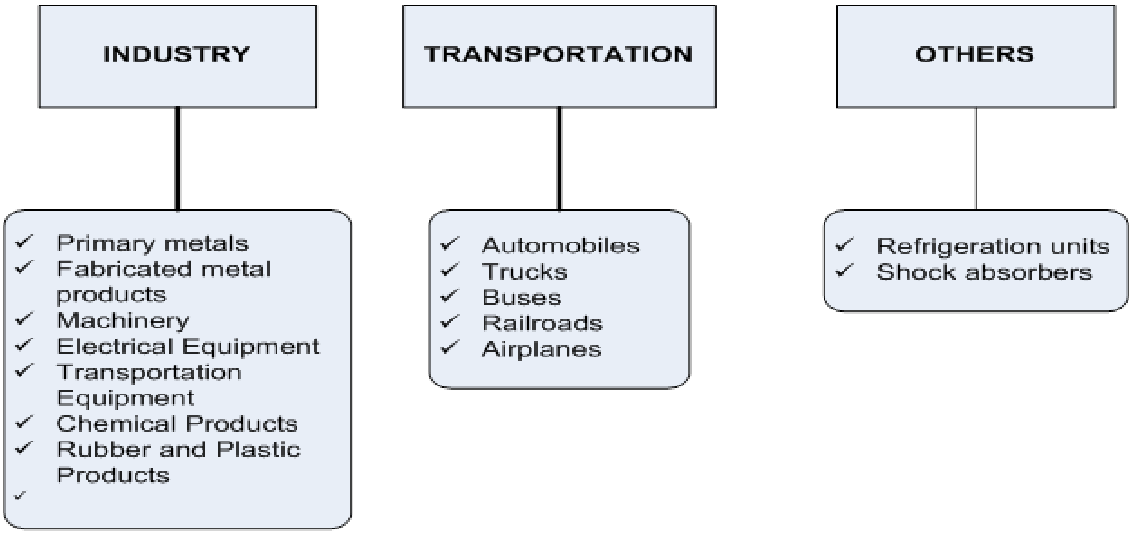


FIG.1: MAJOR SOURCES OF SPENT LUBRICATING OIL IN THE ENVIRONMENT

PLATE 1: IMPROPERLY DISPOSED SPENT LUBRICATING OIL BY ROAD SIDE
Source: Bamiro and Osibanjo (2004)

PLATE 2: STREAM POLLUTED BY SPENT LUBRICATING OIL
Source: Bamiro and Osibanjo (2004)

It has, therefore, become highly necessary to carry out remedial activities that will ensure that SLO is intercepted and removed from the environment to prevent it from impacting its toxic effects on the flora and fauna components. A veritable option that could be useful in this regard is phytoremediation. Phytoremediation is the use of living green plants for the removal of contaminants (Nedunuri, *et al.,* 2007). It potentially offers unique, low cost solutions to many problems of soil contamination since it does not require expensive equipment or highly specialized personnel (Liu *et al.,* 2000).

The objective of this work, therefore, was to determine the potential of *Jatropha curcas* in phytoremediating of spent oil polluted soil with special emphasis on the organic and inorganic components (Total Petroleum Hydrocarbon and Heavy metals) of the SLO. The choice of *Jatropha curcas* is borne out of the fact that it has been used on heavy metal polluted soils especially hexavalent chromium, in some countries of the world (Mangkaedihardjo *et al.,* 2008). Also, it is known to be a highly resistant species which thrives well in adverse conditions (The Biomass Project, 2000).

MATERIALS AND METHODS

STUDY AREA

The experiment was carried out at the Nursery Site of the Moist Forest Research Station (6^0 32'N $5.^0$ 58'E), Forestry Research Institute of Nigeria (FRIN) Benin City, Edo State, Nigeria.

SOIL SAMPLING

Top soil (0 – 15cm) was collected from the forest floor of Acacia plantation of the Research Station. The soil was thoroughly mixed and passed through a 2mm sieve to remove the non-soil particulate. The physical and chemical properties of the soil including heavy metal analysis were determined prior to introduction of the *J. curcas*. Contamination was done at 3 levels (0%, 3% and 6% w/w) of spent oil in 6kg top soil and two classes of soil were used based on amendment with organic manure (amended and unamended soils). In both cases, the soil was thoroughly homogenized.

SOIL PREPARATION AND PLANTING

Six kilogramme (6kg) polythene pots were utilized for the experiment. Experimental Design was 2 x 3 Factorial in a Completely Randomized Design (CRD) and replicated 3 times. The first factor was soil amendment (amended and unamended soil) and the second factor was three levels of spent oil pollution (0%, 3% and 6% weight by weight (w/w)). Ten seedlings were used for each level of pollution, translating to 30 seedlings per replicate and a total of 180 seedlings (90 seedlings for amended soil and 90 seedlings for unamended soil) for the experimental setup.

The pots were filled with topsoil, thoroughly mixed for even distribution of introduced organic manure (10% w/w) and spent oil contaminants and watered to field capacity. Earlier raised seedlings of *J. curcas* were transplanted to the polluted soils at 3 weeks after planting. The investigation was carried out for 12 weeks.

Based on the setup, the treatment combinations used in this study were:

UNAMENDED (w/w)
0% level of contamination
6kg topsoil+0 kg spent lubricating oil **(NP_0)**
3% level of contamination
6kg topsoil + 0.18kg of spent lubricating oil **(NP_3)**
6% level of contamination
6kg topsoil+ 0.36kg of spent lubricating oil **(NP_6)**

AMENDED (w/w)
0% level of contamination
6kg topsoil+0 kg spent lubricating oil + 0.6 kg Organic Manure **(AP_0)**
3% level of contamination
6kg topsoil+ 0.18kg of spent lubricating oil + 0.6 kg Organic Manure (**AP_3)**
6% level of contamination
6kg topsoil+ 0.36kg of spent lubricating oil + 0.6 kg Organic Manure **(AP_6)**

LABORATORY ANALYSIS

Soil and organic waste total Nitrogen (N) and Carbon (C) contents were determined using the Macro-Kjeldahl and Furnace Methods respectively. Exchangeable Calcium (Ca), Magnesium (Mg), Potassium (K) and Sodium (Na) were extracted with neutral normal ammonium acetate buffer. Exchangeable K and Na were determined using Flame Photometer (Gallenkamp Model FH 500) and exchangeable Ca and Mg by Atomic Absorption Spectophotometer (AAS). Soil pH was determined using a Glass Electrode pH metre (Rent Model 720) in distilled water (A.O.A.C. 2003).

Heavy metals determination was done by the Atomic Absorption Spectrophotometry (AAS) after digestion in aqua regia (1:3 of HCl - HNO3) (A.O.A.C 2003). Total Petroleum Hydrocarbon (TPH) analysis was done using the method of Odu *et. al.,* 1989. Ten grammes (10g) of soil was weighed into 50ml flask and 20ml Toluene (Analar Grade) was added. After shaking for 30minutes on an Orbital Shaker, the liquid phase of the extract was measured at 420 nanometre (nm) using DR/4000 spectrophotometer. The TPH in the soil was estimated with reference to a standard curve derived from fresh used engine oil diluted with toluene.

RESULTS

Physicochemical Parameters of Soil Used for Phytoremediation

The physicochemical properties of the soil and organic manure are presented in Table 1. The soil was predominantly sandy with a pH of 6.85.

Total petroleum hydrocarbon (TPH) variation in Phytoremediated Soil

The net percentage loss of TPH of phytoremediated soil (Table 2) reveals higher percentage reduction in TPH at 0, 3 and 6% levels of contamination for amended soil as compared to non-amended soil (29.84, 44.02, 32.52; 12.89, 34.59, 23.20%) at the end of 28 days of remediation. The same trend existed up till the 84th day of remediation; higher percentage reductions were recorded in amended soil as against non-amended soil (31.14, 33.39, 15.02; 19.93, 29.90, 61.81 13.08%). Fig. 2 gives a graphical representation of the total percentage reduction of TPH, for the two soil types and three levels of pollution by the end of the study. Percentage reduction was higher in amended soil (73.49, 91.54, 85.01%) as compared to unamended soil (63.88, 84.81, 73.77%) at 0, 3 and 6% levels of pollution respectively.

Heavy Metal Variation of Phytoremediated Soil

The changes in heavy metal concentration as a result of phytoremediation are represented graphically in Fig 3. It was observed that heavy metal concentrations in organic manure amended soil were higher than the unamended soil. There was a general decline in concentration of heavy metals for both soil types. The mean percentage reduction followed the order Pb>Cd>Fe respectively across the 3 levels of pollution for the two soil categories (Table 3).

TABLE 1: PHYSICOCHEMICAL PROPERTIES OF SOIL AND ORGANIC MANURE USED FOR PHYTOREMEDIATION

PARAMETERS	ORGANIC MANURE	SOIL
Organic Carbon (g/kg)	36.38	0.93
% Sand	6.26	91.84
% Silt	0.00	4.67
% Clay	0.00	3.49
pH	5.78	6.85
N (g/kg)	2.13	0.12
Ca (Cmol/kg)	1.18	0.008
Mg (Cmol/kg)	0.67	0.003
K (Cmol/kg)	1.03	0.011
Na (Cmol/kg)	0.49	0.006
Pb (mg/kg)	2.37	2.21
Cd (mg/kg)	0.18	0.43
Fe (g/kg)	1.863	0.062

TABLE 2: NET PERCENTAGE LOSS OF TOTAL PETROLEUM HYDROCARBON (TPH) IN PHYTOREMEDIATED SOIL

Treatments	TPH% Loss		
	Day28 (4 weeks)	Day 56 (8 weeks)	Day 84 (12 weeks)
NP_0	12.89 ± 1.635	47.35 ± 7.400	19.93 ± 9.815
NP_3	34.59 ± 2.370	66.82 ± 1.185	29.90 ± 1.510
NP_6	23.20 ± 0.460	63.56 ± 1.875	61.81 ± 13.735
AP_0	29.84 ± 0 .845	45.12 ± 1.055	31.14 ± 0.270
AP_3	44.02 ± 3.810	77.18 ± 1.825	33.39 ± 0.010
AP_6	32.52 ± 3.195	73.83 ± 0.525	15.02 ± 0.525

TPH – Total Petroleum Hydrocarbon; N - Unamended Soil; A - Amended Soil; P_0, P_3 and P_6 – 0,3 and 6% Pollution Levels

TABLE 3: PERCENTAGE REDUCTION IN HEAVY METAL CONTENTS OF CONTAMINATED SOIL AT 12 WEEKS

SAMPLE	Pb(%)	Cd (%)	Fe(%)
NP_0	51.48±0.430	39.32±7.740	20.45±1.900
NP_3	51.97±0.390	29.77±1.685	9.38±1.210
NP_6	25.76±0.050	28.66±3.060	8.91±0.130
AP_0	28.17±0.250	32.85±2.450	9.43±0.100
AP_3	22.80±0.515	20.70±0.800	8.05±0.460
AP_6	31.59±0.375	9.93±1.080	7.10±0.495

N - Unamended Soil
A - Amended Soil
P_0, P_3 and P_6 – 0,3 and 6% Pollution Levels

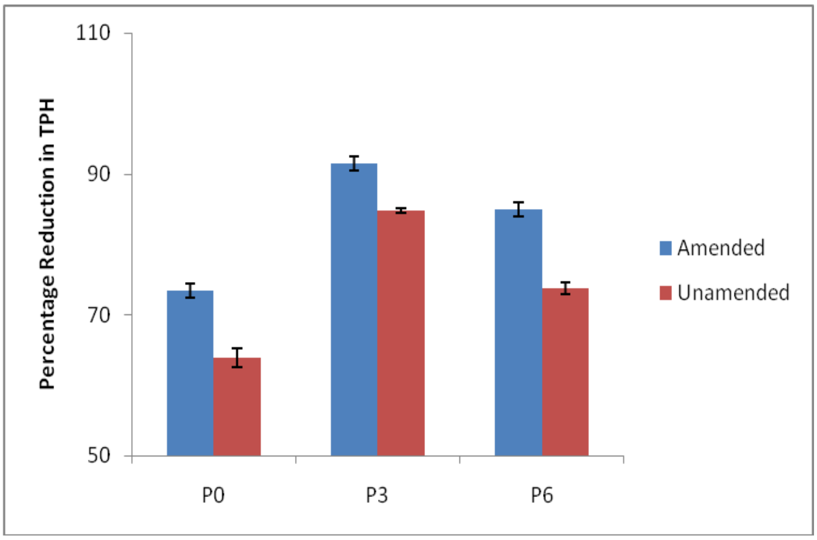
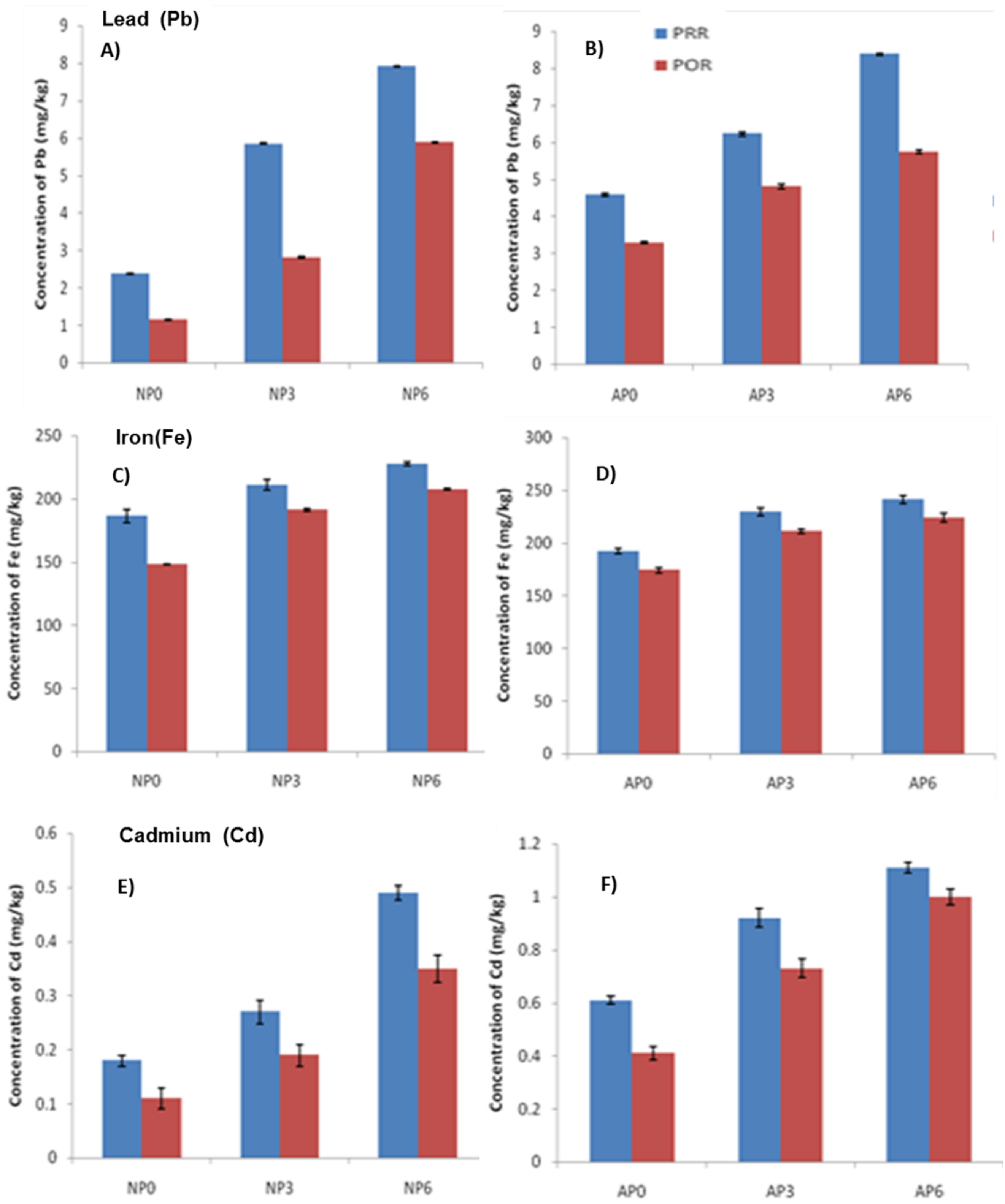


FIG 2: PERCENTAGE REDUCTION OF TPH OF PHYTOREMEDIATED SOIL AT 12 WEEKS
P_0, P_3 and P_6 – 0,3 and 6% Pollution Levels

Figs. 3a-3f: Lead, Iron and Cadmium Concentration in SLO Polluted Soil for Amended and Unamended Soil before and after Phytoremediation. N - Unamended Soil; A - Amended Soil; P_0, P_3 and P_6 – 0,3 and 6% Pollution Levels; PRR- Pre-remediated concentration; POR- Post-remediated concentration



DISCUSSION AND CONCLUSION

This study revealed after 12 weeks of phytoremediation, a general minimal reduction in the concentrations of heavy metals in the order (Pb>Cd>Fe). The least percentage reduction in concentration was observed in Fe which interestingly had the highest concentration (186.30 – 241.30 mg/kg). The effectiveness of *Jatropha curcas* in the removal of heavy metals from polluted soil has been well studied. Jamil *et al.,* (2009) reported, in their work, that *J. curcas* especially when supplied with basic plant nutrients, can be very useful in accumulating heavy metals such as Cu, Mn, Cr, and Fe. Mangkoedihardjo and Surahmaida (2008) stated that *J. curcas* could be used in the phytoremediation of heavy metals especially if the initial maximum concentration is not more that 50mg/kg. This might be the reason why, in this study, percentage reduction in Fe concentration was least after phytoremediation since its concentration far exceeded 50mg/kg.

Other studies on the applicability of *J. curcas* in phytoremediation include that of Surendra and Rana, (2010) who investigated the translocation and tolerance of *J.curcas* to Fe and concluded that the species is suitable for phytoremediation of Fe-contaminated wasteland soils. Also, Mathiyazhagan and Natarajan (2013) investigated the use of *Vigna unguiculata, Vigna radiata, Jatropha curcas* and *Oryza sativa* in the phytoremediation of Cd, Pb, Zn, Cr, Mn and Fe polluted waste dump site and concluded that *J. curcas* compared to others showed reasonable uptake of the elements. More importantly, Chehregani and Behrouz (2007) explained that the plant being a species of *Euphorbiaceae* family could be effective in removing Pb and Cd as demonstrated by *Euphorbia cheirandenia.* This might explain why Pb and Cd had the highest reduction in concentration after phytoremediation in this study.

This study also examined the biodegradation of the organic component of the SLO in the form of Total Petroleum Hydrocarbon (TPH). From the results, there was reduction in TPH within the first 28 days of phytoremediation. Organic amendment enhanced the rate of degradation. This is in line with the submission of Winnike-McMillan *et al.,* (2003) that organic matter enhances the bioavailability of hydrophobic organic pollutants in hydrocarbon polluted soils and also in accordance with Abioye *et al.,* (2009) who reported enhanced biodegradation of SLO in polluted soil with the use of organic wastes; Banana Skin, Spent Mushroom Compost and

Brewery Spent Grain. In the same vein, Agamuthu *et al.,* (2010) utilized *J. curcas* in the phytoremediation of SLO contaminated soil at 1 and 2.5% levels of contamination. It was reported that the addition of organic waste to *J. curcas,* remediated the soil rapidly by enhancing the removal of SLO from the contaminated soil. The enhanced TPH degradation in the phytoremediated soil could be due to increased activities of rhizospheric bacteria within the root zone of the *J. curcas* plants. Plants can enhance biodegradation of organic pollutants by microbes in their rhizosphere through the process of phytostimulation or rhizodegradation according to Nwoko *et al*., (2007).

In conclusion, this study has shown that *J. curcas* seedlings together with organic soil amendment is a veritable tool for phytoremediation of SLO polluted soils as well as phytoextraction of Pb, Cd, Fe in SLO polluted soils.

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ANALYSIS OF CHOICE OF INDIGENOUS SOIL MANAGEMENT TECHNOLOGY AMONG FLUTED PUMPKIN FARMERS IN AKWA IBOM STATE, NIGERIA

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ABSTRACT

The study identified the indigenous soil Management technologies used by fluted pumpkin (*Telfairia occidentalis*) farmers in Akwa Ibom State. It also identified factors that influence the choice of use among farmers in the state. Two hundred and fifty fluted pumpkin farmers were randomly sampled and used for this study. Structured questionnaires were used to collect data needed for the analysis. Descriptive analysis and multinomial Logit model regression was used to analyze data collected. The use of wood ash, decomposed crop residues, land fallowing, making of molds or heaps, tillage, cover cropping and the use of animal droppings are popular indigenous soil management technologies common among fluted pumpkin farmers in the state. The result of the empirical estimation of the multinomial logit revealed that, gender (female), age, household size, farm size, frequency of extension agent contact, years of membership in a social group, frequency of rainfall, number of sunshine hours, access to credit, farming experience and marital status of fluted pumpkin farmers are important decision variables that influenced the use of selected indigenous soil management technology in the study area. Based on the research findings, it is recommended that, the socio-economic characteristics of vegetable farmers should be taken into consideration when formulating climate change policies and also when introducing adaptation strategies or technologies to rural farmers in the study area. A standard metrological center should be established at strategy positions in the state to monitor rainfall and sunshine variations in the state.

Keywords: Farmers, fluted pumpkin, multinomial logit, adaptation, soil management

INTRODUCTION

In recent years, adaptation to climate change has become a major concern to rural poor farmers, researchers and even policy-makers alike. Common adaptation methods in agriculture especially in the developing countries include; the use of new crop varieties, livestock species, poultry birds, irrigation, crop diversification, adoption of mixed crop, Fadama cultivation, and the use of improved soil management technology among others (Nhemachena and Hassan, 2007). Rapidly declining soil productivity amidst diminishing per capita holdings of arable land poses a severe threat to sustainability of agricultural production and livelihoods for the majority of the farming population in Sub Saharan Africa. Due to their heavy dependence on agriculture, efforts to sustain the soil resource base are critical to stimulating economic development in these countries. Unfortunately, adoption of improved recommendations still remains very minimal, while efforts to understand farmers' decision-making environment with regard to adoption of soil conservation technologies have been sidelined (Kabuli and Phiri, 2005)

To enhance policy towards tackling the challenges that climate change poses to farmers, it is important to know factors influencing farmers' adaptation to adverse climate change. According to Intergovernmental Panel on Climate Change (IPCC) (2001), cited in Ekpo *et al.,* (2012), climate change means a change in variability of weather of a region over a period of at least thirty years. The climate change has considerable and sustained effects on agriculture in developing countries, and according to the Nigeria Environmental Study Team (NEST) (2004), the effects of climatic change on agriculture in developing countries have implications for food security in a long run especially in Africa.

Akwa Ibom State is one of the states in the South-South region of Nigeria. The state is basically an agrarian society. Vegetable crops cultivation is popular in this region following the presence of rich water bodies along the coastal region and in some spotted upland regions. Popular among vegetables grown in the area is *Telfairia occidentalis* or fluted pumpkin (Akpan and Aya, 2009). The crop is cultivated on upland during rainy season and in wetland (alluvial soil) or F*adama* areas during dry season. It is the most preferred homestead crop among the *Ibibios* and *Efiks* in the region. The crop is cultivated for it leaves and flute. Thus leafy *Telfairia occidentalis* constitutes an important additive to the dietary requirement of majority of residents in the region. The demand for this leafy vegetable is high, and is all year round. Owing to the importance of this leafy vegetable there is need to identify those factors that influence *Telfairia* farmers' decisions on the choice of adaptation of indigenous soil management technology. Based on this premise, the study was basically designed to achieve the following specific objectives:

- Identify the indigenous soil Management technologies used by fluted pumpkin *(Telfairia occidentalis)* farmers in Akwa Ibom State.
- Identify factors that influence the choice of indigenous soil management technology among *Telfairia* farmers in Akwa Ibom State,

Research Methodology

The Study Area and Sampling Techniques and Data Collection

The study was conducted in Akwa Ibom State, Nigeria. Combination of sampling procedures was used to select *Telfairia* farmers in the study area. A total of 250 *Telfairia* farmers were used for the data collection.

Empirical Model specification

The Multinomial logit regression

The Multinomial Logit (MNL) model was employed to determine factors influencing the choice of indigenous soil management technique among *Telfairia* farmers in Akwa Ibom State. The study assumes that the choice of indigenous soil management techniques among *Telfairia farmers* is influenced by the changing nature of the environment, which has a direct bearing on climate change. The MNL model was preferred because of its flexibility and ability to analyze multi-decision on indigenous soil management techniques among *Telfairia* farmers in the study area.

The MNL model is expressed as follows:

$$P(y=j) = \frac{e^{\beta_j x_i}}{\sum_{k=0}^{4} e^{\beta_j x_i}}, \qquad j = 0,1,2,3,4 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where, *y* denotes a random variable taking on the values {0, 1, 2… J}, for a non-negative integer *J;* while *"x"* denotes a set of conditioning variables. In this study, *y* represents soil management techniques while x represents *Telfairia* farmers' socio-economic characteristics and farm specific constraints.

Where;

$$Y_{i=0.1,\dots,J} = \delta_0 + \delta_1 GEN + \delta_2 AGE + \delta_3 EDU + \delta_4 HHS + \delta_5 FAS + \delta_6 OFI + \delta_7 FIN + \delta_8 EXT + \delta_9 CRE + \delta_{10} SGP + \delta_{11} LOW + \delta_{12} EXP + \delta_{13} MAS + \delta_{14} FRF + \delta_{15} NSH + \mu_1 \dots\dots (1)$$

Where

Y_0 is the choice of not using any indigenous soil management technology

Y_1 is the choice of using animal droppings as soil management technology

Y_2 is the choice of using wood ash as soil management technology

Y_3 is the choice of using Tillage/bedding as soil management technology

Y_4 is the choice of using decomposed crop residues as soil management technology

The explanatory variables are:

GEN = Gender of *Telfaria* Farmer (dummy variable: 1 for female and 0 for male)

AGE = Age of respondent (years)

EDU = Farmer's years of formal education

HHS = Household size of Telfairia farmer (number)

FAS = Farm size of *Telfairia* farmer (hectare)

OFI = Off- farm income of *Telfairia* farmer (naira per annum)

FIN = Farm income derived from *Telfairia* cultivation (Naira per annum)

EXT = Contact with extension agent (number of times)

CRE = Access to credit facilities (dummy variable; 1 for access and 0 otherwise)

SGP = Member of a social group (years)

LOW = Method of land ownership (1 for inherited land and 0 otherwise)

EXP = Farming experience (years)

MAS = Marital status of respondents (dummy variable; 1 for married and 0 otherwise)

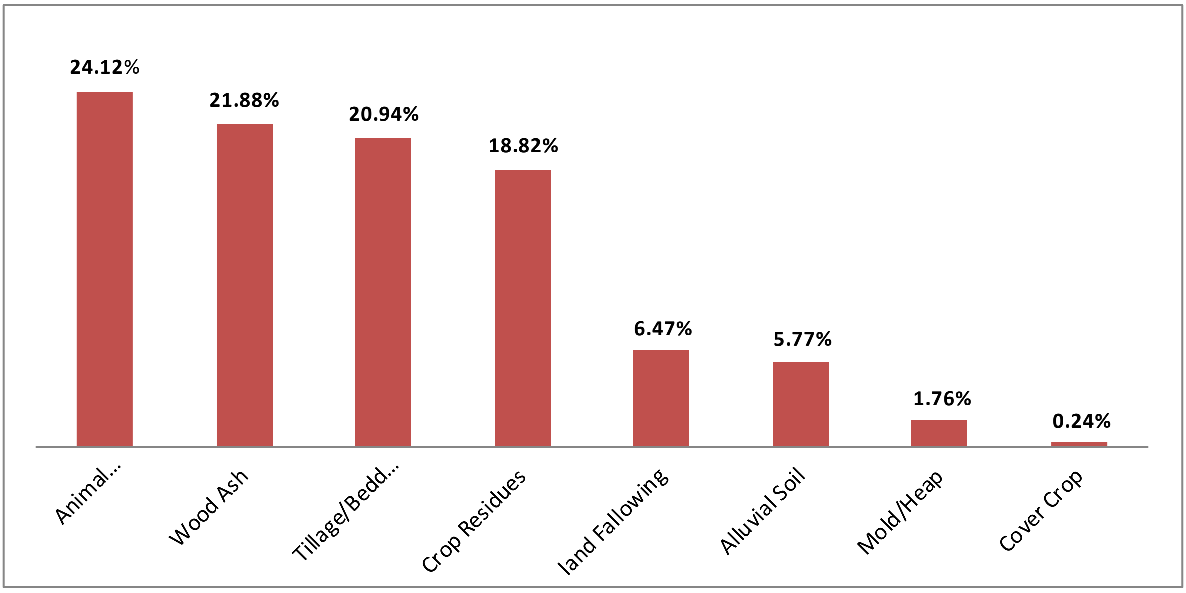
FRF = Perceived frequency of rainfall (dummy; 1 for much rainfalls and 0 otherwise)

NSH = Perceived hours of sunshine (dummy; 1 for much hours and 0 otherwise)

RESULTS AND DISCUSSION

Indigenous soil Management Technologies Used by *Telfairia* farmers in Akwa Ibom State

The study identified seven popular indigenous soil management technologies among *Telfairia* farmers in the study area. Figure 1 shows the popular indigenous soil management technologies among farmers in the region. The use of animal droppings (poultry litter, cow dung, goat dropping) (24.12%); wood ash (21.88%), tillage/bedding (20.94%) and the use of crop residues (18.82%) were prominent indigenous soil management technologies among respondents.



Other indigenous soil management technologies available to fluted pumpkin farmers in the area includes; land fallowing/shifting cultivation (6.47%); planting in alluvial soil (5.77%), the use of mold/Heap (1.76%) and cover cropping (0.24%) .

Result of the Multinomial Logit Regression

Table 1 presents the estimates of the Multinomial Logit model for choice of indigenous soil management technology by *Telfairia* farmers in Akwa Ibom state. The result revealed that, the log likelihood ratio of 159.400 is significant at 1% probability level. This indicates that the specified model has a strong explanatory power. The pseudo R^2 of 0.79586 shows that about 79.59% of variability in the dependent variables are associated with the specified explanatory variables.

Determinants of the choice of animal dropping technology among Telfairia farmers in Akwa Ibom State

For the choice of animal droppings technology, the empirical result revealed that, the coefficient of education is negative and statistically significant at 5% probability level. This implies that, the choice of using animal droppings as indigenous soil management technology among *Telfairia* farmers in Akwa Ibom State decreases with increase in acquisition of formal education. On the other hand, farmer's age (5%); household size (1%); farm size (1%); farm income (1%), extension contact (10%); membership of a social group (1%); farm experience (5%) and perceived frequency of rainfall (1%) are significant positive determinants of the choice of using animal droppings among fluted pumpkin farmers in the study area.

Table 1: Estimates of the Multinomial Logit parameters of adoption choice of soil management techniques among *Telfairia* farmers in Akwa Ibom State

Variables	**Use of Animal Droppings**	**Use of wood ash to fortified the soil**	**Use of Tillage/Bedding**	**Use of decomposed crop residues**
	Logistic coefficient	Logistic coefficient	Logistic coefficient	Logistic coefficient
Constant	21.89 (1.96)*	-7.72 (-1.52)	30.94 (2.69)***	-23.42 (-1.99)*
GEN	5.67 (0.78)	1.54 (0.66)	-5.29 (-2.56)**	1.51 (0.63)
AGE	0.12 (2.97)***	0.17 (2.29)**	-0.16 (-2.27)**	-0.19 (-2.85)***
EDU	-0.31 (-2.08)**	-0.08 (-2.19)**	0.38 (3.07)***	0.07 (0.02)
HHS	0.21 (3.84)***	0.75 (1.93)*	-0.23 (-0.91)	0.80 (1.4)
FAS	8.90 (6.03)***	-5.23 (-2.69)***	-7.91 (-3.08)***	-3.84 (3.43)***
OFI	-1.68e-04 (-1.12)	1.17e-04 (0.57)	3.62e-04 (1.36)	1.01e-04 (1.12)
FIN	1.34e-04 (5.10)***	-1.5-4e-04 (-3.57)***	2.0e-04 (3.39)***	-1.90e-04 (-3.43)***
EXT	0.19 (2.08)**	-0.54 (-0.67)	0.15 (1.01)	-0.55 (-2.56)**
CRE	1.89 (1.06)	-2.69 (-1.58)	1.81 (1.06)	1.69 (1.10)
SGP	0.31 (3.34)***	-0.51 (-2.57)**	0.92 (2.61)**	0.12 (1.01)
LOW	1.01 (0.74)	2.41 (1.33)	1.98 (0.62)	3.23 (1.12)
EXP	0.65 (2.15)**	0.14 (3.29)***	0.75 (2.87)***	0.14 (1.20)
MAS	2.21 (0.22)	2.49 (0.30)	2.51 (2.24)**	4.40 (2.46)**
FRF	0.75 (3.45)***	0.14 (1.57)	0.75 (1.85)*	0.19 (4.20)***
NSH	-2.21 (-0.24)	4.89 (4.31)***	-1.73 (-0.64)	-4.89 (1.19)
Schwarz criterion	517.87	Hannan-Quinn		366.65

Number of cases 'correctly predicted' = 227 (90.82%) Akaike criterion 331.85
Likelihood ratio test: = 159.400 [0.0000] Pseudo R^2 = 0.79586

Note: *, ** and *** represent 10%, 5% and 1% significant levels respectively. Figures in bracket are t-values. Variables are as defined in Equation 1.

Determinants of the choice of wood ash technology among *Telfairia* farmers in Akwa Ibom State

The result revealed that, farmers' age (5%); household size (10%); farm experience (1%) and perceived hours of sunshine (1%) are significant positive determinants of the choice to use wood ash among *Telfairia* farmers in the study area. The result implies that, increase in these variables increase the choice of wood ash as the preferred indigenous soil management technology among *Telfairia* farmers. For instance, increase in household size provides incentive for lower cost of farm inputs especially farm labour; while increase in sunshine hours increases the availability of wood ash. Contrary, increase in farmers' education (5%); farm size (1%); farm income (1%) and years of membership in a social group (5%) decline the use of wood ash technology among farmers.

Determinants of the choice of Tillage/Bedding technology among *Telfairia occendentalis* farmers in Akwa Ibom State

The empirical result showed that, the coefficients of farmers' education (5%), farm income (1%), membership of a social group (5%), farm experience (1%), Marital Status (1%) and perceived frequency of rainfall (10%) are positive and statistically significant with respect to the decision or probability to use bedding/tillage technology by *Telfairia* farmers. This means that, as these variables increase, the chance of using bedding/tillage technology maximizes among farmers. For instance, farmers that are married, have higher probability of using bedding/tillage soil management technology than the single ones. Perhaps, the cheap family labour available could be responsible for this result; and for the single farmers, it could be the high cost of hired labour or its scarcity in most farming communities in the area. On the opposite side, the slope coefficient of gender (5%), age (1%) and farm size (1%) are negative and statistically significant with respect to the decision or probability to use bedding/tillage technology by *Telfairia* farmers. The result satisfied the *a priori* expectations because increase in farmers' age reduces the potential of bedding/tillage activities in the farm. Also, tillage and bedding are tedious farm activities that are effectively handled by men folks. Therefore, higher proportion of women among *Telfairia* farmers reduces these activities in the farm. Moreover, increase in farm size will make manual tillage and bedding costly.

Determinants of the choice of decomposed crop residues Tillage/Bedding technology among *Telfairia occendentalis* farmers in Akwa Ibom State

The analysis revealed that, age (1%), farm size (1%) and farm income (1%) as well as contact with extension agent (5%) are negative determinants of the choice of decomposed crop residues as soil management technology among *Telfairia* farmers. On the other side, perceived frequency of rainfall (1%) and marital status (5%) of farmers are promoters of the choice of decomposed crop residues among *Telfairia* farmers in the region. This technology is mostly practiced during the rainy season, so that decomposition is enhanced.

Recommendations

Based on the research findings, it is recommended that, the socio-economic characteristics of arable crop farmers should be one of the important areas of consideration when formulating climate change policies and also when introducing soil or agricultural adaptation technologies to rural farmers. Exogenous supports such as formation of farmers' social or cooperative groups will enhanced adaptation of improve soil management technology among farmers. Strengthening the state extension system will guarantee that, up to date information on climate change and other farm technologies or innovations reached *Telfairia* farmers at appropriate time and form. A standard metrological center should be established at strategy positions in the state to monitor rainfall and sunshine variations in the state.

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PART V : Social science and agriculture in an era of environmental change

BARRIERS TO EFFICIENT SUPPLY CHAIN MANAGEMENT IN THE BROILER INDUSTRY IN AKWAIBOM STATE, NIGERIA

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ABSTRACT

This paper examines the supply chain in the broiler industry in Akwa Ibom State, Nigeria. The objectives were to identify the actors in the broiler supply chain, identify the barriers to efficient supply chain management and make recommendations for efficient supply chain management in the broiler industry. Data were collected using qualitative methods namely; Key Informant Interview with important actors in the broiler supply chain namely input suppliers (distributors of DOC, drugs, feed and equipment), farmers, traders (wholesalers and retailers), processors and the consumers. These groups of operators were identified as the key operators in the broiler supply chain. The barriers that are faced in the chain include; poor and lack of infrastructural facilities and equipment, poor co-ordination and collaboration among stakeholders, inadequate funds, inadequate extension services, inadequate veterinary service, high cost of feed and drugs, unstable market, lack of technical skills by small scale producers and disease infestation.

1.0: Introduction:

In Akwa Ibom State, poultry is a very important sector. The state is the leading producer of poultry and poultry products, particularly broilers and is virtually self-sufficient in the production of live-birds and eggs. It currently supplies live-birds and eggs to neighboring states such as; Cross River, Rivers and Abia State. However, many operators/entrepreneurs in the broiler sub sector have been voicing out their frustrations in carrying out their business due to a number of constraints including lack of vital inputs such as day-old chicks, feed, and drugs, among others. However, like any other economic venture, efficient broiler production depends on efficient flow and utilization of resources. Thus, efficient supply chain management becomes crucial.

Supply chain is a network of facilities and distribution entities (suppliers, manufacturers, distributors and retailers) that performs the function of procurement of raw materials into intermediate and finished product to customers (Islam and Habib, 2013). It is principally concerned with the flow of products and information between supply chain member organization which include procurement of materials, transformation of materials into finished products, and distribution of products to end customers .According Lambert et al (1998), 8 key processes make up the core of supply chain management namely (i) Customer relationship management, (ii) Customer service management, (iii) Demand management, (iv) Order fulfillment, (v) Manufacturing flow management (vi) Procurement, (vii) Product development and commercialization and (viii) Return management

Supply chain management according to Nyamah et al (2014) has become a major part of companies/firms management systems due to the numerous benefit associated to supply chain in today's business environment. It also has an important role to play in moving goods quickly to destinations. This paper examines the broiler industry in Akwa Ibom State to establish a better understanding of the industry by;

(i) Identifying the actors in the chain.
(ii) Identifying the barriers to efficient supply chain management and;
(i) Based on the findings of the study, make suggestions for efficient supply chain management in the broiler industry.

3.0: Methodology/Approach

Qualitative data were collected for analysis through in-depth interview of key informants in the broiler industry in Uyo metropolis. Uyo metropolis is the capital city of Akwa Ibom State and according to records available in the State Ministry of Agriculture, has the highest concentration of broiler farmers in the State. A total of 7 KII (Key Informant Interviews was conducted with the following categories of key stakeholders/operators in the broiler sub-sector; broiler producers (backyard and small scale producer), DOC distributor, trader, processor (live-bird market processors and soya meat processors) who were chosen based on their years of experience in the industry and consumers. Interview guide questions covered poultry industry practices and standards; farmers, traders and processors concerns; values, barriers and aspirations in the industry.

4.0: Results and Discussion

4.1: The Broiler Supply Chain in Akwa Ibom State

Actors in the Broiler Chain: The important actors in the broiler supply chain in Akwa Ibom State include:

Inputs Suppliers: They include distributors of day-old chick (DOC), drugs, feed and equipment suppliers. These groups of suppliers render services both in wholesale and retail to farmers.

In the past, some companies were found to import fertile eggs for hatching but their farms are no more functional, while no company has been found to operate hatcheries with parent stock. Several companies import DOC for sale to farmers from the western part of Nigeria particularly Ibadan. These distributors extend the geographical and client reach of the hatcheries to ensure timely delivery of DOC to producers. Distributors agreed to the fact that DOC demands are usually in much more high demand towards peak holiday periods like Christmas, New Year, Easter and Salah which means that timing of delivery of DOC is critical. Formerly these distributors pay their ways to purchase the chicks. But presently, DOC distributors deposit large sums of money with hatchery operators to ensure timely supply and at the same time providing a type of credit facility to the hatchery operators.

Feeds are booked by retailers from outside the state in large quantities and sold out at retail outlets to farmers. Drugs, feed additives and equipment are sold by veterinary shops. Most of these items are imported while those produced within are known to be of low quality.

Producers: Broiler producers in Akwa Ibom State are basically small and medium scale producers. The small scale producers house their birds mostly in cages or place them on deep litter, providing them with medication and water on a regular basis. Most small scale producers often have other income earning activities in addition to poultry production. Their stock of birds ranges from 50 – 200 birds on each booking basis. The medium scale producers have highly organised housing, feeding and health care plans. Most of them are highly integrated and educated, compounding their own feed, processing and packaging their broiler for the final consumer market. They are very few and their stock of birds ranges from 200 – 2000.

Producers buy DOC and other inputs from distributors and raise them for 6 – 8 weeks. These birds attain a live weight of between 2 – 2.5kg and dressed weight of between 1.5 – 1.9kg at which stage they are ready for market. One problem that affects the business is that farmers do not produce for a particular market, but rather look for market after production.

In broiler production, actors who support it include; investors (owners), farm managers, and farm workers. The investors plan, locate, finance, setup physical infrastructures and employ workers with appropriate qualifications of competence to execute the project. They then supervise and monitor the operations, taking appropriate action as and when necessary. They also beat the risk and earn the residual margin after all costs, levies and taxes have been paid. Workers carry out the day-to-day operations taking prompt actions to ensure growth, harvest and prevention of disease of careless handling of operation. But in the case of small-scale producers, they embody all of these functions themselves.

Also, producers are directly dependent on other actors, both in terms of inputs and services to support their production activity such as DOC, feed and health care supplies .And in terms of market outlets for their product , they depend on collectors (traders or retailers) and transporters.

Live bird Traders: These categories of operators go from poultry farm to poultry farm collecting live birds for sale. Sometimes, they buy from primary (rural) markets, bulk and transport to secondary (urban) or tertiary live-bird markets for subsequent sale to consumers. They often form an association with rules to guide their operations, particularly in the aspect of having a fixed price. It is observed that their association is not well co-ordinated. Their leaders are usually chosen by the traders based on their age, experience and capacity to manage critical situations such as settling conflicts.

Also to be found among live bird traders are the broiler producers. They are the main actors in the live bird trade and consist of commercial poultry farmers and backyard poultry keepers. Others are service providers (veterinary doctors), processors, transporters, supermarkets, restaurants, hotels, and suya spots and the final consumers. In the industry, traders form partnership with producers helping to provide market outlets for the finished products.

Processors: In most cases, they are traders or retailers who also act as processors. In the study area, about 90% of these processors are traders who sell live birds. They dress the birds for a fee in addition to the price paid for the bird. While 10% are individuals waiting around to be invited by the traders to dress one or two live birds that are bought by consumers for a fee of 100naira per bird.

Another category of processors are suya spot processors. They purchase, dress, butcher, cook and roast broiler meat for immediate consumption. The prices consumers pay covers the cost of the ingredients like salt, pepper and groundnut oil used. The birds are butchered into different parts such as; 2 thigh, 2 wings, giblets (heart, liver and neck), 2 breast split and 2 feet. All of these parts are sold at different prices. Fast food joints and hotels also act as processor. They buy live birds, process and sell at a much higher price. Processors can be found in major market in the city. These processors own tables, water holding drums, boiling pots, sharp knives and cutlasses. They serve the city dwellers particularly working class persons who do not have sufficient time to attend to processing of live birds. The processors, usually young men would boil water, dip chicken in hot water, de-feather, eviscerate and cut up the birds into various sizes. Observation showed that they make an effort to keep the processing environment clean though some others do litter the environment.

Supermarkets, restaurants, institutions, suya spots: Some other consumers of broiler meat purchase already cooked chicken from suya spots, hotels, restaurants and supermarket.

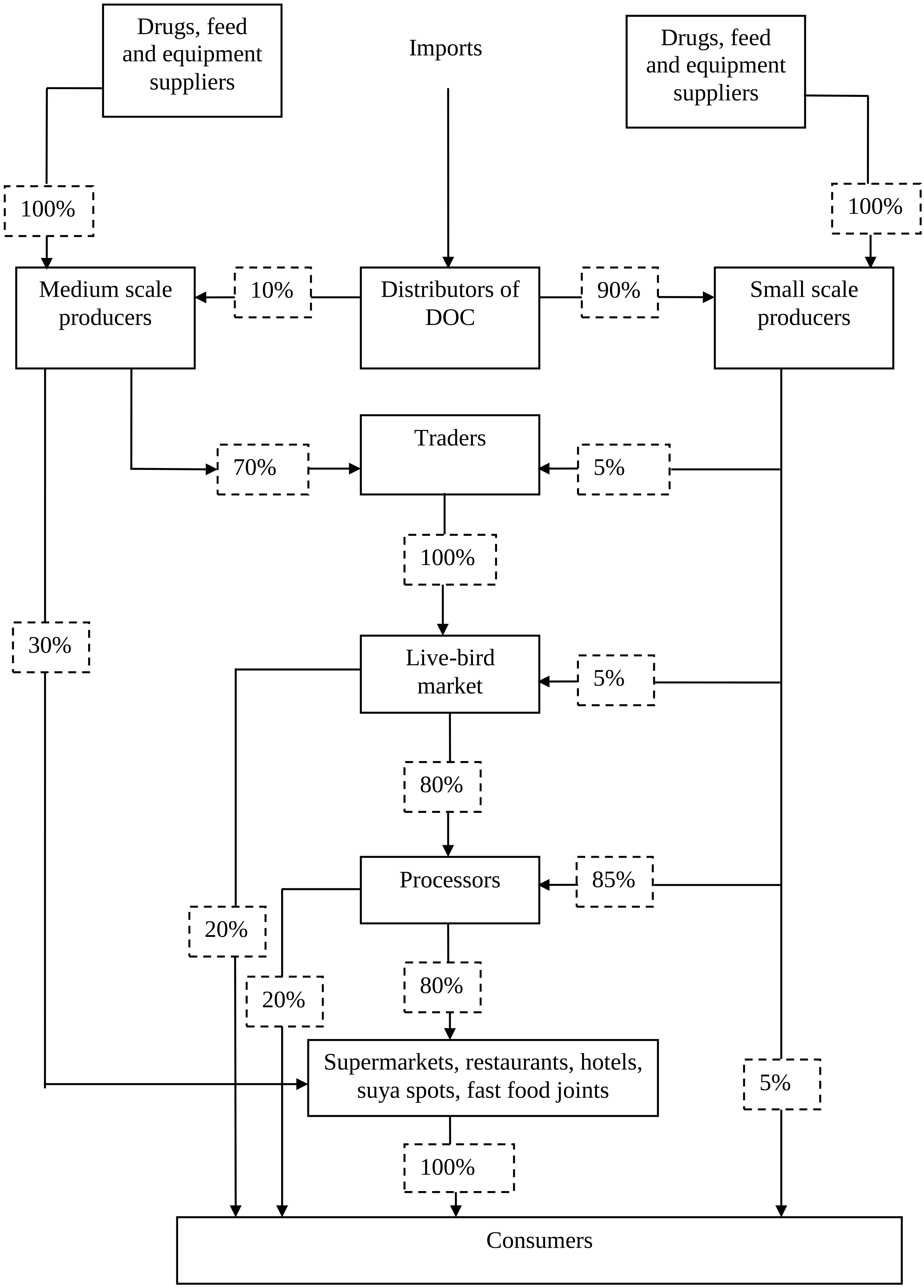
Consumers: Customers for retailers of live birds are mainly individual consumers who buy for domestic purposes. Generally most customers buy live birds and slaughter in their homes themselves while other customers request for the bird to be slaughtered and dressed for them by the retailers.

Finally, these consumers help various participants in the chain to earn income which provides livelihood or part thereof.

A part from the above actors, there are other supporters and influencers in the broiler chain. They include the extension workers, road transporters, and veterinary service directorate.

4.2: Flows and Values in the Broiler Chain

The supply chain of broiler in Akwa Ibom State begins with the distributors of day old chicks (DOC). As presented in figure 2 below, majority of this distributor are into drugs and feed supplies as well. These DOC are sourced from the south-west particularly Ibadan into the state. These distributors sell off 90% to small scale farmers and 10% to medium scale farmers. This is because the industry is dominated by small scale entrepreneurs. They use their financial power to prepay for the chicks and thus make substantial profit when they serve producers punctually. Medium scale farmers mostly form partnership with collectors (traders) who help provide market outlets for the finished products. As such, 70% of their live bird goes to the traders while 30% goes to clients such as supermarkets, restaurants, suya spots and hotels, which in turn further process broilers prior to sale to consumers. Small scale producers rely heavily on sales to processors who are their major clients (85%) while 5% each goes to the traders, live-bird market and consumers. Traders visit several farms to assemble broilers for further supplies. Feed and drug suppliers are also important actors because broiler requires varying amount of feed (starter, grower, and finisher) which they made available when needed by producers. Large number of birds is handled in the live-bird market because traders transport 100% of their sales there. Of these, an overwhelming majority of 80% are sold by the traders to the processors, who then sell 80% to restaurants, suya spots, hotels and supermarkets and only a small portion of 20% to consumers.



Source: Field Survey, 2014

Fig. 2: Flows and values in the broiler chain in Akwa Ibom State

4.3: Barriers to Efficient Supply Chain Management in the Broiler Industry in Akwa Ibom State

The following were identified as barriers to efficient supply chain management by discussants as well as key informants:

- **Poor infrastructural facilities and equipment**

Hatchery: Hatchery is essential for the production and supply of day old chicks to poultry farmers. However, in Akwa Ibom State, there is no functional hatchery. The only hatchery in the study area located in Idu Uruan, Uruan L.G.A is no longer in operation. This is a serious hindrance to efficient broiler supply chain management in the state because it increases the cost of production for farmers.

Feed Mill: There is no functional feed mill in Akwa Ibom Sate. This was identified by discussants as an impediment to efficient broiler supply chain. The delays and the cost of transporting feeds from distant places to the state were said to constitute a drain on the revenue of broiler farmers. They also make it difficult for the various operators to deliver efficient services.

Transport: Interstate roads are in very poor conditions. Poor conditions of interstate roads was said to bring about mortality of birds in transit. Traffic jams and 'galloping' on these roads were said to lead to delay of the delivery of DOC and live birds to destinations. This causes heat stress and ultimate death of birds.

- **Poor co-ordination and collaboration among stakeholders**

Poor co-ordination and collaboration among stakeholders is one of the challenges faced by the broiler industry in the state. The farmers and traders revealed that since their union is inactive, this leads to overpriced inputs and underpriced output and thus discourages increased production. Birds are sold at a much lower price by some traders against the agreed price.

The governance mechanism in the industry is primarily adhoc in nature, with limited co-ordination between different actors in terms of facilitating rules or standards for transaction. Producers in the chain have limited power because there are numerous, atomistic and price takers for input or output prices. Changes in input or output prices simply affect farm profits, and farmers particularly at the backyard scale. Farm associations in existence serve commercial interest in terms of pricing. Some farmers can mitigate higher prices through establishing their own feed mills, but such practices are restricted to larger farmers because they don't have the financial capacity. The farmers complained that the traders control the market the most because of their detailed knowledge of market outlets for birds supply and thus they take advantage of this situation. Traders play important roles in the provision of credit to retailers. Most times traders try to use their association to prevent farmers from bringing their live birds to the market, though the association is fairly weak in forcing members to stick to set prices. This makes the chain relationship imbued with confrontation rather than co-ordination as a mode of interaction and this constitutes a barrier.

- **Inadequate funds:** Most actors particularly producers do not have sufficient funds to invest in large scale production. Finance is also a hindrance to setting up a hatchery facility that can serve the entire region. Most small scale producers are denied funds by financial sectors because they have no collateral to present. Insufficient funds hinder upgrade of small and medium scale producers to modern and efficient processing equipment, incubators and feed mills.
- **Inadequate extension services:** The actors, most especially the unskilled farmers complained that the extension agents are out of their reach. This exposes them to challenges such as high mortality and lack of managerial techniques to adopt. The organization of a free government training to empower this group of actors will go a long way in boosting their business as recommended by a farmer and trader.
- **Inadequate Veterinary Services:** Only private veterinary services are available to broiler producers though at a higher cost, sometime hardly affordable by most small holders. Only one government veterinary hospital is available in the state. It services is not sufficient to all because of the long lineup of clients at the clinic on daily basis.
- **High cost of feed and drugs:** This was identified by both the small and medium scale producer as a major barrier encountered. This makes the business less profitable. But due to job scarcity, individual producers have no other choice than to stick to it. 85% of the expenses made in production are for purchasing feed and drugs.
- **Unstable market:** Market instability here has to do with “no ready market” for supplies and a constituting factor is the importation of frozen chicken from other countries which circulates all round different states. In 2003, government banned the importation of frozen poultry meat, and that enlarged the market for Nigerian poultry

produced, demonstrating government acknowledgement of the potentials of poultry farming.

Frozen broilers imported are widespread at food cold rooms and supermarkets in the state and they are sold at a much cheaper rate. This hinders sales for broiler producer because of the low cost of these products. This low cost has been found to be associated with the low cost of production of these frozen birds, thus creating a barrier to small holders supply of their birds in the study area.

- **Lack of technical skills by small scale producers:** Poor management is the problem in most cases. Some farmers lack the required skills to efficiently manage their farms. And in such cases, they are prone to errors in action and inaction. For instance, when appropriate drugs are not administered and also when they are not knowledgeable about the effect of accumulated litter on the farm. This directly has an effect on the supply chain.
- **Disease Infestation:** cough and diarrhea were the two aliments complained by the farmers in the study area. It was found that this is linked to poor feeding and poor housing management. This poor husbandry practices results to low productivity and high mortality, thus reducing the quantity and quality of birds supplied. During discussants with the farmers, it was suggested that proper training of farmers in the study area will go a long way in improving their managerial skills

5.0: Conclusion

The result of the study reveals that the broiler farmers, input suppliers, traders, and processors are facing barriers that hinder efficient broiler industry operation. These obstacles in the broiler supply chain should be removed otherwise the contributions of the broiler industry to the economy, the entrepreneur and the households would be missed.

6.0: Recommendations

To overcome the difficulties of broiler keeping and to make the business of broiler keeping and supply more profitable in the state, the following recommendations are put forward for the improvement of the industry:

1) Government and private entrepreneurs as well as corporate bodies should establish feed mills, hatcheries, new veterinary care centers and livestock drug industries so as to help control the prices of feed, DOC and drugs. The presence of a

large and functional hatchery will reduce transportation cost and mortality in birds, though most times mortality may be due to buses break down. Railway was pointed to being an efficient transport system that can translate to savings in delivery cost, inventory, quality, deterioration and wastage.

2) Registration of supply chain operators, quality standardization and trade regulation will help create co-ordination in the chain.

3) Efforts should be made to fix bad roads that lead to the location of day old chicks (DOC) purchase particularly and other inputs in general. This would reduce losses incurred by broiler farmers due to mortality of DOC while in transit.

4) Extension delivery system particularly the communication pattern and input delivery components must be strengthened. This will enable extension and related organizations to be in continual contact with the poultry farmers, traders, processors and together they can fashion out appropriate communication pattern, upgrade knowledge, attitudes and practices.

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VULNERABILITY ASSESSMENT OF CLIMATIC HAZARDS IN COASTAL GHANA; A LIVELIHOOD APPROACH

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ABSTRACT

Sea-level rise is expected to result in annual flooding and salinization of water sources across coastal Africa. Ultimately, the resultant effect will severely affect vulnerable population within low-lying areas. Vulnerability assessment was conducted with the view to identify coping strategies adopted at the community-level in dealing with climate change, with the aim of informing paradigm shifts in planning processes tandem with current global realities. Using Focus Group Discussions and In-Depth interviews in consonance with a livelihood framework tool we assessed the impact and coping strategies to global climate change amongst four dominant socioeconomic groups (i.e. fishermen, farmers, fishmongers and traders) within six communities in Greater Accra Region. Results obtained show negative impacts of climate change on financial, natural and social assets within these communities. Differentiated impacts amongst socioeconomic groups have implications for their collective responses to the effects of climate change. Building resilience amongst and within groups' demands that recognition is giving by government to current climate-related vulnerabilities of the coastal area. Integrated coastal zone management of the zone should be reflective of local ecological knowledge and equally embrace the coping strategies of the people to future climate change scenarios. Ultimately, developing a context specific coastal zone planning and policy will build resilience of the coast and indigenous occupations within the region.

Key Words

Greater Accra Region, Focus Group Discussions, Livelihoods.

Introduction

Impacts of climate change are scale dependent and are unevenly distributed across nations, regions, communities and individuals as a result of differential exposures and vulnerabilities. However, impacts of climate change are expressed quickly at local scales rather than over broad spatial scales; for at the community level experiences with climate extremes can identify inherent characteristics that enable or constrain a community to respond, recover and adapt (Dolan & Walker, 2004). Thus, the assessment of local realities of vulnerabilities to climatic hazards is of importance. But, despite the adoption of bottom-up approaches to issues of climate change, communities within the sub-region appear to be marginalised from developmental processes, as information continues to be focused at the national level. Yet, current projections of climate change (e.g. IPCC, 2007), demands strategic mapping of appropriate adaptation to combat the effect of climate change especially within vulnerable areas. Adaptation strategies require initial learning about different community's indigenous capacities, knowledge and practices of how to cope with climate hazards. This is vital for effective and appropriate policy and practice (Coulthard, 2008). In this light, the present research was designed to inform policy processes and developmental planning of the study area.

Ghana has a coastline of 528 km, with a significant proportion (42%) of the population living within the coast (CIESIN, 2002). The Ghanaian coast is particularly important in artisanal fishery, with economic opportunities related to marine and inland capture fisheries, and women featuring as key players in post-harvest activities (FAO, 2004). Invariably, most household within the coastal zone are natural resource dependent. The current decline in the fishing sector over the past four decades and incremental knowledge on impacts of climate change requires continuous experience-sharing on coping and adaptive strategies (cf. Atta-mills *et al*., 2004; IPCC, 2007; Dasgupta *et al.,* 2009). Livelihood assessment is a useful entry point for characterizing knowledge and practices related to climate change. Hence, the Sustainable Livelihood Framework (SLA) detailed in the next section is particularly useful in translating likely impacts of climate change on rural food production systems.

Sustainable Livelihood Approach as a Vulnerability Assessment Tool

The concept of SLA in rural systems recognizes five key assets (i.e. human, natural, financial, social and physical). It is the combination of these assets and activities which ultimately determines the strength or vulnerability of household strategies (Chambers & Conway, 1992; Badjeck *et al.,* 2010). Within climate change scholarships, the concept of livelihoods is employed to understand the vulnerability context of communities, including impacts and livelihood responses (Paavola, 2008). Importantly, within the purview of this paper, the SLA has been shown as a useful tool in small scale fishing, processing and trading to show how building on human and social capital among people involved in fisheries can support existing attempts to reduce their poverty and vulnerability (Neiland & Bene, 2004; Allison & Horemans, 2006). Vulnerability is a relative term and in many instances it is used together with risks to describe negative outcomes of hazards (Combest-Friedman *et al.,* 2012). In this study, we use the term as referring to the exposure of a social system to a particular climatic hazard and the attendant impacts on such systems. Thus, in the analyses of the vulnerability of the six communities, the following objectives were considered;

- To identify dominant socioeconomic groups most affected by climatic hazards,;
- To identify livelihood assets important for coping strategies and
- To learn from their experiences to inform developmental decision-making processes

Methodology

The Study Site: Greater Accra Region

The study area covered two divisions within The Greater Accra Region; Dangme East District (latitudes 5°45’S and 6°00’N and Longitude 0°20’W and 0°35’E) and Ashiedu-Keteke Sub Metro (5°35’S; 0°06’W). Study communities in Ashiedu-Keteke Sub Metro a subdivision of Accra Metropolitan Area include: James Town, Usher Town and Glefe (figure 1). And those within Dangme East District were; Adafoah, Anyakpor and Totopey (figure 2). Districts within this region, including study communities are widely acknowledged as areas having the greatest risk of flooding associated with Sea Level Rise (e.g. UNFCCC, 2011). Predominant occupation in both divisions of the study area is fishing and fish processing, with some level of commercial farming (mainly shallots and carrots) occurring in Adafoah (Dangme East District). Impacts of sea level rise are evident in all six communities, particularly in Dangme East district, where there has been a significant retreat of the shoreline, with the area closer to the Volta River estuary recording more than 200m of shoreline retreat from 1974 to 2010 (Opoku, 2012).

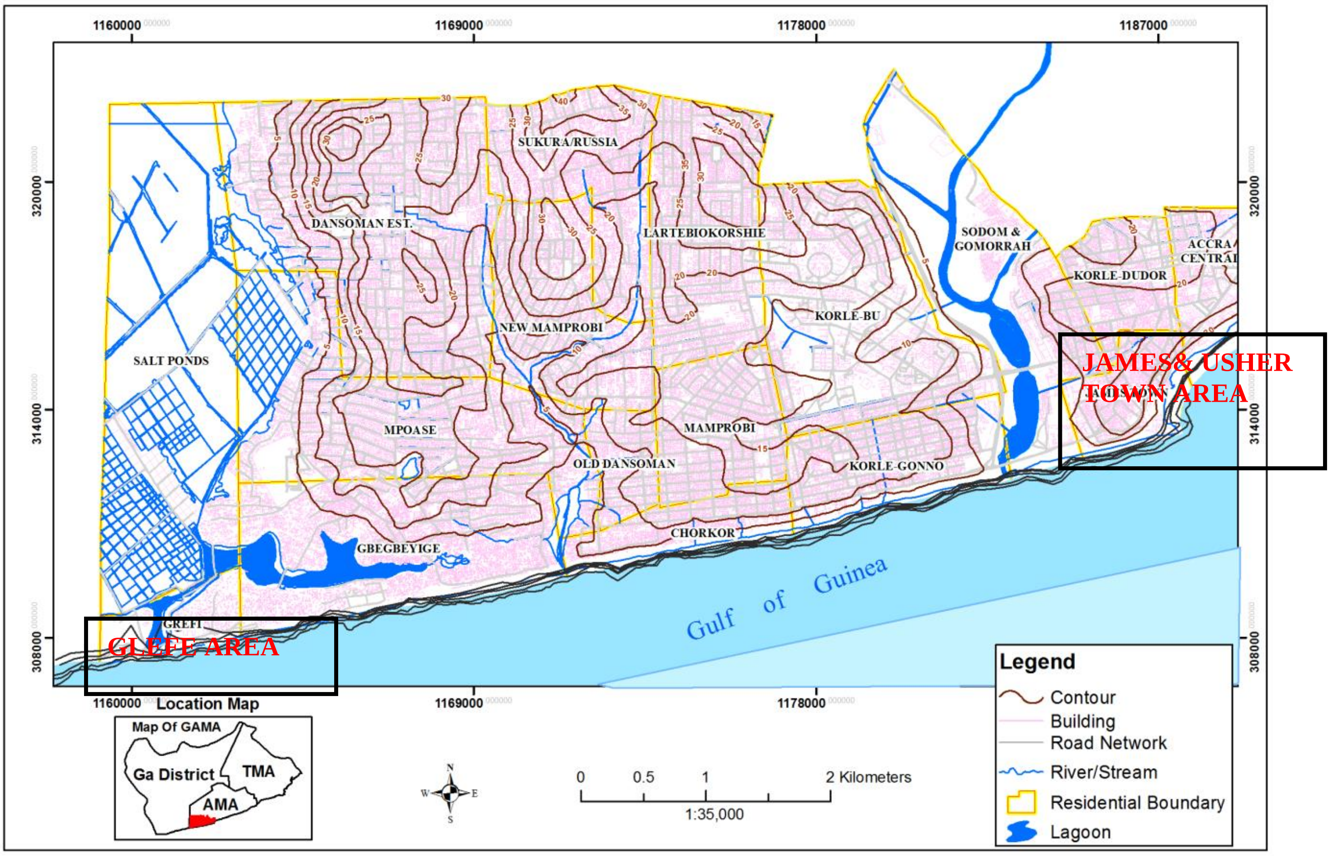

Figure 1: Study Sites in Ashiedu-Keteke Sub Metro (Adapted from Opoku, 2012)

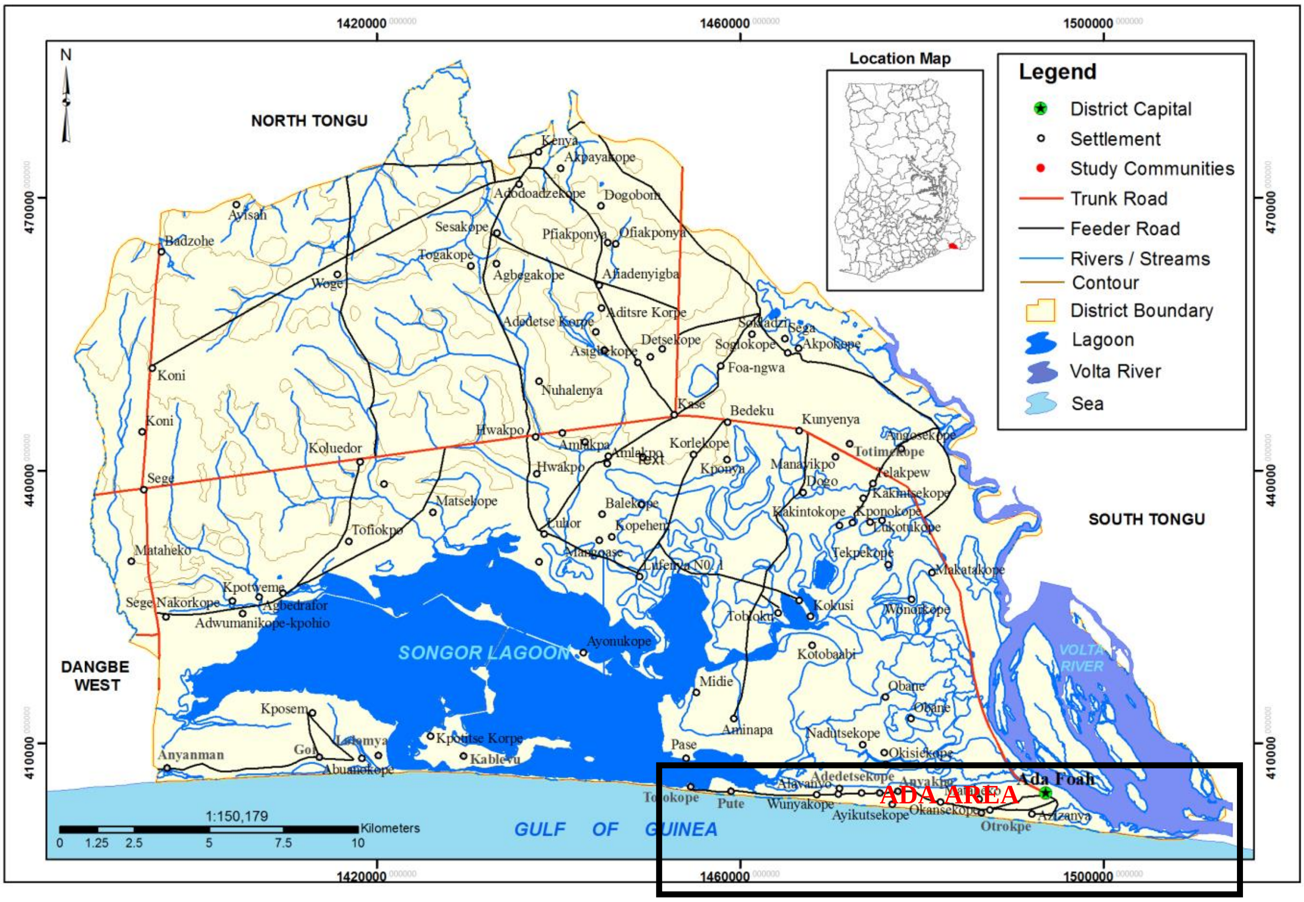

Figure 2: Study Sites in Dangme East (Adapted from Opoku, 2012)

Focus Group Interviews using CRiSTAL Software

Primary data were collected from April to September, 2012 from four dominant socioeconomic groups within these communities. These included farmers, fishermen, fishmongers, and other traders (comprised of petty traders, carpenters, saltpan miners, teachers etc.). Prior to field period, information on climatic hazards were prioritized by community participants from the six project sites during an inception workshop of the project. This was an important initial learning about each locality's knowledge on past and current environmental stressors and changes. Current and potential adaptation strategies were identified using a decision-support tool, 'CRiSTAL' (www.iisd.org/cristaltool/), developed by a consortium of four organizations (IUCN, IISD, Helvetas and SEI-US). The CRiSTAL (Community-based Risk Screening Tool: Adaptations and Livelihoods) builds on both the Sustainable Livelihood approach (SLA) and project impact assessment within communities. Three important hazards identified by community members and validated by facilitators which formed the basis of testing the CRiSTAL tool were; *Sea Level Rise, Floods, Rain Storms*. However, in Ashiedu-Keteke Sub Metro, Extreme Heat replaced Sea level Rise based on the communities experiences.

Results and Discussions

Climatic Hazards and Impacts

Focus Groups were queried on climatic hazards prevalent within their communities and asked to rank the first three important hazards, based on the CRiSTAL tool. Collective responses on impacts of ranked climatic hazards and their coping strategies were noted and validated by participants. Responses as detailed in Tables 1 - 4, indicate similarities across the same socioeconomic group within the two districts. Also, differentiated impacts are noticeable amongst different economic groups.

Coping Strategies and Alternatives

Coping strategies are varied within these communities and it appears the five livelihood assets are important in the survival of the existence of these communities. Some coping strategies are ingenious, whereas others bear the markings of external interventions. For instance is the 'application of fertilizers' to farms that that are affected by Sea Level Rise. Alternative coping strategies speak to this issue, where groups demand engineering provisions such as Sea Defence Wall to combat the impacts of Sea Level Rise in Dangbe East District.

Table 1: Farmers Vulnerability Matrix (Dangbe East District)

Hazard	**Impact**	**Coping Strategy**	**Alternative Coping Strategy**
Sea Level Rise	Crop damage resulting in reduced yields	Application of Fertilizers	Sea Defence Wall; Relocate to other communities
	Affects buildings and roofs	Place stones on roofs as support	Repair roofs
	Makes drinking water salty	Buy sachet (pure) water	Pipe-borne water
Floods	Destroys farms	Create drains around farms	Clearing entire farmland and replanting
	Insects and worm infestations	Regular spraying with insecticides	Hand-pick insects
	Destroys homes and drinking wells	Dig drains around homes	Construction of drains
Rainstorms	Breaks matured crops and covers active seedlings with sand	Fencing of seedlings with branches from coconut tree	Learn other trade/jobs
	Transference of insects across farmlands	Spraying immediately after storm	
	Rips off roofs	Place stones on roofs	

Table 2: Fishermen Vulnerability Matrix ((Dangbe East District and Ashiedu-Keteke Sub-Metro Area)

Hazard	Impact	Coping Strategy	Alternative Coping Strategy
Sea Level Rise (DE) Extreme Heat (AK)	Reduced fish catch/reduction in income(DE) Affects quality of fish/Spoilage (AK)	Rely on savings made from previous fishing season (DE) Increase fishing days to make up for shortfall in income (AK)	Travel to Tema to buy fish (DE)
	Destroys homes/displaced families (DE)	Stay with friends and family (DE)	Borrow money from 'fish fathers and mothers'(DE)
	Destroys fishing boats (DE)	Do other jobs (DE)	Sea defence (DE)
Floods	Flooding of living and business areas (DE) Reduces fish catch (AK)	Dig drains around houses (DE)	Construction of gutters (DE)
	Destroys food items (DE) Affects Health/reduction in fishing days (AK)	Pump water out with pumping machines (DE) Use of traditional medicine (AK)	
	Drowning of young children (DE) Damages building (AK)	Enforce community-wide sanitation (AK)	
Rainstorms	Disrupts fishing (AK)	Borrow money from 'fish fathers and mothers' (AK)	Fish in nearby Lagoon (DE)
	Damage roofs (DE) Causes health problems (AK)	Place stones on roofs (DE) Use of traditional medicine/patent chemist stores (AK)	Repair damaged roofs (DE)
	Increases incidence of drowning (DE)	Swim to shore or nearby canoes (DK)	Wear life jackets (DE)

Notes: Similar responses are only recorded once, irrespective of community; DE – Dangbe East District; AK – Ashiedu-Keteke Sub-Metro Area.

Table 3: Fishmongers Vulnerability Matrix ((Dangbe East District and Ashiedu-Keteke Sub-Metro Area)

Hazard	Impact	Coping Strategy	Alternative Coping Strategy
Sea Level Rise Extreme Heat (AK)	Reduced fish catch /reduced income (DE) Affects quality of fish (AK)	Buy fish from other sources outside community (DE) Fish protected from direct sunlight (AK)	Construction of cold room within community (DE)
	Destroys fish kilns and areas used for smoking/drying of fish (DE)	Create drains (DE)	Sea defence (DE)
	Destroys drinking wells (DE)	Buy sachet water(DE)	Construction of pipe-borne water in community (DE)
Floods	Affects fish smoking/drying process (DE)	Drying kiln placed on constructed platforms (DE)	Fish placed on cement pavements at higher levels around community (DE)
	Low patronage as business is disrupted (AK)	Wait to resume normal business after floods recede (AK)	
	Affects human health (AK)	Use traditional medicine/patent medicine stores/hospital (AK)	
Rainstorms	Fish spoilage increases (DE) Reduced fish catch for fishermen/less fish for trading (AK)	Resort to petty trading (DE) Travel to Tema to buy fish (AK)	Borrow money from friends and family (DE)
	Destroys tents used for fish business (DE)	Use other people's tents (DE)	Construct cement buildings (DE)
	Makes roads impassable (DE)	Fish sales limited to community(DE)	Borrow money (DE)

Table 4: Other Trades Vulnerability Matrix ((Dangbe East District and Ashiedu-Keteke Sub-Metro Area)

Hazard	Impact	Coping Strategy	Alternative Coping Strategy
Sea Level Rise Extreme Heat (AK)	Damage to personal houses (DE) Destroys commodities/reduced patronage (AK)	Seek temporary shelter from friends and family (DE)	Relocate to neighbouring towns (DE)
	Increases debts (DE) Affects mobility of traders (AK)	Borrow money from "Susu"* groups Market goods in front of homes /within community (AK)	Take to farming and other available jobs (DE)
	Erosion around settlements (DE) Affects availability of fish for consumption (AK)	Build barriers (DE) Resort to other forms of protein e.g. eggs, canned fish/ice-fish (AK)	
Floods	Disturbs businesses and schools (DE)	Move to Ada junction (DE) Diversify trade e.g. sale of sachet water (AK)	Wait till flood recedes/salt mining at Aminapa (DE)
	Causes health problems (DE)	Use traditional medicine (DE) Hospital (AK)	
	Block roads to markets	Wait till flood recedes (DE)	
Rainstorms	Damages buildings including roofs (DE) Reduction in income (AK)	Place stones on roofs (DE) Use concrete areas provided by government (AK)	Erect makeshift polythene tents/repair roofs after storms (DE)
	Causes chest problems (DE)	Use traditional medicine/go to hospitals (DE)	
	Destroys canoes (DE) Damage to properties (AK)	Canoes secured at estuaries (DE) Damaged goods sold as scraps to raise money (AK)	

Notes: *Susu groups are informal financial arrangements made through collective agreement.

Livelihood assets influenced by impacts of climate hazards

Table 5 below shows ranking of livelihood assets influenced by impacts of climate hazards. Influence on livelihood assets were determined and subsequently ranked using Likert-type scale provided on the CRiSTAL software package. The Scale ranged from 0 to 5; where 0 indicates no influence and 5 judged as strong influence. A score of 5 in each of the entries was taken as the most important livelihood affected by the impacts of the climatic hazard in question.

Table 5: Ranking of Livelihoods Influenced by Climate Hazards

Assets	Farmers	Fishermen	Fishmongers	Other Trades
Natural	2nd	2nd	1st	2nd
Physical	1st	-	1st	1st
Financial	-	3rd	1st	3rd
Human	-	4th	1st	2nd
Social	-	1st	1st	2nd

All five assets within the livelihood framework are threatened to certain degrees, and parallels could be drawn amongst groups. For instance, irrespective of type of climatic hazards (i.e. Sea Level Rise, floods, rain storms), natural asset loss is considered second place to physical assets amongst farmers, fishmongers and other traders. In the same vein, Social asset loss ranks first amongst two groups (fishermen and fishmongers). The varied rankings are indicative of the various strategies adopted within these communities against periods of stress, shocks and changes. A case in time is the situation of reduced fish stocks (see tables 1 and 2), both farmers and fishermen groups make the alternative decision to travel to neighbouring communities in search of livelihood options. Other alternatives, in the case of fishermen, are borrowing from 'fish mothers and fathers', underscoring the need for a strong social networks. These diverse strategies have been duly observed across various fishing communities in Ghana, where artisanal fishers deal with seasonal variability in a number of ways (Perry & Sumaila, 2007).

Implication for Integrated Coastal Zone Management

Tables 1 to 4 portray the reality of impacts of climate change within the study sites in Ghana. Beyond this is the physical evidence of the magnitude and rate of occurrence of these climatic hazards mentioned elsewhere (Opoku, 2012). What is clear from observations made from this study is that local residents within coastal communities are indeed familiar with happenings around their immediate environment. However, it appears that national policy planning struggle with inclusion of their knowledge into planning agenda. Ghana's national climate change policy was launched in 2014; however it is devoid of any local meaningful adaptation intervention. Building resilience within coastal communities will demand that the national government take into cognizance current climate change vulnerabilities of the coastal area and bridging gaps in climate change knowledge within the area. Inclusion of these communities within coastal zone planning will demand a proper assessment of the risk each ecological zone faces, reflective of local knowledge and equally embrace the adaptive strategies of the people to future climate change scenarios. Ultimately, developing a context specific coastal zone planning and policy will build resilience of the coast and indigenous occupations within the region.

Conclusions

This study presents information on climatic hazards and coping strategies of climate change for the Greater Accra Region, Ghana. The assessment will aid understanding of specific socioeconomic group's vulnerability context and associated threats to livelihood assets, which ultimately could inform external interventions and adaptation planning. Thus, results provide baseline data needed for the metro and district assembly's decision-makers to aid developmental planning for these coastal zone areas. Furthermore, information presented here will help planning for and management of future coastal hazards.

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