PROCEEDINGS OF THE 4TH SYMPOSIUM OF THE INTERNATION SOIL TILLAGE RESEARCH ORGANISATION (ISTRO), NIGERIA CHAPTER

THEME: TILLAGE FOR SUSTAINABLE ENVIRONMENT

AT THE AFRICAN UNIVERSITY OF SCIENCE AND TECHNOLOGY, KM 10 AIRPORT ROAD, GALADIMAWA, ABUJA

11TH JULY, 2023

PREFACE

One of the main goals of the Sustainable Development Goals (SDGs) set by the United Nations is to alleviate hunger, eradicate extreme poverty and create a healthy environment that enhances quality of life. Soil tillage plays a crucial role in achieving these goals.

The aim of the 2023 ISTRO-Nigeria symposium, the 4^{th} in the series, with the theme "**Tillage for Sustainable Environment**" was to provide a platform for scientists, researchers, policymakers and the academia to come together and find sustainable ways to manage soil to ensuring adequate food supply for both present and future generations. It offers an opportunity for participants from government and private organizations to collaborate and discuss various aspects of soil, tillage, and the environment.

The symposium received a keynote address on the theme and four lead papers. In addition, nineteen technical papers were received and blind reviewed. Those accepted are contained in this proceedings. We appreciate the contributions of all authors who made necessary adjustments based on reviewers' feedback. We also extend our appreciation to the reviewers and everyone who contributed to the success of this publication. Authors whose papers were not accepted are encouraged to continue their efforts for future editions and are acknowledged for their participation.

It is anticipated that the recommendations contained in this publication, if carefully implemented, will significantly contribute to the promotion of a healthy environment and a nation free from hunger and extreme poverty.

While this publication remains the property of ISTRO-Nigeria, authors are solely responsible for the content of their respective papers.

Thank you.

Engr Dr. Utunji Isaac Tanam MNIAE, MNCS
Secretary, ISTRO Nigeria / Symposium Organizing Committee (SOC)
Department of Environmental Management
Bingham University, Karu – Nasarawa State

WELCOME ADDRESS

WELCOME ADDRESS BY PROF. AZIKIWE PETER ONWUALU, FAS, FAEng PRESIDENT, SOIL TILLAGE AWARENESS AND DEVELOPMENT INITIATIVE (ISTRO-Nigeria) AT THE 2023 TILLAGE SYMPOSIUM

The opening statement of the landing page of United Nations Department of Economic and Social Affairs that describes the 17 GOALS states as follows: "The 2030 Agenda for Sustainable Development Goals adopted by all United Nations Member States in 2015, provides a shared blueprint for peace and prosperity for people and the planet, now and into the future. At its heart are the 17 Sustainable Development Goals (SDGs), which are an urgent call for action by all countries - developed and developing - in a global partnership. They recognize that ending poverty and other deprivations must go hand-in-hand with strategies that improve health and education, reduce inequality, and spur economic growth – all while tackling climate change and working to preserve our oceans and forests" (www.sdgs.un.org/goals). A critical analysis of the 17 Goals shows that Sustainable Agriculture is one of the major ways of achieving most if not all the goals. This is because if we achieve sustainable agriculture, a number of the goals would have been achieved. These include: Goal 1 (No poverty); Goal 2 (Zero Hunger); Goal 3 (Good health and well-being); Goal 8 (Decent work and economic growth); Goal 12 (Responsible consumption and production; Goal 13 (Climate Action) and Goal 15 (Life on Land). Agriculture itself is made up of a value chain. The components of the value chain for crop production part of agriculture include: Bush clearing and land development, tillage, planting, crop protection, harvest, post-harvest handling and preservation, storage, transportation, packaging, processing for food and industrial raw materials, distribution and waste management. Tillage, bush clearing, land development and management form the foundation of the value chain and therefore, if these are not done right, the other components of the chain will be weak and sustainable agriculture cannot be attained and hence SDGs cannot be achieved.

Soil & Tillage research provides the bedrock for developing the knowledge base and technologies for ensuring successful sustainable agriculture for any economy. The International Soil Tillage Research Organization (ISTRO) was formed as a network of researchers, policy makers and field practitioners in order to develop and apply technologies for agricultural practitioners to optimize soil preparation and planting of crops in a sustainable manner. Many countries, including Nigeria formed the country branch of ISTRO to ensure that stakeholders in tillage can work together towards achieving the global objectives of ISTRO and at the same time solving local problems. ISTRO Nigeria was formed some years back but over the years activities of the branch went down. By late 2022, some members got together and agreed to revive the Nigeria branch of ISTRO.

The main aim of ISTRO Nigeria is "to inspire scientific research in soil tillage and related subjects, and encourage the application of research results to sustainable agricultural production". The specific objectives are to:

a. bring together persons involved in soil and tillage research;
b. organize regular meetings of members;
c. organise conferences, workshops, public lectures, capacity building training, and symposia where soil and tillage related matters are presented and discussed;

d. publicise research findings with relevant bodies and general public through website, journal, newsletter, electronic and print media, etc;
e. organise excursions relevant to soil and tillage research;
f. link and collaborate with related and similar organisations within and outside Nigeria;
g. recognize and encourage persons who make significant contributions in soil and tillage research and practice.

Early this year, we agreed to revive the organization through a number of activities in 2023:

- Formation of interim Executive Committee and Board of Trustees (BoT)
- Mobilization of membership
- Registration as an NGO with the Corporate Affairs Commission (CAC).
- Opening of Corporate Accounts
- Development of a website
- Interaction with the Global ISTRO
- 2023 Tillage Symposium
- A book on Tillage in Nigeria
- Encouragement of members to attract grants for Tillage Research
- Journal Publication

I am happy to report that we have completed implementation of most of the activities above while the other ones are on-going. The remaining activities will be accomplished before the end of the year. The organization has now been registered with CAC as Soil Tillage Awareness and Development Initiative with Registration number 7032776 of 28th June, 2023. We shall now be known and addressed as: **SOIL TILLAGE AWARENESS AND DEVELOPMENT INITIATIVE (ISTRO-Nigeria)**

As we host the 2023 Tillage Symposium today, we have only a few activities to accomplish our targets for the year 2023. These include: Development of a website and a book on Tillage in Nigeria. As I ask for your support and cooperation in achieving the remaining targets, I ask that you come up with activities you would want us to plan against 2024. This will help the Exco to prepare the plan of activities and budget for 2024.

I welcome all of you to the conference and I wish you safe journey back to your stations.

Professor Azikiwe Peter Onwualu, FAS, FAEng
Soil Tillage Awareness and Development Initiative (ISTRO-Nigeria)
Email of ISTRO Nigeria: istronigeria@gmail.com
ADDRESS of Organization:
National Centre for Agricultural Mechanisation, NCAM, Km 20 Ilorin – Lokoja Highway, Idofian, 240103, Ilorin, Kwara State.
11th July, 2023

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REPORT OF THE 4TH TILLAGE SYMPOSIUM OF THE INTERNATIONAL SOIL TILLAGE RESEARCH ORGINISATION, NIGERIA BRANCH (ISTRO-NIGERIA) HELD ON 11TH JULY 2023 AT THE AFRICAN UNIVERSITY OF SCIENCE AN TECHNOLOGY, ABUJA

The theme of the conference was "**TILLAGE FOR SUSTAINABLE ENVIRONMENT**"

Opening ceremony commenced at 10:40 am on July 11th, 2023 with the introduction of guest speakers and keynote speaker. There were 21 online participants and 22 physically present. Notable among those present were Prof. Adeniyi Olayanju, former Vice-Chancellor of Landmark University, the Head of Department of Environmental Management of Bingham University, Dr Goma Danbaba, representing the Vice-Chancellor of the university, Dr. A. B. Hassan and Dr. N. B. Ibrahim both of University of Abuja, ISTRO International President-elect, Prof J. O. Olaoye, Dr. O. A. Ogunjirin of the National Centre for Agricultural Mechanization (NCAM) and Prof. M. G. Yisa, former Ambassador Extraordinary and Plenipotentiary of the Federal Republic of Nigeria to Japan. Senior members of the organization who participated online included Prof. A. F. Alonge, Prof. S. Asoegwu, Prof. Mrs O. Fawole and Prof. Peter Nnabude. The keynote speaker, Prof S. Z. Abubakar was represented by Dr. Taofiq Olanrewaju.

Following the introductions, Dr. U. I. Tanam led an opening prayer.

Prof. A. P. Onwalu, the President of ISTRO-Nigeria and Acting President of the host institution, African University of Science and Technology (AUST) delivered the welcome address. This was followed by goodwill messages from Prof. J. O. Olaoye, on behalf of ISTRO International. He acknowledged the achievements of ISTRO-Nigeria since its establishment and the strength of its membership. He encouraged ISTRO-Nigeria members to participate in the upcoming ISTRO international conference scheduled to take place in the United States of America in September 2024. He also mentioned the on-going work on the ISTRO-Nigeria journal and book. Prof. Peter Nnabude delivered his goodwill message virtually. Next was the goodwill message from The Executive Director of National Centre for Agricultural Mechanization (NCAM), Dr. A. R. Kamal, represented by Dr. O. A. Ogunjirin. He acknowledged the activities of ISTRO-Nigeria and expressed assurance of continued collaboration between both organizations.

The keynote paper titled "**Advancing Sustainable and Environmentally Friendly Agriculture in Nigeria: The Place of Digitalization and Artificial Intelligence (AI)"** was presented by Prof S. Z. Abubakar, President, Council for Regulation of Engineering in Nigeria (COREN) through Dr. Taofiq Olanrewaju, a Senior extension specialist at National Agricultural Extension & Research Liaison Services (NAERLS). At the end of his presentation, Prof. M. G. Yisa, the Special Guest of Honor, expressed sincere appreciation for the significant impact ISTRO-Nigeria is making, specifically recognizing the efforts of its executives in reviving and boosting the organization's activities.

The technical session commenced at 12:55 pm after the Tea break. Three lead papers were presented by Professors Olaoye, Alonge and Fawole. Prof Olaoye's paper centred on **Digitizing Agricultural Operations For Sustainable Environment**. That of Prof Alonge was on the **Applications of Artificial Intelligence in Soil Tillage** while that of Prof Fawole was on **Soil**

Conservation and Management for Sustained Environment and Agricultural Productivity.

Other papers presented included **"Variability of Soil Compaction in a Tropical Alfisol"** by Prof. M. G. Yisa and other online presentations.

Following a Question-and-Answer session and further deliberations, the following observations were made:

1. soil tillage is critical to environmental sustainability;
2. mechanisation is difficult due to land fragmentation;
3. impact of National Agricultural Land Development Authority (NALDA) as a leading agency in agricultural land development, is not being felt by Nigerian farmers;
4. sustainable food production requires the application of emerging technologies;
5. the current methods of land preparation contributes to environmental degradation;
6. integration of precision farming and smart farming can be achieved through the implementation of intelligent software and hardware; and
7. adoption of artificial intelligence (AI) in agriculture would play a vital role in meeting the increasing global demand for food while minimizing the negative ecological consequences of traditional farming practices

The symposium therefore recommends as follows:

1. government should strengthen NALDA to realistically solve the problems of agricultural land development in the country;
2. there should be synergy between ISTRO, NIAE, NALDA and other stake holders to fashion out ways to deliberately assist farmers with land development operations to overcome the problem of land fragmentation
3. there should be a deliberate move to digitise and digitalise agricultural operations;
4. artificial intelligence (AI) should be considered a crucial aspect in the development of soil tillage practices;
5. new and efficient software tools should be developed for better farm management and field operations; and
6. there should be conscious efforts towards capacity development in digital agriculture.

The symposium ended at 4:40 pm with a closing prayer led by Dr. N. B. Ibrahim.

KEYNOTE SPEAKER

Advancing Sustainable and Environmental Friendly Agriculture in Nigeria: The Place of Digitalization and Artificial Intelligence (AI)

By

Abubakar, S.Z[1] and Olanrewaju, T.O[2]

1-Capital City University, Kano,

2-NAERLS, Ahmadu Bello University, Zaria,

Introduction

Agriculture has become a major sector in Nigeria that contributes immensely to the national Gross Domestic Product (GDP) through majorly its subsistence practice. Due to its subsistence nature, resulting from land fragmentations, mechanization has become difficult and where practiced, they are semi-mechanized. Several attempts have been made by successive government to promote and improve agricultural productivity in Nigeria by formulating suitable policies. Such policies were among those that brought Nigeria's agricultural system into fore. However, most of the successes achieved in the sector, irrespective how huge and life changing they seems to be, most if not all were not appropriately documented for future development, especially, documentation for Research and Development (R&D) as well as policy formulations. Documenting agricultural activities is an important activity for national development, and a tool to achieve sustainable agricultural production which are in turn environmental friendly. Achieving a sustainable and environmental friendly agriculture is expedient and these can be facilitated through the implementation and adoption of digital technologies in general and in particular Artificial Intelligence (AI). It is on this premise that this article looked at the means to achieve a sustainable and environmental friendly agriculture in Nigeria through the adoption and application of AI. Few studies conducted in relation to AI were presented as possibilities of achieving a sustainable agriculture and gaps to fill with the adoption and application of AI also narrated.

Digitization

The process of converting and transforming analogue information like documents, images, audio, video into binary representation capable of being processed and stored electronically, that is digital format.

Process of digitization include conversion, encoding, storage, and retrieval as explained below.

i. **Conversion:** The analog data or physical objects are transformed into digital form using various methods based on the nature of the data to be converted. For instance, a hand written document can be typed, saved and/or printed, printed documents can be scanned to be stored or to create digital images, while audio and video recordings can be digitized as MP3 and MP4 files that are storable, accessible and transferable on several devices.

ii. **Encoding:** The converted digital data is encoded, that is, prearranged or programmed using standardized formats or codecs for universality. This is done to ensure compatibility, efficiency, and ease of storage and transmission. This encoding process assigns specific patterns or codes to represent the data accurately.

iii. **Storage:** The digitized content is stored in electronic devices such as computers, servers, or cloud storage systems. It allows for efficient organization, retrieval, and preservation of the digital assets.

iv. **Access and Retrieval:** Once digitized, the content becomes easily searchable and accessible through digital systems. It can be retrieved and displayed when needed on various devices like computers, smartphones, or tablets.

Few advantages of digitization over analog formats are preservation, accessibility, searchability, manipulation and enhancement and cost efficiency. The digitized information can be preserved by replicating and storing without degradation or quality time loss. They become easily shared, transmitted and remotely accessible by widespread distribution. The tendency of the digitized content to be indexed and searched within a large data set, then they can be improved upon by some editing to enhance the data using some software tools to improve the quality and create new versions. The cost of digitizing information is far less when compared with physical means (Klerkxa *et al*., (2019) and Alina *et al*., (2019).

Digitization has had a significant impact on various industries and sectors, by transforming the way information is created, stored, accessed, and shared, enabling greater efficiency, convenience, and innovation in the digital age. The field of agriculture is not left out in some of the impacts of digitization felt. Information transformed through digitization becomes data, hence, will be referred as such.

Digitalization

The process of leveraging on digital technologies to transform and optimize activities in an organization, industry, or society is known as digitalization. This is the integration of digital tools, systems and strategies to improve efficiency, enhance operations and deliver new value propositions. Digitalization can occur only when information is already digitized. This implies that information that are digitized to a data format are then processed with digital technologies to improve efficiency and better service delivery.

Principal aspects of digitalization are:

i. **Digitized Processes:** Digitalization involves converting analog or manual processes into digital workflows. It often entails automating tasks, streamlining operations, and eliminating paper-based or time-consuming procedures to achieve greater speed, accuracy, and efficiency.

ii. **Data Utilization:** Digitalization harnesses the power of data by collecting, analyzing, and leveraging information for decision-making and optimization. It involves using data analytics, Machine Learning (ML), and Artificial Intelligence (AI) to gain insights, identify trends, and make data-driven decisions.

iii. **Connectivity and Collaboration:** Digitalization fosters connectivity between people, devices, and systems, that is machines and gadgets. It as well enables seamless communication, information sharing, and collaboration across teams, departments, and even geographies in order to enhance productivity, innovation, and agility.

iv. **Innovation and Value Creation:** Digitalization encourages innovation by leveraging emerging technologies like Internet of Things (IoT), automation systems, precision systems and digital capabilities. New products, services, business models, and revenue streams become enabled and unlock new opportunities, disrupt markets, and stay competitive in the digital age.

v. **Agility and Adaptability:** Digitalization is flexible, open to experimentation, and embracing a culture of continuous improvement using digital technologies.

vi. **Ecosystem Integration:** Digitalization often involves integrating with external partners, platforms, and ecosystems to leverage complementary capabilities and expand market reach. It includes collaborations, partnerships, and the utilization of Application Programming Interfaces (APIs) to create interconnected digital ecosystems.

Digitalization has a profound impact on industries, organizations, and individuals, transforming the way they operate, interact, and create value. It offers opportunities for increased efficiency, innovation, competitiveness, and improved customer experiences. However, successful digitalization requires careful planning, investment in digital infrastructure, talent development, and a strategic approach to leverage the full potential of digital technologies (Alina *et al*., 2017; Fu and Zhang (2022); and Gupta and Rhyner (2022).

Moreover, full digitization, also known as “digital transformation”, is the comprehensive integration of digital technologies into all aspects of an organization or system, fundamentally changing how it operates and delivers value. It involves the adoption and utilization of digital tools, processes, and strategies to streamline operations, enhance efficiency, improve customer experiences, and drive innovation.

In a fully digitized environment, traditional analog processes and manual operations are replaced or automated with digital solutions. This can include the digitization of data, workflows, communication, and services. Key aspects of full digitization are digital data, digital workflows, automation, cloud computing, and data analytics. These aspects are intertwined to achieve minimal interference of man in an organization daily activity for increased efficiency, competitiveness, and the creation of new opportunities for growth and value creation.

Artificial Intelligence

Artificial Intelligence (AI) refers to the development of computer systems and algorithms that can perform tasks that typically require human intelligence. AI enables machines to mimic cognitive functions such as learning, problem-solving, reasoning, perception, and language understanding. It encompasses a wide range of techniques and approaches aimed at creating intelligent systems capable of performing complex tasks autonomously or with minimal human intervention.

Key concepts in Artificial Intelligence include:

i. **Machine Learning (ML):** Machine Learning involves training algorithms on large datasets to recognize patterns, make predictions, or take decisions without being explicitly programmed. It enables systems to improve their performance through experience and data analysis.

ii. **Deep Learning:** Deep learning is a subset of ML that utilizes large datasets and Artificial Neural Networks (ANN) with multiple layers to process and learn from. Its significance is in the area of image and speech recognition.

iii. **Computer Vision:** This enables machines to analyze, understand, and interpret visual data from images or videos. It involves tasks such as object recognition, image classification, and facial recognition.

iv. **Robotics:** AI is often applied to robotics to create intelligent machines capable of perceiving their environment, making decisions, and performing physical tasks. Robotic systems can be used in various fields, such as manufacturing, healthcare, exploration and even agriculture.

v. **Autonomous Systems:** AI is employed in developing autonomous systems that can operate and make decisions independently without human intervention. Examples include self-driving cars, autonomous drones, and automated industrial processes.

AI has evolved in many developed countries and fast spreading to developing countries with its applications found in areas of education, cybersecurity, entertainment, healthcare, transportation, education and agriculture. AI has the potential to revolutionize industries, enhance productivity, improve decision-making, and solve complex problems in its numerous areas of applications. However, ethical considerations such as privacy, bias, and the impact on employment are also important factors to consider in the development and deployment of AI technologies.

Having established the relationship between digitization and digitalization, it is necessary to emphasize that effective use of AI begin with digitized data.

Relationship Between Digitalization and Artificial Intelligence

Digitalization and Artificial Intelligence (AI) are closely intertwined and mutually reinforcing in the modern technological landscape. While digitalization involves leveraging digital technologies to transform processes and operations, AI utilizes digital data and algorithms to create intelligent systems capable of performing complex tasks. Here are some key relationships between digitalization and AI:

i. **Data Availability, Quality and Processing:** Digitalization provides the foundation for AI by generating vast amounts of digital data. As organizations digitize their processes and operations, they generate digital data that can be leveraged by AI algorithms for learning, analysis, and decision-making. Digitalization efforts also often involve data cleansing and standardization, improving the quality and reliability of data used in AI applications.

ii. **Data-driven AI**: AI algorithms heavily rely on large datasets for training and learning. Digitalization efforts, which lead to the digitization and collection of diverse data sources, enable AI systems to access and utilize comprehensive datasets for tasks such as ML, deep learning, and predictive analytics. The availability of digitized data accelerates the development and deployment of AI applications.

iii. **Automation and Efficiency:** Digitalization aims to streamline operations and automate processes using digital tools and technologies. AI complements this goal by enabling intelligent automation through ML, natural language processing, and robotic process automation. AI-powered automation can optimize digital processes, reduce manual efforts, and enhance overall efficiency and productivity.

iv. **Intelligent Decision-making:** Digitalization provides the infrastructure for capturing and storing digital data, while AI leverages this data for intelligent decision-making. By analyzing patterns, trends, and correlations in the digitized data, AI algorithms can generate valuable insights, support decision-making processes, and improve process outcomes.

v. **Innovation and New Opportunities:** Digitalization and AI foster innovation by leveraging emerging technologies and digital capabilities. Digitalization provides the data infrastructure necessary for AI development, while AI brings intelligence and automation to digitalized processes. This combination unlocks new opportunities for organizations to create innovative products, services, and models that drive competitive advantage.

The relationship between digitalization and AI is highly synergistic. Digitalization provides the data infrastructure and digital processes that enable AI algorithms to learn, analyze, and make intelligent decisions. In turn, AI enhances digitalization efforts by automating processes, improving decision-making, and enabling innovative solutions. Together, digitalization and AI accelerate transformation, foster innovation, and drive organizational growth in the digital age

Digitalization, automation, Machine Learning (ML), Artificial Intelligence (AI), and the Internet of Things (IoT) are interconnected facets driving the transformative potential of today's technological landscape. Through digitalization, organizations and individuals are transitioning their processes and systems into digital formats, enabling the seamless flow of information and fostering data-driven decision-making. Automation complements digitalization by streamlining operations, reducing manual effort, and increasing efficiency. Machine Learning and Artificial Intelligence amplify these advancements by enabling systems to learn from data, adapt to changing circumstances, and perform complex tasks with human-like intelligence. As a result, the Internet of Things (IoT) emerges as a network of interconnected devices, sensors, and objects that leverage digitalization, automation, Machine Learning, and Artificial Intelligence to gather, analyze, and utilize data for real-time insights, enabling smarter and more connected ecosystems that drive innovation and improve our lives.

Agriculture

Agriculture is the practice and science of cultivating plants, animals, and other organisms for the purpose of producing food, fiber, medicinal plants, and other products used to sustain and enhance human life. It encompasses a wide range of activities, including cultivating crops, raising livestock, and managing natural resources such as water, soil, and biodiversity (Harris and Fuller, 2014).

In agriculture, various techniques and technologies are employed to optimize production and ensure the efficient use of resources. These may include irrigation systems, fertilizers, pesticides, genetic modification, and mechanization. The goal of agriculture is to maximize yields, improve crop quality, and enhance overall productivity while minimizing negative environmental impacts.

Agriculture plays a crucial role in providing food security and supporting the livelihoods of millions of people worldwide. It encompasses diverse practices such as crop farming, horticulture, livestock rearing, poultry farming, aquaculture, forestry, and agroforestry. Additionally, agriculture contributes to rural development, economic growth, and the overall sustainability of communities and nations.

Agriculture plays a crucial role in our environment, as it intersects with various aspects of sustainability and conservation. As a primary user of land and water resources, agricultural practices have the potential to significantly impact ecosystems. Sustainable agricultural practices aim to minimize environmental harm by promoting soil health, reducing water consumption, and mitigating pollution from fertilizers and pesticides. Additionally, agricultural systems can contribute to environmental preservation through practices such as agroforestry and organic farming, which prioritize biodiversity conservation, soil carbon sequestration, and reduced greenhouse gas emissions. Moreover, the responsible management of agricultural landscapes can protect natural habitats, promote wildlife conservation, and enhance ecosystem resilience. By recognizing the delicate balance between agriculture and the environment, we can cultivate a harmonious coexistence that sustains both food production and the health of our ecosystems.

Application of AI in Agriculture

Certainly, Artificial Intelligence (AI) is an emerging area, especially in the field of agriculture. Only few research work has been reported and documented, despite its enormous application in the field of agriculture. Common among the studies documented were reviews as reported by Konstantinos et al., (2018) did a comprehensive review of research dedicated to applications of machine learning in agricultural production systems. The review was analyzed based on crop management, including applications on yield prediction, disease detection, weed detection crop quality, and species recognition; livestock management, with focus on applications on animal welfare and livestock production; water management; and soil management. The article further demonstrated benefits of agriculture from machine learning technologies through the application of sensor data. Farm management systems are evolving into real time artificial intelligence enabled programs that provide rich recommendations and insights for farmer decision support and action. Another comprehensive literature review survey on application of artificial intelligence techniques in agriculture that covers crop management, pest management, soil and irrigation management, disease management, weed management and yield production were carried out by Gouravmoy et al., (2018). Challenges of disease and pest infestation, improper soil treatment, inadequate drainage and irrigation that leads to severe crop loss coupled with environmental hazards relating to excessive chemicals usage were postulated to be addressed by artificial intelligence due to its rigorous learning capabilities. The multidimensional development of agro-intelligent systems within the last 34 years was the focus bringing to fore the applications of artificial intelligent techniques in the major subdomain of agriculture.

Eli-Chukwu et al., (2019) presents a review of the applications of AI in soil management, crop management, weed management and disease management, focusing on the strength and limitations of the application and the way in utilizing expert systems for higher productivity. They further stated some limitations like response time and accuracy, require big data, implementation method, high data cost, and flexibility, though can be surmounted over time. Another comprehensive review was conducted by Jha et al., (2019) on different automation practices like IoT, Wireless Communications, Machine learning and Artificial Intelligence, Deep learning in areas of crop diseases, lack of storage management, pesticide control, weed management, lack of irrigation and water management. The ability of having an autonomous system that can decipher issues like use of harmful pesticides, controlled irrigation, control on pollution and effects of environment in agricultural practice. Their review revealed that automation of farming practices has proved to increase the gain from the soil and also has strengthened the soil fertility.

Javaid et al., (2023) studied AI and its need in Agriculture. The process of AI in Agriculture and some Agriculture parameters monitored by AI were briefed, significant applications of AI in agriculture were as well identified and discussed. Figure 1 shows the key applications of AI in agriculture as studied in their review.

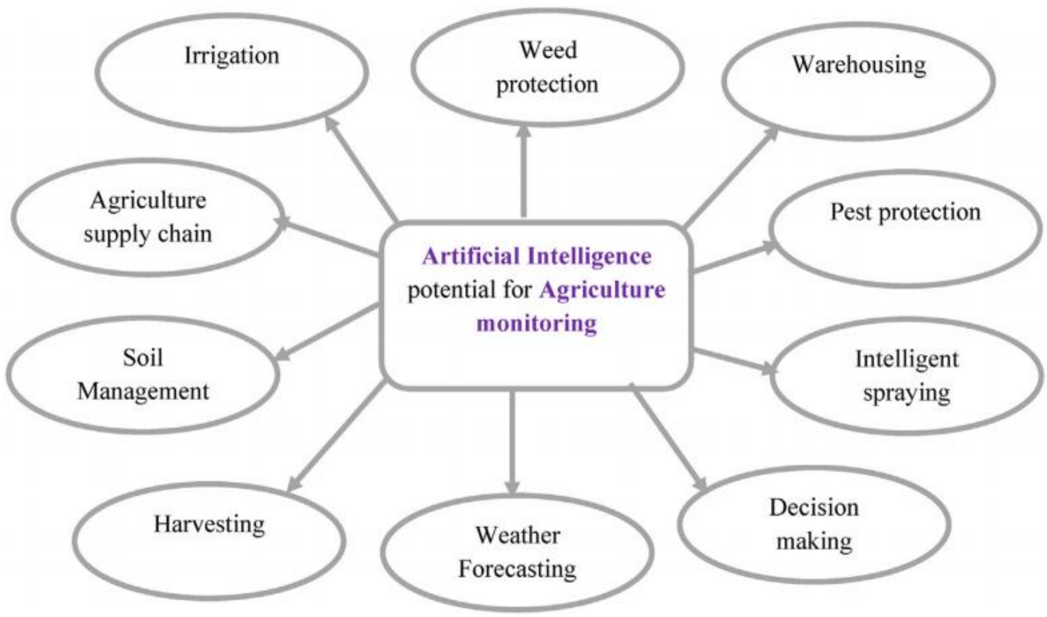

Figure 1: Selected applications of AI in agriculture
Adopted from Javaid et al., (2023)

AI offers data on weather forecasts, help farmers produce more with fewer resources, increase crop quality, and hasten product time to reach the market. It also aids in understanding soil qualities, helps farmers by suggesting the nutrients they should apply to increase the quality of the soil, help farmers choose the optimal time to plant their seeds.

Some of the barriers to use of AI in agriculture were also reviewed. Few that were mentioned were the lack of simple solutions that seamlessly incorporate and embed AI in agriculture. Also, most farmers lack the time and digital skills to investigate AI solutions on their own, hence, incorporating and embed AI will require integration into existing and legacy infrastructure and systems that farmers already use, lack of awareness and technical knowledge, unavailability of large amount of temporal data required to train machines and make predictions, and building a robust ML model takes significant time.

Also, Awodele and Jegede (2009); Chen et al., (2002); Farayola et al., (2020) Garske et al., (2021) worked on neural networks and its application in engineering, machine vision technology for agricultural applications, digitalization in developing country. They all focused their review on the application of these different technologies in the field of agriculture and how they can be used to improved agricultural productivity. In Nigeria, some models were developed, data collected, system automations developed and few prototypes AI and ML developed at different locations for different purposes (Igbekele et al., 2006; Obidike, 2011; Samson et al., 2021; Olanrewaju, 2020 and Olanrewaju et al., 2021).

It is pertinent to emphasis that most studies reviewed on AI focused on general agriculture, especially, areas of agricultural production relating to soil analysis, crop production, crop climatic requirements, pests and disease infestations, and weeds control. Few went ahead to study and research on tractor control systems and tractions management during tractor operations. However, there has been several unreported studies on the applications of AI in areas of crop harvesting, agricultural products handling, packaging and distribution systems and as well as irrigation control systems. Nigeria, been a developing country with vibrant agricultural systems, AI can be applied in any of the major agricultural sector and some few other sub-sectors. Some researches conducted on AI in Nigeria are hereby described.

Olanrewaju et al., (2018) did a simulation of a conceptual fresh tomato fruits packaging container for transportation. Design calculations were done and these calculations were transferred to a computer using solid works 2016 model for the simulation as presented in figure 2. A single large tomato fruits was placed inside the container and the discretization was done for all members of the container, that is, handle, base, cover and the walls. Likely stresses – stress at handles, base, cover, drop height and stack height were of the container was then analyzed through the simulation. Values of the maximum allowable stresses as suggested by the simulation were then used for the design of the packaging container.

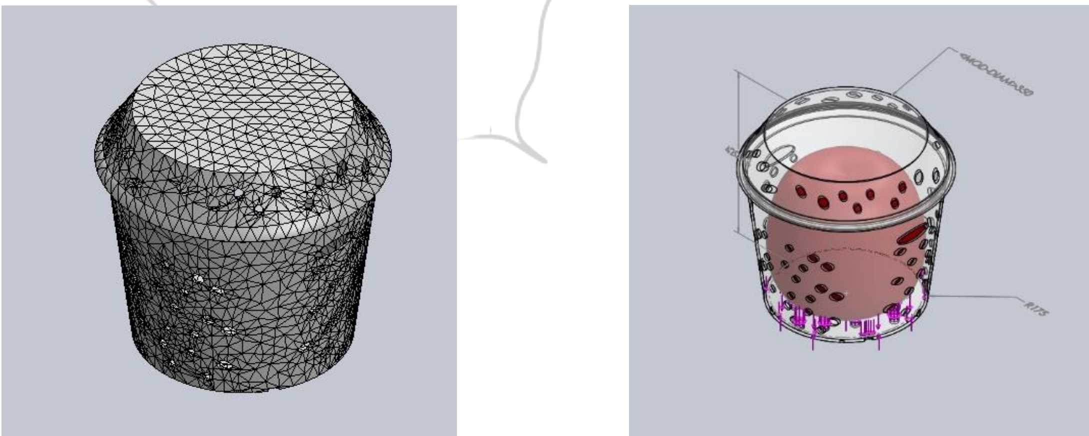

Figure 2: Simulation of the tomato packaging container

Olanrewaju (2020) developed an instrument that measures the tomato fruits firmness. This was done from local materials which are combination of PVC pipes, springs, stainless steel rod and a programmable Arduino component (Figure 3). The instruments was then calibrated and used to collect data on tomato fruits firmness before transportation and after transportation to determine the quantity of postharvest losses experienced during transportation.

Figure 3: Auto-manual tomato fruits firmness tester

Data collected from these instruments can be used for decision making or Machine Learning that could guide how tomato fruits can be arranged inside a packaging container and what happens during its handling generally.

Knowledge of tomato fruits temperature and vibration is vital during transportation of fresh tomato fruits, especially from farm gate to other parts of the country. Olanrewaju (2019) also developed a 3-in-1 instrument that measure the temperature of the tomato fruits placed inside the baskets, temperature of the inside of the transporting vehicle and as well the vibration of the vehicle during transportation as shown in figure 4. The readings were taken every 3 minutes throughout the transportation duration and logged on a SD card. The card was then pulled and data retrieved (2,500 entries from one instrument from a single trip) on to a personal computer for further processing.

Figure 4: Temperature-vibration measurement instrument

Data retrieved from these is a relevant one that can be useful in the data required for AI and ML for an effective and efficient tomato fruits handling during transportation and as well make decisions based on airflow, climatic conditions and basket types suitable for transportation. Data collected from the developed temperature-vibration tomato fruits measurements instruments was further applied in a digital twin to evaluate quality changes in tomato value-chain in Nigeria as studied by Nwaizu et al., (2022).

Olanrewaju et al., (2020) evaluated the performance of an automatic monitoring device developed for grain storage. The device was a prototype developed to determine the temperature and relative humidity level and as well the air flow rate inside a storage structure automatically. The device (Figure 5) was as well designed to take decisions like controlling the fan to operate as an impeller or an expeller when required and to as well activate a buzzer when a critical temperature or relative humidity level is sensed.

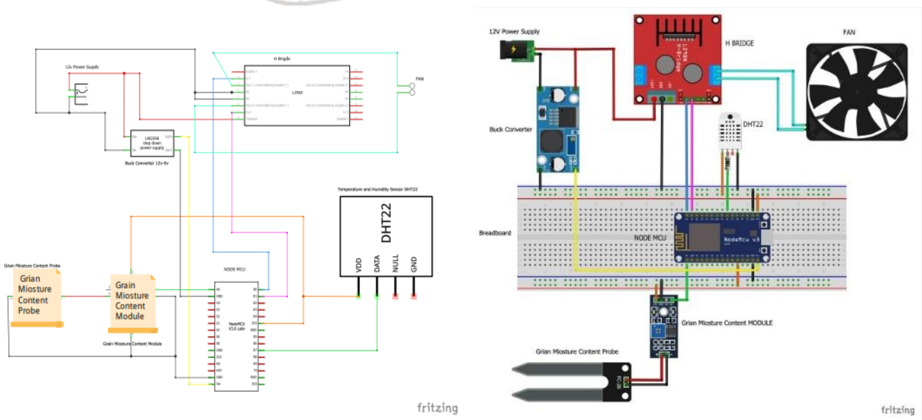

Figure 5: Circuit diagram and plate of the automatic storage structure monitoring device

Olanrewaju et al., (2022) development an automatic tomato pastes production machine that steam and grind tomato fruits automatically. The tomatoes are fed into the hopper, powered with electricity through a single plug as shown in figure 6. When the machine is switched on, the tomato fruits are steamed at a preset time and automatically discharged through a PVC pipe into a blender. The blender comes up when the steaming time has completed and when a homogenous paste is formed from a preset blending time. The entire operation stops automatically, then the switch is off from the socket.

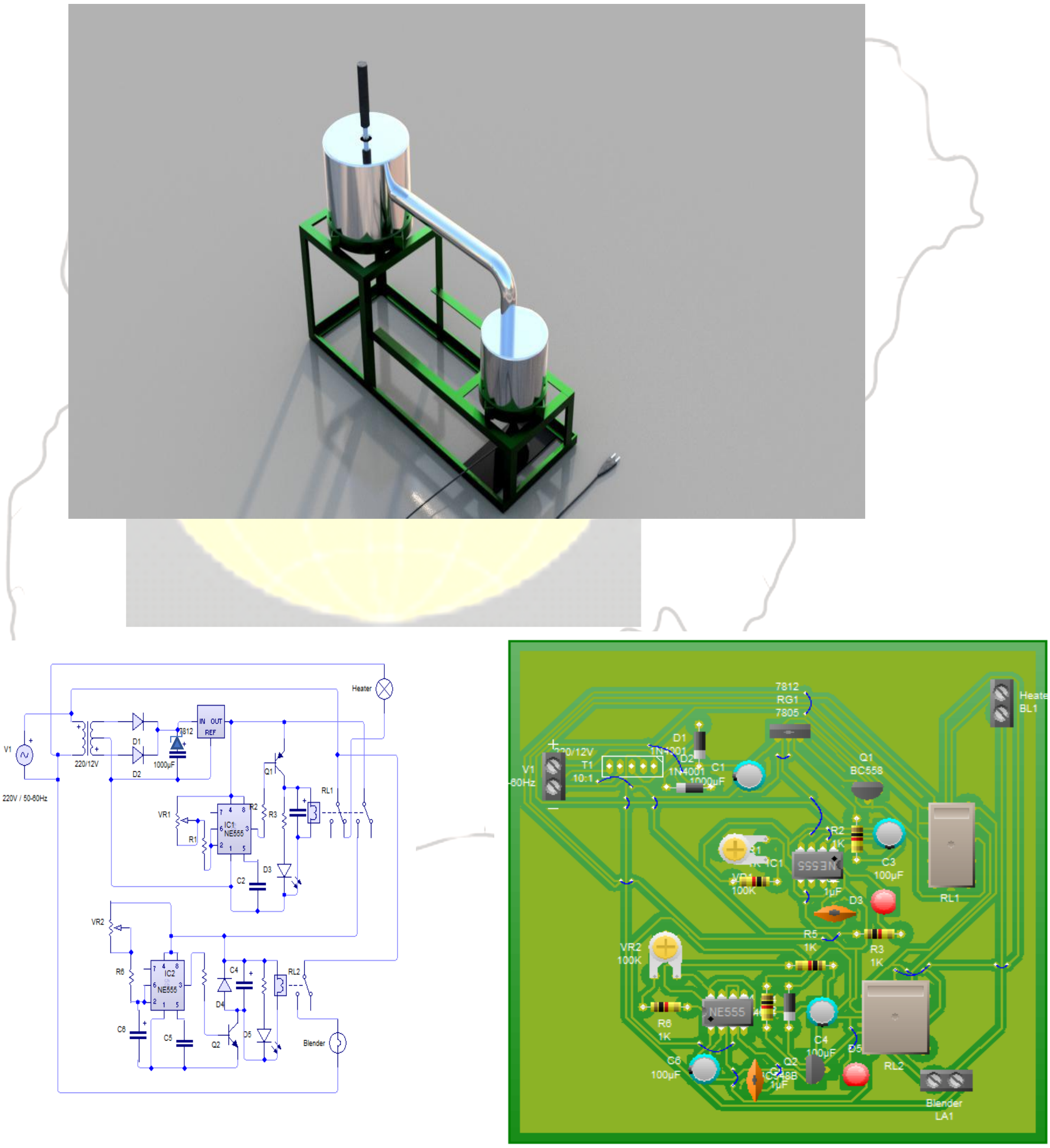

Figure 6: Diagram of the tomato paste machine and the circuit diagram for the automation

Few among the Nigeria agricultural researches that are AI based were listed above, many of which are agricultural products processing based. This is an indication that quite a lot of other fields of agriculture are yet to be explored, hence, the need to refocus on such areas using sustainable means to improve agricultural productivity in Nigeria.

Sustainability of Artificial Intelligence (AI) in Nigeria

Sustainability of AI is a crucial component, especially, in the field of agriculture, some key aspect of AI's sustainability lies in its ability to optimize resource allocation and minimize waste, identify potential risks and opportunities that enable policymakers, businesses, and individuals to make informed decisions. Also, collaboration and knowledge sharing of open-source initiatives, interdisciplinary research, and partnerships between academia, industry, and governments can accelerate innovation and address complex challenges. Agriculture in particular can be sustained through AI by integrating it with Internet of Things (IoT) devices, farmers can remotely monitor and control various aspects of their operations, such as irrigation, temperature, and feeding systems. This enables real-time adjustments and efficient resource allocation, resulting in reduced energy consumption and improved productivity.

However, to ensure the sustainability of AI in agriculture, it is essential to address certain challenges. These include the availability and quality of data, the need for accessible and user-friendly AI tools, consideration of ethical and privacy concerns related to data collection and usage, building the capacity of farmers and agricultural stakeholders to utilize AI technologies effectively, and establishing robust infrastructure and policies to support the adoption of AI in rural areas. This will no longer be a challenge in the near future, as Nigeria's ministry of communication and strategy development has one of its core pillar of mandate as "*Digital society and emerging technology*" which has established a National Center for Artificial Intelligence and Robotics to oversee technologies relating to AI and robotics. Also, a particular center that train farmers on AI technologies was also established. It was named the National Adopted Village for Smart Agriculture. Furthermore, the Federal Ministry of Agriculture and Rural Development (FMARD) initiated a policy on National Agricultural Technology and Innovation Policy (NATIP) to ensure a full incorporation of smart technologies and related innovations into the agricultural sector.

CONCLUSION

Artificial Intelligence (AI) holds tremendous potential to drive sustainable agriculture practices. Leveraging AI technologies, farmers can optimize resource usage, enhance productivity, reduce environmental impact, and contribute to a more sustainable and resilient food system. The responsible and widespread adoption of AI in agriculture have the potential to play a vital role in meeting the increasing global demand for food while minimizing the negative ecological consequences of traditional farming practices. The integration of AI in Nigeria's agricultural sector offers immense potential to promote sustainability and environmentally friendly practices. Embracing AI in agriculture can contribute to Nigeria's food security, environmental preservation, and economic development in a balanced and sustainable manner.

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LEAD PAPERS

DIGITIZING AGRICULTURAL OPERATIONS FOR SUSTAINABLE ENVIRONMENT

J. O. Olaoye
Department of Agricultural and Biosystems Engineering
University of Ilorin, Ilorin, Nigeria

ABSTRACT

The Agric-food system is complex and it takes dozens of stakeholders and transactions to bring food from farmers to consumers. The complex issues revolving around activities, operations, technologies and innovations in Digitizing Agricultural operations were reviewed. Various concepts of Agricultural Digitization were analysed. Attempt was made to summarized Agricultural Digitization as means to affect internal processes in agriculture and to show how the emergence of drones, robots and Artificial Intelligence (AI), remote sensors, and Big Data, penetrating into all aspects of farming and food. This paper explained major issues about the trend of Digitizing Agricultural Operations, and about how it is being used for sustainable environment. The concept of environmental sustainability was also discussed with focus on the challenges of its applications. The benefits and future projections of digitization of agricultural operations were presented with appropriate recommendations. The paper concluded that Digitization of Agricultural Operations had direct influence in sustainability of the environment.

1. INTRODUCTION

According to FAO (2017, 2018), smallholder farmers are estimated to provide up to 80% of the food consumed in Asia and sub-Saharan Africa and account for a significant share of agricultural production in other regions. Despite smallholder farms' key role in achieving global food security and nutrition, they are a vulnerable group not privy to technological advancements in agriculture.

Dependency on purely human muscle as sources or for control of power source in the farm or continuous applications of primitive tools and implements in farming activities cannot deliver the desired output in agricultural production spheres.

The United Nations projects that by the year 2050 the population of the world will be 9.7 Billion. With the relevance of over 60 percent of the world population on agriculture for food, the pressure to increase production to meet demands may be difficult to attain (FAO 2009). Also, 3 Billion people around the world lack access to good food supply. The recent challenges of Covid-19, transboundary pests and diseases, natural disasters and conflict are concern mitigating against Agric-food system (World Bank 2021; FAO 2011; Johnson 2021). Coupled with climate change, which is leading to rising global temperatures, levels of carbon dioxide, and frequency of droughts and floods, along with increasing labour costs, high production costs, and unpredictability poses a major challenge to the future of agriculture. Hence, the goal is to adopt digital technologies or climate-smart agriculture and increase productivity sustainably. To increase sustainability a very precise and calculated set of practices designed specifically for a plot needs to be followed and to follow best practices data needs to be recorded and analyzed digitally.

FAO (2017) harnesses the power of digital technologies to pilot, accelerate and scale innovative ideas with high potential for impact in food and agriculture, transforming digital solutions and services into global public goods. It aims to explore the responsible application and adoption of existing and frontier technologies, design and scale new services, tools and approaches to empower rural households and inspire youth entrepreneurship in food and agriculture.

1.1 Antecedences and Experiences Before Advent or Extensive Deployment of Technology

Going back a few years, remember the time when opening a bank account required a visit to the bank and waiting in long queues? Then, to withdraw your savings or make lodgement into your account seems to be a whole day affair. The activities in banks, hospitals, and most private and public sector organizations require exhaustive paperwork. Today, as a result of recent rapid digitalization this exhaustive paperwork has diminished as these businesses move online. Digitization has reduced the manual work - which was time-consuming, error-prone, and inefficient thus saving corporations millions. As at today at the comfort of your home it is possible to place a call and make booking for an Uber / Bolt or making payments directly through apps on the phone. By these means, you are using a digital platform for performing tasks that were once manual. The incorporation of technology in everyday tasks to improve functionality is known as Digitalization.

According to World Bank (2021), our global Agric-food system is expected to sustain world's ever-growing population, create millions of jobs and is critical in achieving sustainable development goals. At present, the global Agric-food system is not fit for the purpose and stresses the environment by generating up to 29 percent of greenhouse gasses and while there is an overabundance of food, over 800 million of people are under nourished worldwide (FAO, 2018). This is due to the global Agric food system being held back partly by transactions costs and information asymmetries which prevent profitable transactions. The Agric-food system is complex and it takes dozens of stakeholders and transactions to bring food from farmers to consumers (Figure 1). Transaction costs are incurred by business partners to find each other, determine sales conditions such as volume and quality, negotiating prices and return policies.

With advancements in AI, the data analysis capabilities have improved so that all the appliances in our house can be managed by a virtual assistant that can understand human voice commands and respond. Proving to be a boon to every sector, digitalization in agriculture is also slowly revolutionizing this vast and complex sector that remains the center of the world economy as still over 60% of the global population depends on it for survival (Grossman and Tarazi, 2014; Jakovljevic, 2021; World Bank, 2021). Therefore, through digital farming, farmers can even get their queries solved and manage the supply chain directly through applications on their phones. Through pre-harvest and post-harvest management of farms, digital farming aims to take over all the aspects of farming from farm to fork.

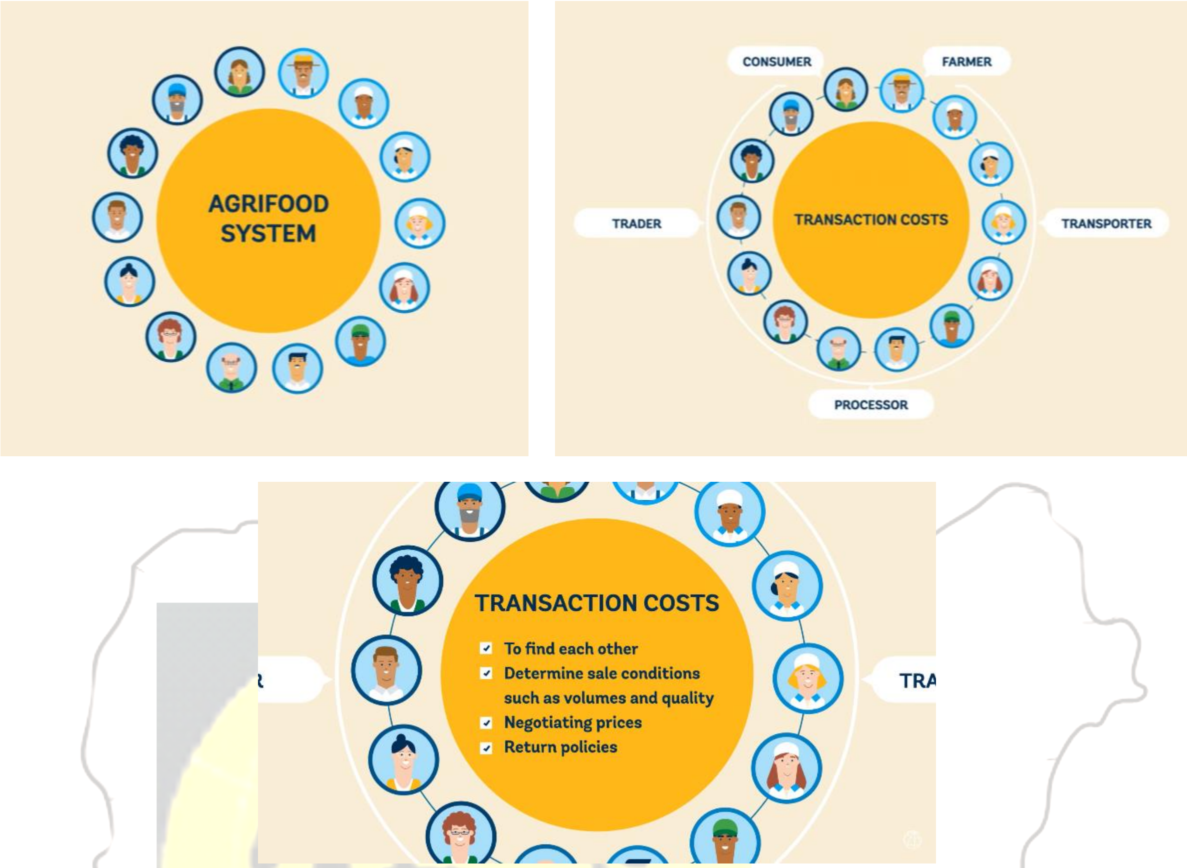

Figure 1: Complex Nature of Agric-food System

2. CONCEPT OF DIGITAL AGRICULTURE

1. Digital agricultural revolution is digitalization process of agriculture which is also known as smart farming or e-agriculture. These are tools that digitally collect, store, analyze, and share electronic data and/or information in agriculture.
2. Productive and efficient Agric-food system that provides food nourishments and support livelihood.
3. The increasingly integrated use of aggregated data services and tools. This is seen as part of a fourth industrial revolution which involves "a fusion of technologies" that can blur the lines between physical, digital, and biological realms.
4. Internet of Things, nanotechnology and digital education development are the 3 main elements that form the foundation of digitization in Agriculture.
5. Digital farming, also known as digital agriculture, refers to the use of digital technologies to improve the efficiency and productivity of agriculture. This can include technologies such as remote sensors, drones, precision irrigation systems, and GPS-guided machinery, as well as the use of data analytics, AI, and machine learning to make informed decisions about crop management and farm resource allocation. These digital farming technologies can be used to collect data about soil conditions, crop health, weather patterns, and other factors that impact agriculture.
6. Digital farming can be defined as the use of technology by farmers to integrate financial and field-level records for complete farm activity management.
7. "Digital Farming is the consistent application of the methods of precision agriculture and smart farming, internal and external networking of the farm and use of web-based

data platforms together with Big Data". Data from each plot can be analyzed to provide information on soil, weather, and crop growth patterns to give actionable geographically relevant timely insights to prevent losses and optimize the productivity of each plot on the farm.

(CROPIN, 2023; Lonie and Makin, 2016; Mattern and Tarazi, 2015; Dercon, G. 2023)

2.2 Digitalization of Farm Data for Actionable Insights

Digital farming gives farmers access to timely valuable insights so that they can adopt best practices and manage farms more efficiently thus reducing losses and maximizing profits. Technologies offer a variety of solutions for adapting to advanced farming. IoT in agriculture consists of sensors, drones, and computer imaging integrated with analytical tools for generating actionable insights. Placement of physical equipment on the farms, monitors and records data which is used to get insights. Due to advancements in satellite imagery, machine learning, and data storage in clouds, predictive analytics software has been pretty favorable as they are highly scalable and easy to use.

3. DIGITIZING AGRICULTURAL OPERATIONS

Digitization of Agricultural operations implies implementation of technology in any agricultural operations that gives farmers the opportunity to drastically increase yield sizes by maximizing output and automating input via the capabilities of Agricultural Technology. This is a way of ensuring that it is necessary to automate and digitize some of the most essential processes in farming operations. The farming operations are logically presented in Table 1. Digitising agricultural operations will help farmers to reap the benefits of optimal sustainability and gradual profitability. It is crucial to realize, that digitization will help us meet the goal of sustaining our growing population, which is, of course, the biggest challenge we are facing due to the ever-increasing number of people on earth.

Table 1: Typical Classification of Stages of Agricultural Production Operations

S/No	Classification of Stages	Operations
Pre Harvest (Crop Production)		
1.	Bush Clearing and Land Development	Bush clearing / Tree Felling / Land levelling / Land preparation
2.	Primary Tillage Operations	Deep Ploughing, Deep Harrowing, Tilling, Ridging, etc
3.	Secondary Tillage Operations	Harrowing, Ridging, Raking,
4.	Irrigation	Flood, Surface, Pivot,
5.	Cultivation	Seed Drilling, Planting, Broad casting, Transplanting, etc
6.	Planting/Fertilizing	Fertilizer Applicator
7.	Plant Protection	Sprayer, duster, weeders sickle, cutlass, knife mower
8.	Harvesting	Sickle, cutlass, knife, mower, reaper etc.

9.	Transportation	
10.	Storage	Storage of Agricultural produce in Appropriate Structures
11.	Marketing	
Post Harvest Operations		
12	Primary Crop Processing	Drying Milling (size reduction) Cleaning (grains eg. Rice, beans, maize Threshers/Decorticators & cleaners Crushers Handling
13	Secondary Crop Processing	Cooking/Sterilizing Pressing/Expressing Juicing
Animal Products		
14	Meat Processing	
15	Dairy and Milking	
16	Cheese production	
17	Fishing	
18	Fish Processing	
19	Poultry	
20	Egg	
21	Handling and Transportation	

Agricultural operations in digital agriculture are not mere activities and technology. These are complex issues revolving around activities, operations, technologies and innovations that are aimed at maximizing sustainability. Digital Agriculture in this case refers to productive and efficient Agric-food system that provides food that nourishes and support livelihood (World Bank 2021).

There are many solutions that will allow us to maximize sustainability. For example, innovations such as precision agriculture is a great method of doing this, however, it does require a slightly different approach compared to a standard historical/manual approach of farming we are using right now.

This approach calls for integration of physical or mechanical, biological, and ecological agricultural practices with the broad knowledge acquired on the biological and ecological characteristics of crop plants and weeds, farmers can successfully manage weeds without herbicides, while maintaining high yields, avoiding building resistance in weed species, protecting soil health and biodiversity, and minimizing erosion (PANE, 2023).

Transformation of Agric-food systems can help transiting to deliver safe, affordable and healthy diets to the world rapidly growing population and at the same time contribute to inclusive economic and socio development.

Innovation is central force to transforming Agric-food systems. Digital technologies are examples of innovation. Therefore, Digital Agric food systems innovation includes Online platforms, Precision Agriculture such as censors, Geodata, Artificial Intelligence, AI, E-extension, E-Commerce, Digital technologies for rural finance, Blockchain and Food sensing technologies. All these are aimed to delivering transparency, traceability, food safety and quality along food value chains (Trendov *et al.,* 2019; World Bank 2021; Consortium and Jakovljevic, 2021).

3.1 Technologies used in Digital Farming

Digital Farming is the integration of precision farming and smart farming and is achieved through the implementation of intelligent software and hardware.

Precision farming is popularly defined as a technology-enabled approach to farming management that observes, measures, and analyzes the needs of individual fields and crops. Smart farming is more focused on the use of data acquired through various sources (historical, geographical, and instrumental) in the management of the activities of the farm.

Digital Farming can be done through the installation of network-connected 'smart' devices as part of IoT (Internet of Things) or they can be Software as a service (SaaS) based Agtech. When hardware transfers data over a network they become 'smart devices' and become part of the Internet of Things (IoT). IoT in agriculture comprises the use of sensors, drones, robots, and cameras. Sensors, cameras, and robots are installed on the farms and record the data (CROPIN 2023; Beuemann 2021).

Drones in agriculture can be used as pay per services or can be bought and stationed on farms. The IoT equipment needs to be connected to an analytical dashboard for the analysis of data. IoTs are used for field-related data only. They can't help manage the overall farm activities and show the data in terms of financial gains or losses. They are just data (CROPIN 2023).

Since IoT utilizes hardware, it requires solid technical knowledge for operating the equipment along with high maintenance and setup cost. The high capital input cost is what keeps IoT out of the reach of most farmers.

Software as a service (SaaS) is the more economical and scalable way to upgrade to digital farming. Leading Agri tech companies like Cropin utilize machine learning and satellite monitoring for performing predictive analysis and delivering customized reports and actionable insights directly to farmers' screens. The intelligent agriculture cloud platform is gaining popularity pretty quickly among businesses as they can assess and manage their overall farm operations with one software and this is a low-risk investment with monthly and yearly subscriptions. Companies like Cropin are becoming one-stop solutions for driving Farm Management, Traceability, Sales Management, and Risk Management in the Agri sector (CROPIN 2023).

3.2 Benefits of Digital Farming and Digital Agriculture Solution for a Food Processing Industry

Digital farming can provide various benefits, such as increased agricultural efficiency, reduced costs, improved crop yields, and reduced environmental impact. It also helps farmers make more informed decisions about crop management and resource allocation, and can help improve food security by maximizing production and minimizing waste.

The benefits of digital agriculture solution are enormous for a food processing industry. It incorporates end-to-end solutions from farm-to-fork, higher yields as inputs are optimized and constantly monitored, better quality due to compliance with food standards and nutrition tracking, less waste due to customized practices accounting for the precise application of resources and thus reducing production costs. It enhances supply chain management from farm to fork, near real-time monitoring is made feasible and it provides avenue for standard package of practices.

Digital farming can offer readily available and accessible management through smartphones and Personal Computers, geotagging for accountability and accurate predictability can be made possible, satellite and weather input-based advisory are ensured, creates platforms for robust and flexible system for farm management, alert log and management on pest infestation, diseases, etc. can be seen at instance and crop reports and insights made easy reporting on the go possible (Cole and Fernando 2012).

3.3 Challenges of Digital Farming

Challenges include the high cost of equipment, implementation, and management of digital farming technologies, limited access to data and connectivity in rural areas, and potential data privacy and security issues. Additionally, there is a learning curve involved in implementing new technologies, as it may take time for farmers to adopt digital farming solutions.

Many digital farming technologies can be expensive, which may be a barrier with high cost of adoption. In some cases, particularly in developing countries or rural areas with limited infrastructure access to digital farming technologies may be limited. There may also be a learning curve associated with using digital farming technologies, and farmers may need to be trained in order to use them effectively.

The cost of in-house development is almost 10 times or more than the cost of implementation of a SaaS Product. Further additional software infrastructure in terms of Servers, Maintenance, and Software Licenses (Microsoft, SQL, Google License, etc.) is a huge cost that the organization has to bear independently. At Cropin, the license and the cost are spread across hundreds of clients which makes it viable for all (CROPIN 2023).

Organizations would require to have teams and products for data security and warehousing so that the information can be effectively used across the years for analysis and decision-making. Many organizations having their in-house product have missed this part thus data utilization has become a big challenge.

3.4 Agri Apps – Agricultural Services and Digital Inclusion in Africa

Various apps are developed to bring agricultural services closer to farmers, providing real-time information on weather and crop calendar, livestock care, markets, and nutrition-related aspects of food production (CROPIN 2023; Decon 2023; Downes 2009).

3.4.1. Weather and crop calendar

This mobile application combines information on weather forecasts and crop calendars.

3.4.2. Cure and feed your livestock

This mobile application provides real time information on animal diseases control and animal feeding strategies.

3.4.3. AgriMarketplace

This mobile application connects producers and traders to facilitate trade and access to prices.

3.4.4. e-Nutrifood

This mobile application provides inhabitants of rural areas with information and technical recommendation concerning the production, conservation and consumption of nutritious foods.

3.4.5. Agricultural Stress Index System (ASIS)

It monitors agricultural areas with a high likelihood of water stress/drought at global, regional and country level, using satellite technology.

Drought affects more people than any other type of natural disaster and is the most damaging to livelihoods, especially in developing countries. ASIS simulates the analysis that an expert in remote sensing would undertake, and simplifies the interpretation and use of the data for non-remote sensing experts.

3.4.6. Water Productivity Open Access Portal (WaPOR)

It provides publicly accessible, near real-time data to monitor agricultural water productivity using innovative satellite technology.

Agriculture is responsible for 70 percent of freshwater withdrawals worldwide. Careful monitoring of water productivity in agriculture is essential. WaPOR taps into a wealth of satellite data to help farmers optimize irrigation systems and achieve more reliable agricultural yields.

3.4.7. System for Earth Observation Data Access, Processing and Analysis for Land Monitoring (Open Foris and Sepal)

It helps countries measure, monitor and report on forests and land use, offering unparalleled access to granular satellite data and computing, for improved climate change mitigation plans and better-informed land-use policies.

Open Foris leverages technical partnerships with Google and others to help countries develop robust national forest monitoring systems. SEPAL provides comprehensive image processing capabilities and enables detection of small-scale changes in forests, such as those associated with illegal or unsustainable timber harvesting.

3.4.8. Event Mobile Application (EMA-i)

It enables data collection and real-time reporting at country level of geo-referenced information on animal diseases, facilitating both surveillance and early warning.

Animal disease surveillance and early warning enable national authorities to take effective and targeted prevention and control measures, and advise at-risk populations. Geo-referenced information on animal diseases is collected from the field and entered into this app. Users can visualize the location and the epidemiological details of a disease event from the field.

3.4.9. Food Price Monitoring and Analysis (FPMA) Tool

It provides an advanced technical solution for dissemination and analysis of price information.

The FPMA Tool provides an easy way to access the large amounts of data present in the database. It allows users to quickly browse single price series, create comparisons among countries/markets/commodities, download of charts, data and basic statistics such as averages, standard deviations and percentage changes.

3.4.9. Information Network on Post-harvest Operations (INPhO)

It is an online technical platform that aims to address the growing demand from member countries for technological solutions to reduce food losses. A large number of producers in the developing world lack access to information on good post-harvest management practices, food processing and packaging options, good transportation handling practices. INPhO facilitates access to this information, through virtual reality (VR), 3D interactive, augmented reality (AR), high-definition video and pictures.

3.4.10 Drones for Desert Locust early warning and preventive control (dLocust)

As part of global Desert Locust monitoring, early warning and preventive control in Africa and Asia, drones could be used to locate areas of green vegetation in the desert, search the areas for locusts, and treat them safely and effectively. Research and development is underway to provide a fixed-wing drone solution. These devices would be integrated with eLocust3, the hand-held rugged tablet used by survey and control teams for recording observations and transmitting them in real-time by satellite.

3.4.11 Fall Armyworm Monitoring and Early Warning System (FAMEWS)

It collects data on Fall Armyworm at the farm level and collates it for sharing at local, national and global levels to manage outbreaks, identify priority areas, and foster early warning mechanisms for all stakeholders.

Fall Armyworm (FAW) is an insect pest of more than 80 plant species. FAMEWS plays a critical role in FAW management as it enables the collection, recording, and transmission of standardized field data by farmers either as individuals or organized as communities.

3.4.12 Eyes in the Sky (Drones)

Drones are used in agriculture for crop production, early warning systems, disaster risk reduction, landscape mapping, illegal fishing detection, and wildlife conservation. When combined with analytical tools, the use of drones allows coverage of much larger areas, access to insecure zones, and makes operations more efficient and effective. Drones are being used for, and not limited to, precision farming to improve productivity; to map forests and landscapes for valuation, monitoring and research; to detect illegal fishing and aid in prosecution of offenders; and to track, inspect and monitor livestock remotely.

4. DIGITAL AGRICULTURE AND ENVIRONMENTAL SUSTAINABILITY

Environmental sustainability is the responsibility to conserve natural resources and protect global ecosystems to support health and wellbeing, now and in the future. The general goal of environmental sustainability is to evens things out. Environmental sustainability provides huge benefits for human health and that of all other species. It reduces our global carbon footprint and reduces our reliance on fossil fuels and other harmful energy practices. But does it benefit us in other ways?

About 24% of global human deaths are caused—directly or indirectly—by avoidable environmental factors. To live long and healthy lives, we need and deserve unpolluted air to breathe, clean water to drink, and to live in places free of toxic substances (Johnson 2021). Sustainability can increase life expectancy by providing healthier living conditions and better healthcare, which could also lessen the divide between the rich and poor. Sustainable development encourages more responsible manufacturing and production, covering the industrial side of waste and pollution. It also encourages companies, industries, and governments to make decisions based on long-term consequences, rather than taking the easiest, cheapest option (Alina et al 2019; Trendov et al 2019; FAO 2017).

Figure 1 shows an illustration of how Digital Agriculture can create societal gains through economic efficiency, equity and environmental sustainability. Digital Agriculture leads to economic efficiency by creating access to multiple markets, lower costs through improved price discovery, creating path ways for buyer – selling matching, improved traceability and quality control. Digital Agriculture enhances equity through the inclusion of small holder farms and marginalized populations. Also, Digital Agriculture brings about environmental sustainability through reducing food waste, better resource management and environmentally friendly practices.

Figure 2 shows how level of intensive application of Digital Agriculture in agricultural operations can lead to increasing economic and environmental performance through increase in productivity of production and reduction in the environmental burden and cost of resources. Five levels of intensive application of Digital Agriculture in agricultural operations were defined (BMEL, 2017) and the implications of each level were analyzed as follows:

Level I is the use in the production process of only one computerized object, such as a machine equipped with sensors, which after processing transmits information directly to the operator;

Level II is the formation of complex objects, for example, tractor units, which are interconnected by an information system with the ability to exchange data to optimize the operating parameters of both tractor and machine;

Level III is an object connected to a network; an example would be a system consisting of several agricultural machines that are interconnected and operated automatically (self-propelled combine, trailers, transport kit, tractor);

Level IV is a digital production system that includes not only individual machines and machine units, but also individual links in the technological chain;

Level V - the highest level of digitization - is a comprehensive mix of systems that are interconnected.

Table 2 presents detailed comparison of economic and environmental effects from the introduction of digital technologies in the agricultural sector (Alina et al., 2019).

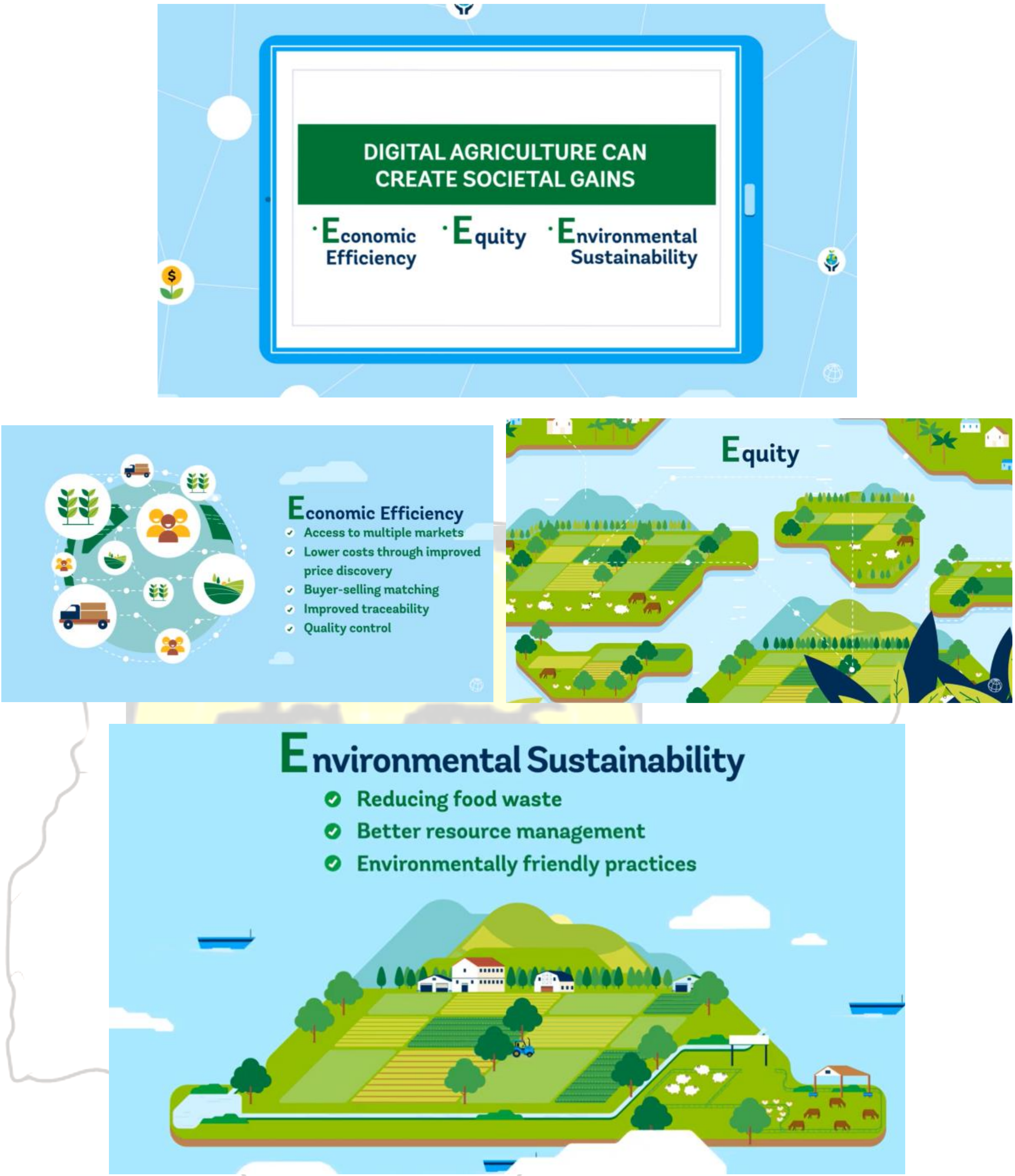

Figure 1: Illustration of Effects of Digital Agriculture on Societal Gains (World Bank 2021)

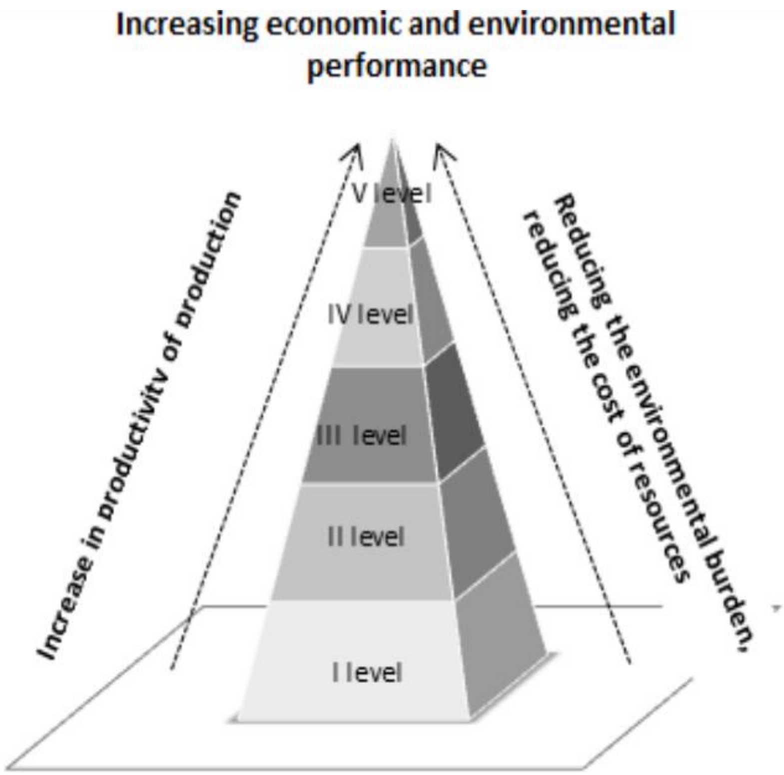

Figure 2: Levels of Agricultural Digitization

Table 2: Comparison of economic and environmental effects from the introduction of digital technologies in the agricultural sector

Applied Technology	Economic Effect	Ecological Effect
Driving in parallel	15% fuel, seed, fertilizer and plant protection cost savings	reducing the load on land resources, improving soil structure and reducing its compaction, reducing the amount of fertilizers and plant protection products
Standards management	resource savings of 10%, increased profits through increased crop yields and animal productivity	automatic application of fertilizers, herbicides, chemicals reduces the negative impact on land and water resources, reduces the level of emissions into the atmosphere
Soil Analysis	reducing production costs, optimizing fertilizer application, increasing yields and increasing efficiency by 10-30%	optimizing fertilizer application, improving soil structure by identifying the need for lime and diagnosing excessive salinity or alkalinity
Drones	fuel saving, minimizing the use of seed, fertilizers and irrigation water, preserving and increasing crops through timely sowing and harvesting, optimizing production costs and improving the quality of production planning for agribusinesses	rational use of land and water resources, optimal application of plant protection products through the use of spot spraying technology in specific areas of the field. Possibility of using bio-organisms
Satellite monitoring	cost savings of fuel, seeds, fertilizers and plant protection products, increase of production efficiency, possibility of land suitability assessment, development of reclamation plan, estimation of potential yield	economical impact on the environment of chemicals through their optimum application according to the mapping of fields and crops
Weather monitoring	increase of efficiency of production operations, increase of yield and its less dependence on climatic conditions, economy of expenses on resources, in improvement of financial results	creation of an archive of data of natural and climatic conditions of the territory

Source: Alina *et al.* (2019)

5. GUIDELINES FOR SUCCESSFUL EXECUTION OF DIGITIZATION OF FARM OPERATIONS

5.1. Setup Research and Goals

A well conceivable aim of what must be achieved and set specific goals to facilitate the entire digitalization process is desired. There is no need to aim with the goals extremely high. Start with a simple connection to the Internet and technology. Thereafter move from simple systems to more complex integration with other systems, weather stations, and devices or sensors that will record detailed farm data and store it in a safe place. Research digitalization on various agricultural portals, take advice from other farmers or connect with people who already managed to digitalize their production successfully.

5.2. Consultative and Instructive Guidance

Activities and recommendation from agricultural advisory centers, bank advisors, agricultural research institutes that have a team of specialists are crucial to successful take off digitization of farm operations. The goal is to seek expertise opinion on concrete steps to remodel and improve the farm's performance. In addition, their offer includes several types of assistance, starting from the preparation of the necessary documentation, performing the implementation of tasks resulting from agri-environmental programmes or providing farm's investment possibilities assessment.

5.3. Government Agencies Programmes and Subsidies

Farmers can patronize various government agencies such as AfDB, the EU, FAO, etc for subsidies. The criteria and the number of subsidies change from year to year. Moreover, there are many subsidies that support innovations and the use of modern technologies. For this reason, it shouldn't be hard to bear in mind the deadlines and documents needed to submit for the appropriate subsidy.

5.4. Benchmarking and Changes in Management

Let's not be afraid to compare with other local entrepreneurs. They are the treasury of knowledge. In other words, they can share valuable tips from their own experience. Why not repeat something that works for them on our own farm. It can be something about new sensors or changes in management. The happier stories – the better, right?

5.5. Modern Tools and Systems, AI Implementation

Are modern technologies for everyone? From simple devices easy to install, such as sensors, weather stations, through drones or satellite imagery, ending with precision farming, keep in mind that everything is created for people like us. Remember that by choosing such solutions, companies will train you how to use a given tool. It's not like buying the item x years ago, where you had to install the device by yourself and solve the puzzle called – and what's next. Times have changed and the quality of the service and the availability of products together with them.

When deciding on AI, a dedicated company will take care of configuration and training, and later also hand it out to customer support. Thanks to these devices/systems, data straight from the field will be collected regularly and stored in the cloud (the safest place). These data will allow analytics, determination of the appropriate time for treatments, timely protection against pests, and much more

5.6. Process Automation

Have you heard about process integration and automation? Why turn on the sprinklers every day if they can turn on and off by themselves. Besides automated irrigation systems, many other technologies can facilitate your everyday life. For example, a farm management system can facilitate the integration and automation of processes. Why go to the field every day to carry out an inspection/ scouting if we can see the changes accurately thanks to the imagery from the satellites and receive a notification of a disturbing anomaly. Thanks to digitization and data obtained from measuring devices, these systems will be activated automatically and will allow to save time, result in more efficient resources management or protection against crop loss. In other words, if you want to digitalize your production you should consider the automation of your processes.

5.7. Making Decisions Based on Real Data

All the above mentioned leads us to one conclusion – digitalization allows more efficient data collection. All the results are being stored in one and safe place and are easily accessible. Thanks to performed analysis, making decisions based on data becomes real and let's be honest – that is the biggest achievement.

6. RECOMMENDATIONS FOR POLICY DIRECTION IN DIGITAL AGRICULTURAL OPERATION IN NIGERIA

6.1 Policy and Frameworks: Adequate policy and incentives frameworks on Digital Agricultural operations must be produced to cater for all regions, along the lines of operations, stakeholders and regulatory guidelines. Well define aim on what must be achieved and set specific goals to facilitate the entire Agricultural digitalization process.

6.2 Bridge the Digital Divide: Accelerate and make available such requirements to bridge the digital divide and allow for more widespread global adoption of Digital Agricultural transformation.

6.3 Appropriate Investments and Allocation of Resources: Public investments in rural connectivity for digital literacy is highly recommended and focussed attention must be directed towards attainment of rural connectivity facilities.

6.4 Digital Database: Government at the three tiers must facilitate coordinate farmers' registration with centrally visible and functional digital database.

6.5 Innovation: Innovation is all about solving complex problems and adding values in new ways. Farmers, herders, foresters and fisher folks are the centre of innovation as custodians of natural resources.

6.6 Motivation and Incentives for Custodians of Natural Resources: Appropriate platforms must be created by concerned government agency to support Custodians of Natural Resources in finding complex solutions to complex issues like business models which may include
a) Contract farming
b) allow producers better access to markets
c) allow better access to income.

6.7 Access to Market and Geographic Indicator Labels: Recent online agriculture platforms helped in COVID 19 and innovation that must ensure access to rural communities in developing countries especially women and youth. Adoption of Geographic Indicators labels for food products is crucial with generation of improved market position and incomes.

6.8 Roles of Women and Youth: Women are key player in all stages of Agric-food systems transformation. Youth are expected to be encouraged to be another major player by applying their education, entrepreneurial potential and technological savviness to support innovation adoption of innovative solutions within their communities.

6.9 Public Private partnership: Public Private partnership will be crucial to help rage investment gaps in infrastructure and access to facilitate smallholder participation in digital economy pilot public private innovation projects targeting developing countries farmers are promising.

7. CONCLUSIONS

Digitization is a trend of modern agriculture, the essence of which is to create, develop and apply innovative methods of using information and communication technologies in the agricultural sector of the economy. Digitalization of farm data for actionable insights revealed how digital farming gives farmers access to timely valuable insights so that they can adopt best practices and manage farms more efficiently thus reducing losses and maximizing profits. Technologies used in digital farming were highlighted. It was concluded that the integration of precision farming and smart farming can be achieved through the implementation of intelligent software and hardware. Benefits of digital farming and digital Agriculture Solution for a food processing industry were discussed. The paper also elucidated how digital agriculture induced environmental sustainability as factors responsible for the conservation of natural resources and protection of global ecosystems to support health and wellbeing, now and in the future. Guidelines for successful execution of digitization of farm operations were presented. Recommendations for policy direction in Digital Agricultural operations in Nigeria were enumerated.

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SOIL CONSERVATION AND MANAGEMENT FORSUSTAINED ENVIRONMENT AND AGRICULTURAL PRODUCTIVITY

LEAD PAPER PRESENTED

At

INTERNATIONAL SOIL TILLAGE RESEARCH ORGANIZATION (ISTRO) SYMPOSIUM

(11TH JULY, 2023)

By

PROFESSOR OLUYEMISI B. FAWOLE

Department of Agronomy,

University of Ilorin

INTRODUCTION

➢What is Soil Conservation?

- A combination of practices used to protect the soil from degradation
- Involves treating the soil as a living ecosystem
- Returning organic matter to the soil on a continual basis
- Prevention of loss of the topmost layer of the soil from erosion
- Prevention of reduced fertility caused by over usage, acidification, salinization or other chemical soil contaminant.

SIGNIFICANCE OF SOIL CONSERVATION

- ➢Crucial concepts that help to maintain health and productivity of soil.
- ➢Without proper conservation and management techniques,
  - soil erosion, nutrient depletion, and other forms of soil degradation can occur
  - significant reduction in crop yields and threats to long -term sustainability of agricultural systems.

SIGNIFICANCE OF SOIL CONSERVATION contd.

- ➢By implementing soil conservation and management practices,
  - farmers can help to prevent soil erosion, improve soil fertility, and reduce the need for synthetic fertilizers and pesticides.
  - results in increased crop yields, reduced input costs, and greater environmental sustainability in agricultural systems

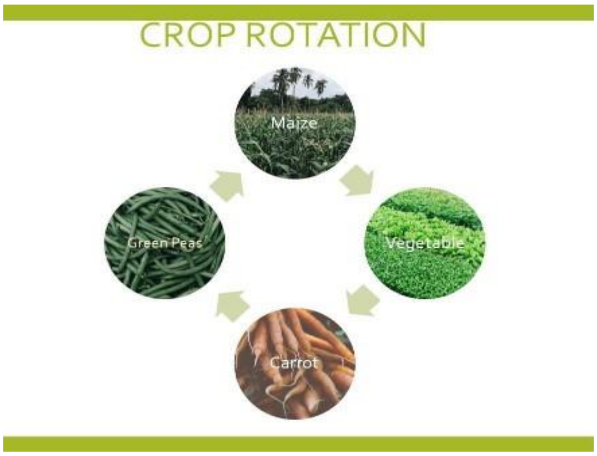
SOIL CONSERVATION AND MANAGEMENT PRACTICES

➢Soil conservation and management practices include:

- Crop rotation
- Mulching
- Reduced tillage
- Cover cropping
- Cross-slope farming
- Application of composts and manure
- Microbiological fertilizers

CROP ROTATION

➢A traditional practice of growing different kinds of crops in succession on the same piece of land.



- A farmer can plant and cultivate vegetables then move on to planting and cultivating tuber/root crops, legumes and then cereals.
- Legumes help fix nitrogen directly into the soil replenishing the ones lost and increasing the ones present for the next sequence of planting.
- Soil fertility in the crop rotation sequence is therefore usually achieved when leguminous crops are planted

Source: https://www.facebook.com/nissng/photos

BENEFITS OF CROP ROTATION

A well-designed crop rotation ;

- promotes good soil structure,
- helps to control weeds , pests and diseases.
- fosters a diverse range of soil flora and fauna that contributes to nutrient cycling.
- improves soil fertility and plant nutrition
- improves crop yield & economic gains
- promotes long-term soil and farm management.

MULCHING

- *Mulching* may be defined as the process of covering the soil surface around the plants to create congenial conditions for the crop growth.
- It creates a microclimate for the plant to grow and perform better

Types

- Organic-derived from plant sources e.g. compost, grass clippings, chopped leaves, straw, , wood chips, shredded bark, sawdust,
- Inorganic e. g. plastics and geotextiles

TYPES OF MULCH

Plastic mulch (Inorganic)

Source: https://www.google.com/url

Compost mulch (Organic)

Source: https://eorganic.org/sites/eorganic.info/files/u118/4871_9.jpg

BENEFITS OF MULCHING

- Reduces the amount of water that evaporates from soil, maintaining soil moisture greatly reducing the need to water plants.
- Improves the quality of soil by breaking up clay and allowing better water and air movement through the soil.
- Provides nutrients to sandy soil and improves its ability to hold water
- Limits weed growth by preventing light from reaching the soil surface.
- Decreases soil temperatures and keeps it cooler on hot days and warmer on cold nights.
- Covers and protects the soil by reducing soil compaction and erosion.
- organic mulches decompose over time.
- Organic mulch can attract insects, mostly slugs and worms, which is great for soil.

Conservation or REDUCED TILLAGE

- A practice of minimizing soil disturbance and allowing crop residue to remain on the ground instead of being thrown away or incorporated into soil.
- Keeps at least a third of the cultivated soil covered with the previous year's crop residue
- Includes mulch till, ridge till, strip till and no till

BENEFITS

- Reduced soil erosion
- Improved soil quality

No till farming

- *No-till farming* is an agricultural technique for growing crops or pasture without disturbing the soil through tillage.

https://notillagriculture.com/wp-content/uploads/2016/10/corn-stand-no-till-farming.jpg

BENEFITS

- Reduced soil erosion (caused by tilling)
- Increased soil organic matter
- Improved soil structure and aeration
- Increased beneficial soil microorganisms
- Retained soil moisture &conservation of water
- Reduced fuel use (from not plowing)

COVER CROPPING

WHAT ARE COVER CROPS?

- plants to cover soils for certain reasons. Unlike primary species, they **support secondary farmer's needs rather than are grown for trade or human consumption**.

➢ Cover crops are *grown either in the season during which cash crops are not grown or between the rows of some crops* (e.g., fruit trees)

TYPES

- grasses,
- legumes, and
- broadleaf non-legumes.

➢ Good cover crops have the following characteristics:

- fast germination and emergence,
- good seedling vigor,
- competitiveness with other plants,
- tolerance to adverse conditions,
- inexpensive establishment and minimal management.

COVER CROPPING

Why use cover crops in a crop management regime?

- to reduce wind and water erosion
- enhance water infiltration,
- mitigate soil compaction
- control weeds,
- control pests, diseases, and
- increase biodiversity.
- improve soil health & fertility
- boost crop yield
- provide food for livestock

CHALLENGES IN PRACTICE OF COVER CROPPING

- the water needs by cover crops may cause a reduction in the amount available to the main crop, or require the use of supplemental irrigation.
- other economic costs must be considered-expenditures for seed and soil preparations as well as labor requirements will change with the introduction of a cover crop.
- while they can reduce the impact of specific pests and pathogens, some cover crops may act as reservoirs for other insects, rodents, weeds, or diseases.
- some cover crops can persist as weeds when the field is transitioned and prepared for subsequent plantings if improperly selected or managed

Cross- slope farming

- Terrace cultivation, method of growing crops on sides of hills or mountains by planting on graduated terraces built into the slope.
- Though labour-intensive, the method has been employed effectively to maximize arable land area in variable terrains and to reduce soil erosion and water loss

APPLICATIONS OF MANURES

- Manures are organic wastes from plants and animals that are used to fertilise crops.
- As they break down, they provide useful nutrients.

TYPES

- Farmyard manure
- Green manure
- Compost manure

- Benefits
- Improved soil microbial community
- Improved mineral uptake
- Reduced toxicity from heavy metals
- Improved water holding capacity & buffering capacity of soil
- Improved crop productivity

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https://housing.com/news/whatis-manure-manure-types-and-benefits/

APPLICATIONS OF BIOCHAR

- Biochar is a stable form of carbon derived from thermochemical pyrolysis of organic materials .
- Benefits-improvement & remediation
  - ➢Enhances Soil structure
  - ➢ increases soil water retention and aggregation
  - ➢Decreases acidity
  - ➢Improves porosity
  - ➢Reduces nitrous oxide emissions
  - ➢Improves soil microbial properties

https://imgbin.com/freepng/biochar

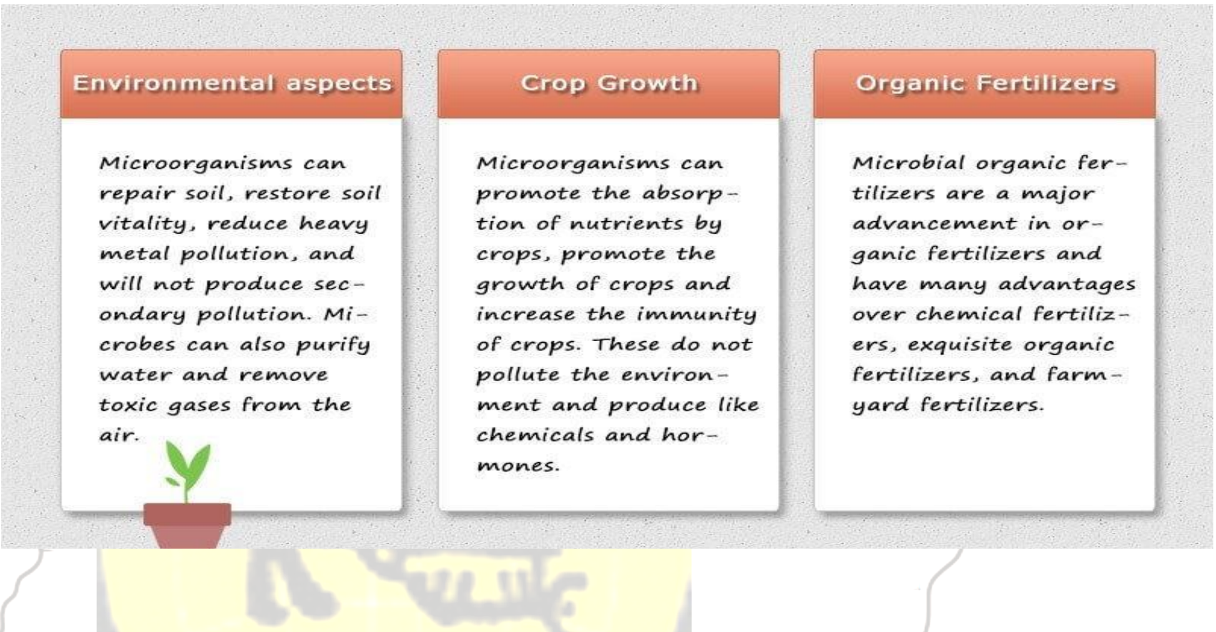
Microbiological fertilizers

- Biofertilizers are microorganisms that support the growth of plants by enhancing the nutrient supply to the host plant when given to seeds, plants, or the soil
- **Microbial fertilizers** have the effect to improve soil condition, restore soil fertility, prevent soil-borne diseases, maintain the balance of rhizosphere microflora and degrade toxic substances.
- The most important groups of microbes used in the preparation of microbial biofertilizer are: bacteria, fungi, and cyanobacteria, majority of which have symbiotic relationship with plants

https:// doraagri.com/ wp-content/uploads/2018/06/Microbes -in-soil.jpeg

BENEFITS OF Microbiological fertilizers

Roles of microbiological fertilizers in crop improvement and the environment



Conclusion

- It has become a major challenge for the world to meet the sustainable development goal of zero hunger (SDG 2) in food, feed, and other agricultural products especially in developing countries.
- Improving and sustaining agricultural crops yield without posing negative impact on environment should be the ultimate goal.
- Thus, “Conservation Agriculture - a concept for resource-saving in agricultural crop production that strives to achieve acceptable profits with high and sustained production levels while concurrently conserving the environment” continues to be promising in achieving this goal.

THANK YOU !

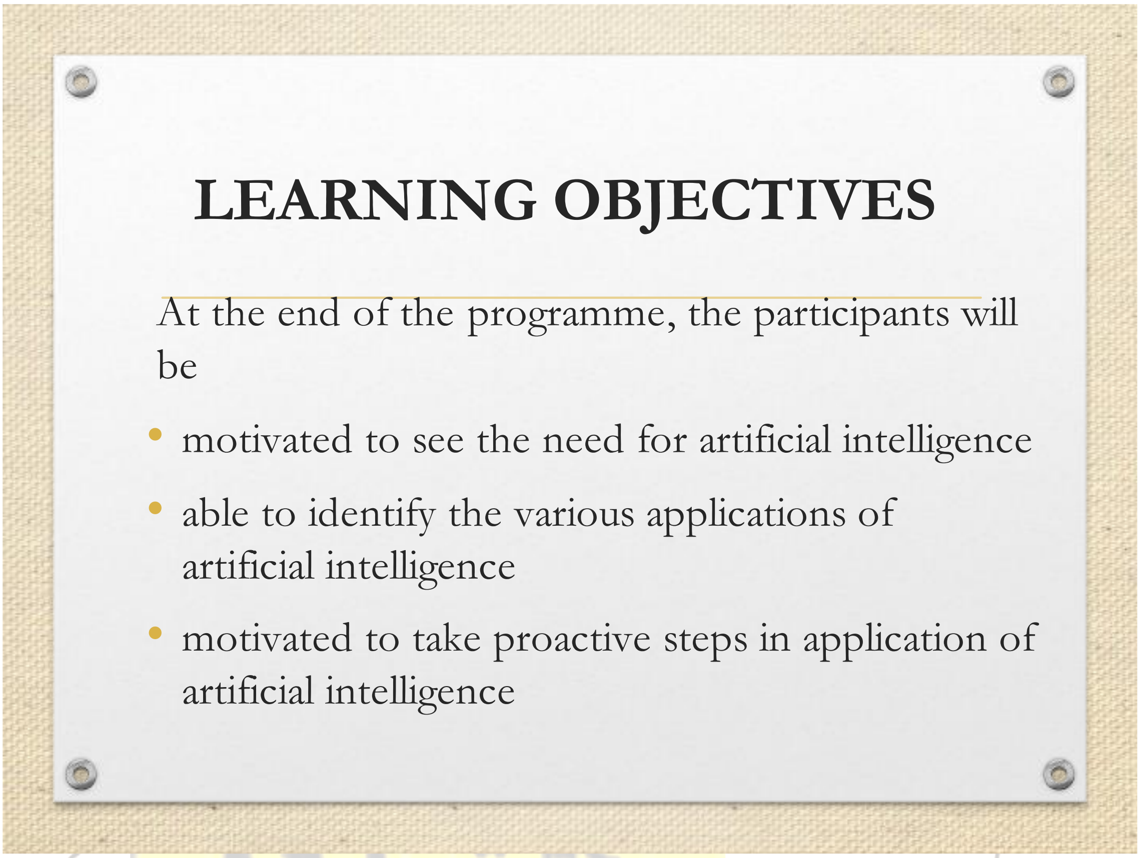
ARTIFICIAL INTELLIGENCE APPLICATIONS TO SOIL TILLAGE

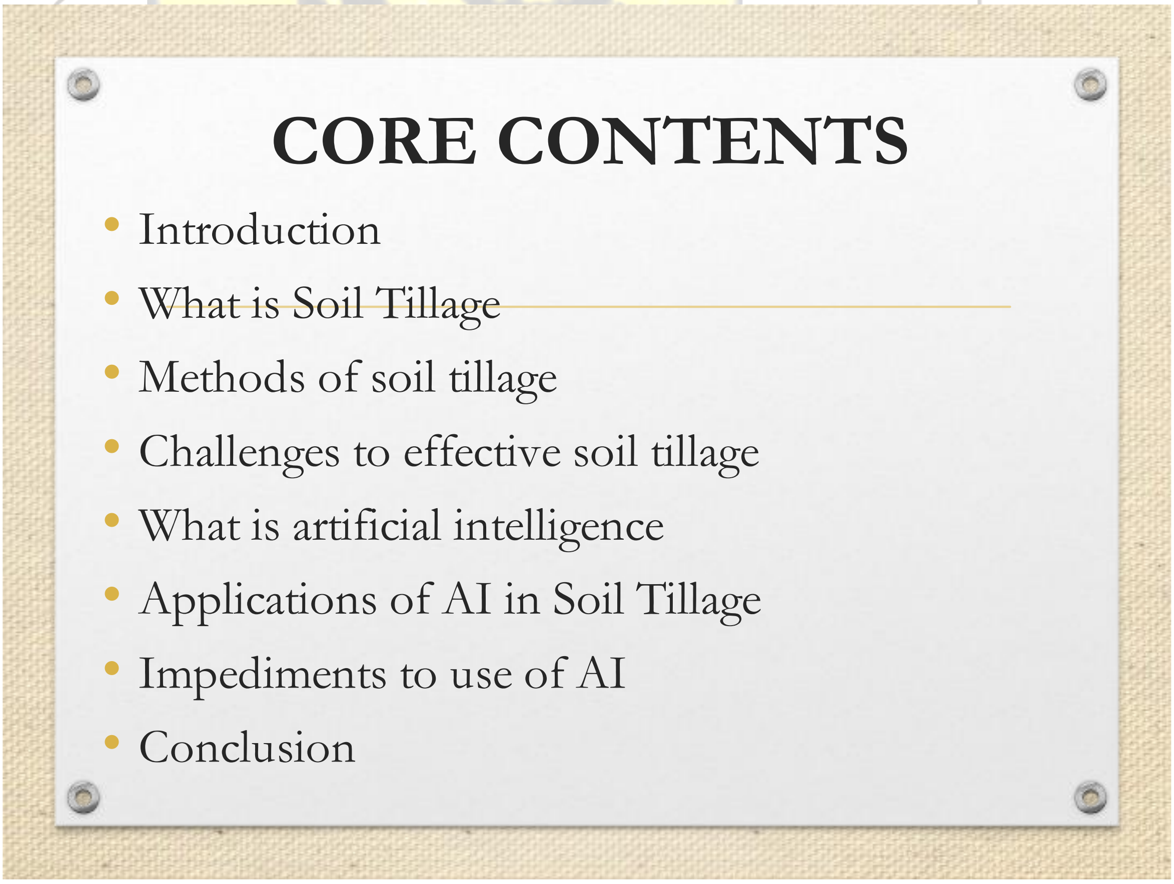
Prof Akindele Folarin Alonge
Dean, Faculty of Engineering
University of Uyo, Uyo, Nigeria
Email: akindelealonge@uniuyo.edu.ng
&
Dr John Audu
Department of Agricultuiral Engineering
Joseph Tarka University of Agriculture
Markudi, Benue State

Paper presented at the International Soil Tillage Research Organisation Symposium 2023 on Tuesday, July 12, 2023 by 12pm

OVERALL PURPOSE

- The participants will be motivated to see the need for embrace artificial intelligence in soil tillage research and activities


LEARNING OBJECTIVES
At the end of the programme, the participants will be
motivated to see the need for artificial intelligence
able to identify the various applications of artificial intelligence
motivated to take proactive steps in application of artificial intelligence


CORE CONTENTS
Introduction
What is Soil Tillage
Methods of soil tillage
Challenges to effective soil tillage
What is artificial intelligence
Applications of AI in Soil Tillage
Impediments to use of AI
Conclusion

Introduction

- Soil tillage is the process of preparing soil for planting crops. It involves breaking up and loosening the soil to create a suitable environment for seed germination and plant growth.
- The goal of soil tillage is to create a seedbed that is loose, level, and free of weeds, rocks, and other debris that can interfere with plant growth.
- Proper soil tillage can also improve soil structure, increase water infiltration, and promote nutrient availability, all of which can lead to higher crop yields. However, excessive soil tillage can also be detrimental to soil health, as it can lead to erosion, compaction, and loss of organic matter.

Methods of Tillage

- 1. **Plowing:** This is the traditional method of soil tillage, which involves turning over the soil with a plow to create a seedbed. Plowing can be done with a moldboard plow, chisel plow, or disc plow.
- 2. **Harrowing**: This involves breaking up clods of soil and smoothing the surface of the seedbed. Harrowing can be done with a disc harrow, spring-tooth harrow, or spike-tooth harrow.
- 3. **Cultivating:** This involves loosening the soil and removing weeds. Cultivating can be done with a cultivator or rotary hoe.

- 4. **Strip-till:** This involves tilling only a narrow strip of soil where the seed will be planted, leaving the rest of the soil undisturbed. Strip-till can be done with a strip-till machine or a modified planter.
- 5. **No-till or zero tillage**: This involves planting seeds directly into untilled soil, leaving the previous year's crop residue on the soil surface. No-till can be done with a no-till planter or drill.
- 6. **Reduced-till**: This involves reducing the intensity of tillage to minimize soil disturbance while still preparing a suitable seedbed. Reduced-till can be done with a minimum-till or conservation-till planter.

- The choice of tillage method depends on several factors, including
- - soil type
- - crop type
- - weather conditions
- - and equipment availability.
- Farmers must carefully consider the benefits and drawbacks of each method to determine the most appropriate tillage practice for their specific situation.

Challenges to effective soil tillage

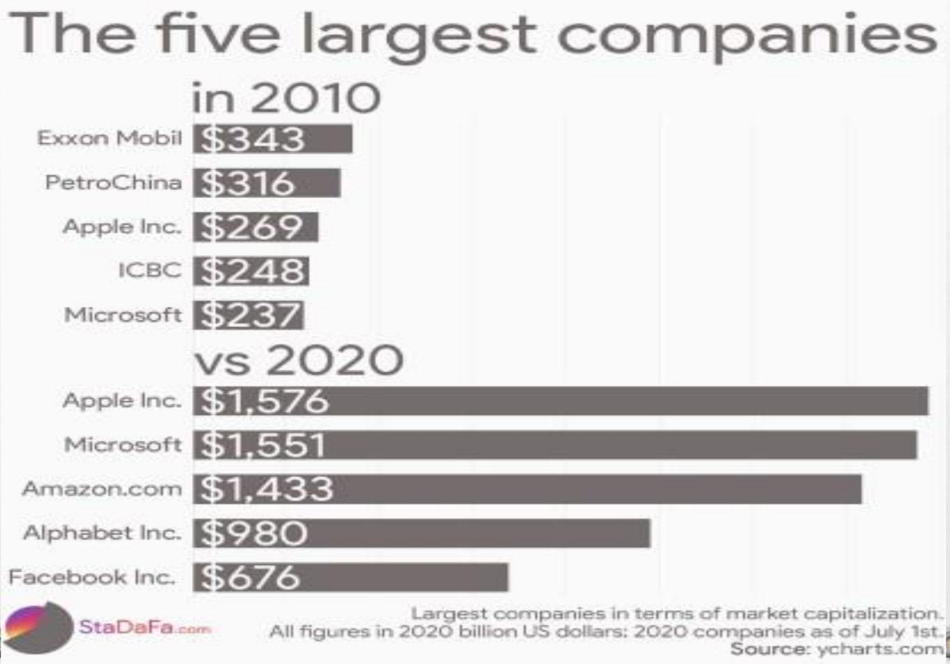
- 1. **Soil erosion**: Excessive tillage can lead to soil erosion, which can result in the loss of valuable topsoil and reduce soil fertility. This can be mitigated by using conservation tillage practices, such as no-till or reduced-till.
- 2. **Soil compaction**: Over-tilling can lead to soil compaction, which can reduce water infiltration and root growth. This can be mitigated by reducing the number of tillage passes and using appropriate tillage equipment.
- 3. **Weed control**: Tillage can help control weeds by burying weed seeds and disrupting their growth. However, over-tilling can also bring new weed seeds to the surface and increase weed pressure. This can be mitigated by using integrated weed management strategies that combine tillage with other weed control methods.

- 4. **Soil health**: Excessive tillage can reduce soil organic matter and disrupt soil structure, which can negatively impact soil health and reduce crop yields. This can be mitigated by using conservation tillage practices that maintain soil structure and organic matter.
- 5. **Energy use**: Tillage requires energy, which can be a significant cost for farmers. This can be mitigated by using conservation tillage practices, which require less energy than conventional tillage.
- 6. **Cost:** Tillage equipment can be expensive to purchase and maintain, and the cost of fuel and labor can also be significant. This can be mitigated by using appropriate tillage equipment and practices that minimize costs while still achieving the desired results.

What is Artificial Intelligence?

- Artificial intelligence is **the simulation of human intelligence processes by machines, especially computer systems**
- Artificial intelligence (AI) refers to the simulation of human intelligence in machines that are programmed to think and learn like humans.
- It involves the development of computer systems that can perform tasks that typically require human intelligence, such as speech recognition, problem-solving, decision-making, and language translation.
- AI can be categorized into two types: narrow AI, which is designed to perform specific tasks, and general AI, which aims to possess the ability to understand and learn any intellectual task that a human being can do.

A global shift to Digitalization



AI – one of the emerging Technologies Linked to 4IR

- 1. Big data
- 2. Big Data analytics
- 3. Robotics/Robots
- 4. Additive manufacturing
- 5. Artificial intelligence
- 6. Blockchain
- 7. Machine-to-machine
- 8. The Internet of Things (IoT): Is the Internetworking of physical devices
- 9. Drones
- 10. Cloud computing

AI use in Soil Tillage

- AI in soil tillage typically involves the use of machine learning algorithms and other AI techniques to process and analyze data related to soil health, crop growth, weather patterns, and other factors that impact soil tillage. Some examples of how AI is use:
- 1. Data analysis: AI algorithms can be used to analyze large amounts of data related to soil health, crop growth, and weather patterns. This data can be used to identify trends and patterns that can help farmers make more informed decisions about soil tillage .
- 2. Autonomous tillage equipment: AI -powered robots and other autonomous equipment can be used for soil tillage. These machines can use sensors and other technologies to detect soil properties, adjust tillage depth and speed, and optimize soil preparation for planting.
- 3. Precision agriculture: AI can be used to create detailed maps of soil properties and nutrient levels. This information can be used to optimize tillage practices and improve crop yields.
- 4. Predictive maintenance: AI algorithms can be used to predict when tillage equipment needs maintenance. This can help farmers avoid costly downtime and reduce repair costs .
- Overall, AI in soil tillage can help farmers make more informed decisions about soil health and tillage practices, leading to increased efficiency, productivity, and sustainability .

Applications of AI to Soil Tillage

- 1. **Precision Agriculture** : AI algorithms can analyze soil data, weather patterns, and crop growth data to determine the optimal time and method for tillage. This can help farmers reduce costs, increase yields, and minimize environmental impact .
- 2. **Autonomous Tillage** : AI-powered robots can be used for soil tillage. These robots can use sensors to detect soil properties, adjust tillage depth and speed, and optimize soil preparation for planting .
- 3. **Predictive Maintenance** : AI algorithms can be used to predict when tillage equipment needs maintenance. This can help farmers avoid costly downtime and reduce repair costs.
- 4. **Soil Analysis** : AI algorithms can analyze soil samples to determine nutrient levels, pH, and other properties. This information can be used to optimize tillage practices and improve crop yields.

Impediments to the use of AI in soil tillage

- 1**. Cost**: The initial cost of AI technology can be high, and many farmers may not have the financial resources to invest in this technology. Additionally, ongoing maintenance and upgrades can also be expensive.
- 2. **Lack of technical expertise** : AI technology requires specialized technical knowledge and skills, which may not be readily available in rural areas where many farms are located. This can make it difficult for farmers to implement and maintain AI - based tillage systems.
- 3. **Data quality:** AI algorithms rely on high-quality data to make accurate predictions and recommendations. However, soil and weather data can be variable and difficult to collect, which can impact the accuracy of AI -based tillage systems.

- **4. Compatibility with existing equipment:** Many farmers already have tillage equipment that may not be compatible with AI-based systems. This can require additional investment in new equipment or modifications to existing equipment.
- **5. Resistance to change**: Some farmers may be resistant to adopting new technology, especially if they have been using traditional tillage methods for many years. This can make it difficult to convince farmers to adopt AI -based tillage systems.
- **6. Privacy and security concerns** : AI-based tillage systems rely on data collection and analysis, which can raise privacy and security concerns. Farmers may be reluctant to share sensitive data with third-party providers or worry about the security of their data.

CONCLUSION

The adoption of AI in soil tillage faces several impediments, and addressing these challenges will require collaboration between farmers, researchers, and technology providers.


• THANK YOU FOR LISTENING

TECHNICAL PAPERS

CONSERVATION AGRICULTURE TECHNOLOGY (CAT): A PANACEA FOR SUSTAINABLE AGRICULTURAL PRODUCTIVITY AND UNEMPLOYMENT

A. S. Adesanya
Department of Agricultural Education, Sikiru Adetona College of Education, Science and Technology, Omu Ajose, PMB 2128, Ijebu - Ode, Ogun State, Nigeria.
adesanyaas@yahoo.com

ABSTRACT

The continued increase in world population demands corresponding increase in food, feed and fiber. This, in turn demands progressive development of agricultural methods and techniques that will lead to sustainable agricultural productivity. The goal of this paper is to show that Conservation Agriculture Technology (CAT) can provide solutions to food insecurity and unemployment problems in Nigeria and around the world. There is vast amount of literature on Conservation Agriculture Technology and its increasing potentials to serve as alternative to the use of intensive or conventional mechanized agriculture. Its (conservation agriculture) intrinsic nature is micro biological – processes of the eco-systems which sustain the soil fertility and also eliminates activities and processes that lead to soil degradation. This paper reviews how the appropriate technology of CAT reduces or eliminates drudgery and tedium in land cultivation but in a cost-effective manner for sustenance of food security. The paper identifies factors that show why and how intensive (or conventional) and traditional agriculture systems are not compatible with the natural soil structuring and nutrients cycling processes. The tripartite relationship between the government responsibility to create enabling environment, the small holder farmers power output, and the entrepreneurs' partnership particularly, at the harvesting and processing stages if fully and effectively harnessed with the adoption of CAT will enhance sustainable food production, good soil-water relationship and high-level employment status. The minimal use of only farm machinery with low axle load for agricultural operations is recommended.

Keywords: Conservation agriculture, technology, sustainable food production, job creation

1. INTRODUCTION

The continuous increase in both human and animal population is responsible for the progressive development of agricultural methods and techniques for overcoming the challenges of producing enough food, feed and fibre for both human and animal consumption. Every stage of agricultural production involved work, and power performs the work. Secondly, some mechanical devices may be employed to do the work. When hoe, cutlass and other related hand tools are used to perform farm operations; this method of farming is referred to as traditional farming method and the source of the farm power is manual power. Because of the ineffectiveness of this method to contribute meaningfully to food production; the use of animal power was invented but soon was found to have contributed negligible increase to food production and reduction of drudgery in agriculture.

The shortcoming in the use of animal power led to the invention of tractor, farm machinery, fertilizers, improved seeds and other related developments to increase farm size and food production capacity of farmers when the techniques are fully and effectively used on the farms Most of the techniques employed under traditional and intensive farming systems in the tropics gradually destroy the eco-systems when the agricultural soil is bare. As a result, there is severe erosion and the fertility status of the arable soil is depleted continually. Unemployment in Nigeria is presently very high, tertiary institutions turn out graduates into saturated labour markets. The challenges of increased number of under-employed and un-employed youth are enormous. It is no longer news that graduates commonly seen as commercial motor bicycle riders and large number of applicants for jobs that require less than ten employees. Soil degradation and unemployment are problems demanding attentions and actions of all the stake-holders to holistically find solutions to the problems by using appropriate technology.

Technology enables us to develop and the adopt various methods to provide for man's needs in order to make life more comfortable. Such needs include food, shelter, clothing, advancement of knowledge and skills (Akorede, 1998). The importance of developing various methods to minimize soil erosion and conserve soil resources first came to national attention in the US during the 'Dust Bowl' period in the early 1930s, when the combination of intensive tillage, drought, crop failure and wind-driven erosion of 33 million acres of farmland occurred in the Great Plains region of the US. In the decades that followed, several reduced soil disturbance or conservation tillage production systems emerged in the Mid-West and the South-East US, to address soil loss (Aina, 2011). Sanu (2003) reported technology as a tool for development and good living; development means finding solutions to the various human needs and this should be constantly sought. Rapid diffusion of conservation tillage has been called the latest revolution in the Americans agriculture, a tool for sustainable development. Due to its success in North America, the technology has also found its way to places like Australia, South America and countries of the former Soviet Union. Therefore, the paper focus on techniques in conservation with the aim of making recommendation for its application in agriculture in Nigeria and emphasizes the roles of government to improve the lives of farmers.

2. CONSERVATION AGRICULTURE TECHNOLOGY (CAT)

Crop residue management includes all field operations that involve residue amounts, orientation, and distribution for periods requiring crop plants protection. Conservation Agriculture Technology is based on reduced soil disturbance planting systems: no-till, ridge-till, mulch-till, or strip-till, and reduced tillage (Aina, 2011) Conservation tillage is site specific and no single blue print of cultural practices is universally applicable. A no-till technique is planting in herbicide – killed vegetation, the latter which serves as mulch and protects soil surface. Ojeniyi (2011) reported that land preparation and tillage methods that ensure presence of vegetation and trees, stumps and eliminate widespread burning of bush and residues are environmentally friendly. Therefore, the selection of appropriate tillage equipment should match with the objective to be achieved in the tilled soil (Ijioma, 2011).

2.1 The fundamental concepts of conservation agriculture technology

Crop residues on the soil surface protect the soil from the physical impact of the sun, rain and wind while it also stabilizes the soil moisture and temperature in the surface layers. As a result, varieties of fauna, and flora (including wild life) increased in this zone which becomes the habitat for insects down to soil borne fungi and bacteria. These organisms macerate the mulch, incorporate it, mix it with the soil, decomposed it to mineralized the soil which later formed the organic residues called humus to stabilized the soil. The activities of earthworms in the soil further illustrate more functions of organisms in the soil. The worms have profound effects on soil structure both via the casts they excrete (microstructure) and via production of burrows (macrostructure) for fast water infiltration and extensive root development. There are numerous species of earthworms and they behave in different ways. Worm number is greatest in clayey soils of humid regions and it is virtually zero in sandy soils in arid regions.

Tillage exerts drastic effects on earthworm by reducing their population density to about 15 % of its value in non-tilled soils. Worms can move around by pushing soil aside or by ingesting the soil to make tunnels in it. Earthworms can exert a mean maximum axial pressure of 73 kPa and a mean radial pressure of 230 kPa. Ingested soil is molded in the guts of earthworms at pressures of about 260 Pa, when excreted, at much lower bulk density (around 1.15 t/m^3) in comparison with the soil in which the worms live, 1.5–1.6 t/m^3. The activities of the soil fauna (edaphon) in the soil is referred to as biological tillage. With increased mechanical tillage, the biological soil structuring processes will disappear (Wikimedia, 2007). Some prior knowledge in agriculture and new techniques in conservation agriculture constitute conservation agriculture technology aimed to conserve the social capital in agriculture by ensuring that; (1) soil is disturbed as little as possible; (2) soil cover is kept as much as possible; (3) crops are rotated and mixed; and (4) controlled-traffic is used to eliminate the need for any tillage (Morrison, 2011). Social capital consists of energy, land, water, genetic material, climate, and knowledge to sustain production increase (Olubanjo, 1996). The chemical elements in the soil are the plants' foods, non-renewable sources and soil life, to nourish the crop plants after germination for proper establishment, vegetative growth and fruiting. Ojeniyi, (2011) states in his report that surface hoeing, row tillage, manual construction of heaps and ridges across slopes, zero tillage, use of previous year ridge or heap for planting and non-inverting tractorized tillage implements during planting and related operation should be adopted. Application of poultry manure enhances the micro-biological processes needed to sustainable crop production. It was found that zero tillage with organic manure mostly enhanced yield of cocoyam and sorghum in Owo area of Nigeria.

Other benefits of Conservation Agriculture Technology (CAT) are: (1) Significant reduction in draft power requirement, (2) Greater biological pest control, (3) Reduces fuel per hectare and hence reduction in emissions of CO_2, CO and SO_2 gases-the major air pollutants (Ohu, 2011), (4) Untilled soils withstand vehicle and animal traffic, less compaction and structural damage than tilled soils,(5) Improves surface water quality, (6) Reduces turbidity, (7) Enhances ground water resources, conservation farming caused natural springs that had dried up many years ago to flow again in some areas. (8) The potential of massive adoption of conservation farming on global water balances is yet to be realized (Wikimedia, 2007), (9) Improves wildlife habitat, (10) Improves air quality, and (11) Sequesters carbon in soil (Aina, 2011), and (12) Farmers save \$3.5 billion from water treatment and waterway maintenance.

2.2. Deleterious Aspects of Conventional Tillage

Accelerated runoff and erosion resulted in soil degradation which is high after bulldozing the soil (Ojeniyi, 2011). Soil compaction has been identified as the main cause of soil degradation particularly, the soil fertility of large areas of cultivated land in the world (Peng et al., 2003). It is estimated to be responsible for the degradation of an area of 6.8 × 104 km^2 world-wide, of which 3.3 × 104 km^2 is located in Europe, adversely affecting crop production as well as environmental quality (Berli et al., 2003). Compaction of subsoil is regarded as particularly problematic because of its persistence and the difficulty to remediate it. Other damaging and harmful aspects of intensive agriculture practices include: (1) Increases runoff from agricultural lands which carries sediments, chemical fertilizers, pesticides, nitrates and selenium all of which degrade water quality on the surface and in the ground to upset ecosystems of streams and lakes, reservoirs, rivers and resulting in serious environmental problems. (2) Intensive agriculture is heavily dependent on non renewable energy sources, (3) High costs of: (a) fuel consumed, (b) wear and tear of equipment, (c) operator services, (d) feeding and caring for animals used as power source, (4). The biophysical effects of increased emission of CO_2 through burning, greenhouse gas emissions and fossil consumption include: (a) rising in temperature, (b) global warming, (c) crop failure, (d) water loss and desertification (Ojeniyi, 2011), (5) Air quality is affected by: (a) smoke from agricultural burning, (b)dust from tillage, traffic and harvest, (c) pesticide drift from spraying, and (d) nitrous oxide emissions from the use of nitrogen fertilizer. (6) Tillage erosion increases landscape heterogeneity through: (a) Creation of distinct landforms and (b) Relatively rapid re-distribution of soils from upland positions to depressions. (7) Mechanical tillage offers temporary relief from compaction. (8) Decreases nutrient supply and subsequently productivity.(9).Reduces infiltration, (10) Increases turbidity and consequently, (11) Induces crusting, (12) Induces soil surface sealing, (13) severe erosion by water could lead to: (a) Sedimentation which lowers the available water storage capacity of rivers, seas and the natural basins, (b) Gullies which could destroy or reduce size of farm lands, roads and even houses resulting in environmental problems, (14).Tilled bare soil surface is prone to wind erosion,(15). Extensive energy utilization in soil tillage operation destroyed the soil structure and its ability to further resist deformation, (16). The soil is continuously pulverized, (17). Economic pressure, (18). Many of the tillage machines produced or imported failed when existing conditions are not suitable for their use, (19). Motorized tillage operations on Nigerian agricultural soil is still relatively low. (20). Tillage operations significantly: (a) Disrupts the micro-climate, (b) Reduce the flora and fauna population, (21). Motorized tillage is not compatible with the natural soil restructuring processes. (22). Motorized tillage exposed soil organic matter to the air for oxidation which leads into mineralization of the soil organic matter and hence significant reduction in organic matter, (23). Disruption of soil pores and reduction in inter-pores spacing, (24) Axle weight of a machinery compacts the soil below the soil surface, into the sub-soil and deeper into the soil. (25). Small holder farmers still consider cost of private ownership of tractor prohibitive.

2.3 Indispensability of Tillage

In continuous no-till, intermittent tillage is necessary to reduce soil bulk density, disease, pest and weed infestation, water logging and decomposition of vegetative matter. For the LORD GOD took man and put him in the garden of Eden to till it (Genesis 2:15). And when man was driven out of Garden of Eden, the instruction given him was to till the land (Genesis 3:23). For he who tills the land will have plenty of bread (Proverb 28:19). Therefore, tillage have divine basis (Ojeniyi, 2011). Conservation Agriculture Technology positioned the farmers as initiators rather than actors in the task of tilling the soil.

3. THE ROLE OF GOVERNMENT

Conservation agriculture technology (CAT) requires farmers to use power-saw and simple farm tools for the production of the quantity of food, but better quality, in tandem with the status to food production in an Industrial agriculture system. The government must create enabling environment for the entrepreneurs' partnership in the CAT schemes particularly, at the harvesting and processing stages. The Nigeria government at all levels should be responsible for the purchase of farm produce immediately after maturity and at approved prices for processing and distribution. The farmer responsibility in the scheme is to clear the land, cultivate it and raise animals. Mechanisms should be created to supply farmers with improved varieties of seeds and other farm input like power saw, matchets, brush hooks and so on (Kaul and Egbo, 1985). A good example is the Green Revolution in Asia, farmers got access to high-yield varieties of rice and wheat and the production of these crops increased enormously (International Commission of Agricultural Engineering, 1999).

Government at all levels should intensify research efforts into appropriate technology (CAT) and funds reserved every year for the purchase of fertilizers, farm machinery and their maintenance cost should be use to execute the CAT schemes. According to Babatunde (1996), the accumulated repair costs of tractors may be as high as 1.6 times the purchase price with due regards to inflation. Manual labour still predominated Nigerian agriculture despite huge government investments on the purchase of farm machinery. The axle load and the functions of the farm machineries expose the soil to further biophysiochemical degradation. Manuwa (2011) reported that the axle load of tractors has increased from less than 3 tons in 1940's to approximately 20 tons today. Currently, there is no or low level use of appropriate technology (CAT) and high level of dependent on rain fed agriculture (Olubanjo, 1996).

Edeoghon, Ajayi, and Ugboya, (2008) reported that the poor performance of Nigerian farmers is attributed to non usage of sustainable agricultural practice and lack of its awareness.

Federal Government should adopt a mechanism to identify existing farmers, under-employed and unemployed Nigerians direct them to report at the local government of their choice and forming them into cooperatives. The vacant apartments in the existing farmers' localities should be identified and documented. The first set of applicants should be lodged in these apartments and feeding allowance given to them free monthly. Relevant training would have been conducted earlier before farm plots and farm inputs are supply for a period of two years. The training and supervision by relevant government agencies must be progressive with attention allotted to the farmers view in all cases before policies are formulated. New farm settlements with housing facilities should be constructed as more people joined the schemes. Bankole (1995) reported that food come from rural areas. Adequate support and increase welfare of the rural populace is relevant to efficient and sustainable food production. The rural economy constitutes the cornerstone of the economy of most developing countries, and Nigeria is no exception. The issue of sustainability is now global and real (Akinbode, 1996).

3.1 Land Clearing Technique

Skilled men should be formed into teams and equipped with power - saw and farm tools to clear new agricultural land. Nigeria has about 98 million hectares of land, 83 million hectares are suitable for cultivation, and only 30 to 34 million hectares are presently under cultivation (Oni, 2011). For meaningful agricultural development to take place in Nigeria there is need to minimized drudgery and tedium in agriculture but in cost-effective manner, this agricultural approach is intrinsic in conservation agriculture technology, a panacea to problems of intensive tillage systems in Agriculture. Adesanya (2012) reported that conversion from intensive tillage system in agriculture to Conservation Agriculture Technology can increase the mechanical strength, pore functioning of soil and resulted to increased air and water conductivity in soil to greater depth over a longer period of time.

4. HOW CAT CAN REDUCE UNEMPLOYMENT IN NIGERIA

Only 1 % of farm power is supplied by mechanical means in sub-Saharan Africa, 10 % by animal draught power while the remaining 89 % is from human labour (Oni, 2011). Babatunde (1996) reported that stocks of immobilized tractors abound, representing large waste of mechanical power resources due to many reasons. Nigeria is said to have 20,000 to 30,000 functional tractor units. The nation still requires about 1.5 million tractor units to boost its food production (Oni, 2011). He further stated in his report that a unit of tractor with matching implements would do the work of 500 labourers per hectare. This projection is from FAO recommendation on tractorization intensity of 1.5 hp (1.125 kW) per hectare. Having taken the present and changing cost of tractor into consideration and an hectare is 100 m by 100 m or 10,000 m2 (Amusan et al., 2008). It is estimated that 1.5 million tractor units will require about

750 million farmers to give the same work output on estimated 1.5 million hectares of arable land with hand tools. A 200 m2 of arable land is estimated to support 91,464 stands of maize plants (2- maize grains per hole, using plant spacing of 90 x 70 cm); about ₦1,829,280.00 is estimated to be realize on maize cropping alone. More than double of this amount is expected as income in a single planting operation because CAT concept stresses mixed cropping and mixed farming on rotational basis. A farmer using traditional method of farming will requires 200 m2 farm land for crop production while the same farmer will require more land when CAT concept is adopted because more energy and time are available for land cultivation, therefore, increase in farm size, early planting and more profit are possible.

The Nigerian small-scale farmers are estimated to account for the cultivation of about 90 percent of the total cultivated land area in Nigeria, producing nearly 90 per cent of total agricultural output (Oni, 2011). In intensive crop production systems, tillage accounts for over 50 percent of the energy expended from land clearing to harvesting (Onwualu, 2011). Conservation tillage systems represents alternative as economy requires flexibility in crop production (Aina, 2011).

4.1 The Relevance of Material and Human Resources

World population is expected to be 8.5 and 9.0 billion by 2025 and 2050 respectively (Ohu, 2011). This view is corroborated by Gbadegesin (2005) that the current world population is just over six billion and is projected to reach the 10 billion mark by 2050. In Africa, food consumption exceeded domestic production by 50 per cent during the mid-1980s and more than 30 per cent in the 1990s. Population in most African countries has been growing at an alarming rate beyond the rate of food production leading to scarcity and shortage of food for both human and animal consumption at different rate in countries of Africa. The combination of about 750 million under-employed and unemployed human population in Nigeria, 53 million hectares of uncultivated vast arable land and huge financial resources expected to be diverted from the purchase and the running cost of more than 30,000 farm machinery are adequate and appropriate synergy to attain food production equal in status to food production in an Industrial agriculture system and create employment opportunities; constitutes a major challenge facing the country today (Olunuga and Salawu, 1995).

Out of 15 million businesses in United States of America, more than 99 percent are small because they employ fewer than 100 persons; small business, a vital force to the economy. It employs 58 percent of the nation’s work force and earns a higher return on owners’ equity than big businesses. Small businesses are at the center of modern society, touching lives. Few if any parts of United States of America economy could run without small businesses endless flow of products and services. Equally important, its ingenuity sparks invention, innovation, job creation, financial performance and opportunities (U.S. Small Business Administration, 1980). The CAT scheme when fully and effectively implemented will pave way for agricultural invention and innovation in agriculture particularly in land clearing, land cultivation and harvesting that are indigenous to Nigeria apart from high foreign exchange earnings.

5. CONCLUSION

General acceptance of Conservation Agriculture Technology Schemes will make possible: The reduction or elimination of elements of drudgery and tedium in tillage, crop plants protection, harvest, post-harvest processing and marketing of farm produce. Good soil and water relationship, and deeper top soil depth will be established for better control of flood and flood encroachment, problems of climate change, socioeconomic life of the rural dwellers, and problems of crime. Keeping the farmers permanently in the business of cultivating the land and raising animals on a particular farm plots on long term basis. There will be increase in food production output to the status of food production output in an Industrial agriculture system when the established triangular relationship existing between the government manual power output, and the entrepreneurs' partnership particularly, at the harvesting and processing stages have been fully and effectively harnessed.

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MECHANIZING RICE FARMING IN NIGERIA: ADAPTATION OF MACHINERY AND TECHNOLOGY TO THE RESCUE

Ademiluyi, Y. S.[1], Dada-Joel, O. T. [1], Onyemize, U. C. [1], Okoro N. O. [1], Eneh, K. C. [1], Olarenwaju, J. S. [2], Awu, J. I. [1], Oyedokun, J. A. ,[1], Oyelade, O. A.[1] , T. Wakatsuki[3] and A. R. Kamal[1]

[1]National Centre for Agricultural Mechanization (NCAM), Ilorin, Kwara State.
[2]New Sawah Project
[3]Emeritus Prof. Shimane University, Matsue, Japan

ABSTRACT

Rice (Oryza sativa) has become the most consumed food in Nigeria due to the ease of cooking and the change in the consumers' lifestyle. The local production level is far below the demand for rice. This has brought about the high importation of rice into the country. The traditional way of rice farming involving the use of hoe and cutlass is bedeviled with low productivity, low yield, drudgery laden and time consuming. Nigeria having attained the position of the largest producer of rice in Africa cannot guarantee the sustenance of the continuous use of this traditional method with the hope of retaining this number one position in Africa. To increase rice production without incurring high cost of production, appropriate machinery of low-cost, easy maintenance, availability of spare parts and its adaptation to different operations should be considered. The power tiller alongside the Sawah Eco-technology for rice farming (SERIF) is considered the best technology to the rescue. The execution of this study became necessary in showcasing the activity of rice production in Nigeria through the use of machinery. The National Centre for Agricultural Mechanization (NCAM) is playing the leading role in popularizing Sawah Eco-technology for farmer's use in the country which have recorded tremendous success stories where the technology have been used. Sawah Eco-technology have tremendous advantages even though with some challenges that can be overcome with persistence.

Keywords: Rice, Power tiller, Sawah, Adaptation, Rescue

1. INTRODUCTION

Rice (Oryza Sativa) is a cereal belonging to the Graimnea, a large monocotyledonous family of some 600 genera and around ten thousand species (Wibberley, 1989). It is valued as the most important staple food for over half of the world's population and ranks third after wheat and maize in production on a world basis.

More than half of the world's population depends on rice as a major source of calories (FAO, 2003). Two species have emerged as our most popular cultivated rice, Oryza Sativa and Oryza Glaberima of which the Otyza. Sativa is widely produced. Akande (2003) reported that rice consumption in Nigeria has risen tremendously to about 10% per annum due to changing consumer preferences.

Rice production according to (Ajala and Gana, 2015) started in Nigeria in 1500BC with the low-yielding indigenous red grain species of Oryza. glaberima Steud and then widely grown in the Niger Delta area. WARDA (1996) reported about the high-yielding white grain of *Oryza Sativa* that was introduced in 1890 and by 1960 it accounted for more than 60% of the rice grown in Nigeria. Also, Figure 1 shows the trend of rice production in Nigeria from 1968 through 2008 (A four-decade study). Rice production remained at a low level from 1968 to 1978 perhaps due to dietary preference of tubers. A decline in the production of rice in Nigeria is observed between 1988 and 1993, also between 1999 and 2008 which may be attributed to periods of massive importation of rice into Nigeria which is a disincentive to Nigerian rice farmers leading to rice production declines.

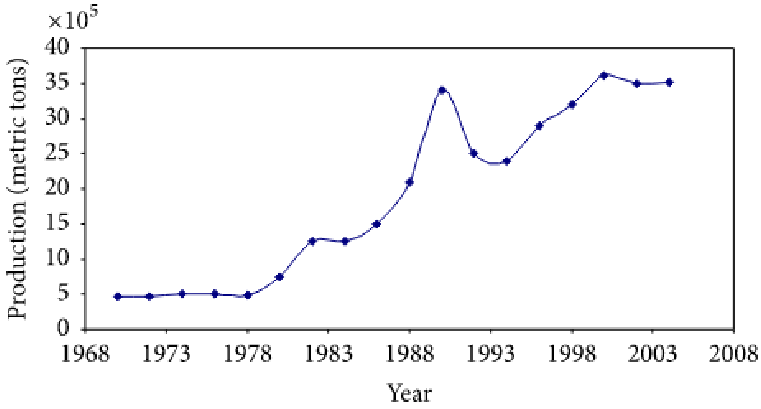

Figure 1: Rice production in Nigeria. Source: United State Department of Agriculture.

WARDA (1996) also reported that paddy rice production had risen from 134,000 to 344,000 tons in 1970 and the area cultivated increased from 156,000 to 255,000 ha. Since then, paddy rice production has been on the increase. Tremendous increases in area planted, output and productivity in paddy rice production were achieved over the last two decades and now stand at 1.09 million tons. Since 1980, Nigeria has become the largest rice producing country in West Africa and the third largest in Africa, after Egypt and Madagascar (WARDA, 1996). The production reached the peak in 1990 in which Nigeria was producing 3.4 million tons of rice from about 1.2 million tons (Imolehin and Wada, 2000) before it slightly fluctuated down the slope in 1993. However, the production soared from 1993 to 2006 when the production remained at 3.8 million metric tons.

Power tiller otherwise known as single axle tractor together with its accessories and other equipment are commonly used in Nigeria for rice farming in lowlands. Power tillers are more desirable for use for lowland rice farming than the normal conventional tractors. This is because power tillers are cheaper in cost, easier to maintain, versatile in operation, supported with gage wheel which is suitable for lowland operations which includes inland valleys, flood plains, river basins commonly known as FADAMAs in Nigeria. Today, Nigeria has attained the position of the largest producer of rice in Africa, however, the country needs to maintain this position for the next decades. The Nigerian government needs to do all it takes to make rice farming in Nigeria a thing that farmers will wish to put in all their effort. In view of this, this study on mechanizing rice farming in Nigeria: adaptation of machinery and technology to the rescue is of great importance to rice farmers in Nigeria.

2. MECHANIZATION OF RICE PRODUCTION IN NIGERIA

Agricultural mechanization simply refers the development, introduction adaptation and use of mechanical devices for all forms of agricultural production. This includes any level of technological sophistication. Its task is to reduce human drudgery, improvement in the timeliness and efficiency of various agricultural operations, utilizing more land for cultivation (Odigbo, 2000; Azogu, 2009). Alam (2006) describes mechanization as the interjection between people and materials handled by them. Agricultural materials such as soil, water, environment, seed, fertilizer, pesticides, growth regulators, irrigation, agricultural produce and its by-products.

Mechanization can be driven by various factors which include socioeconomic conditions, farming systems, rural labour wages and farmers' support for agricultural mechanization (Pingali, 2007). This explains why some countries will achieve increase in rice mechanization though cooperative societies, tractor hiring services and other agro-allied services for personal irrigated rice farming systems, which is key to lowland rice mechanization using appropriate machinery known as the work behind a tractor, single axle tractor or the hydro-power tiller and the sustainable Sawah Eco-technology to the rescue (Ademiluyi et al., 2011).

3. THE SAWAH SYSTEM

The term sawah according to Wakatsuki et al. (2009) is a man-made, improved rice-growing environment with demarcated, bunded, leveled and puddle fields, for water control. Sawah is soil based eco-technology. In a simpler form the term Sawah refers to leveled, bunded and puddled rice field with water inlet and outlet to control water and manage soil fertility, which may be connecting irrigation and drainage facilities including Sawah to Sawah irrigation and drainage. Thus to effectively apply these scientific technologies, farmers have to develop typical sawah or similar alternatives which can conserve soil properties and control water.

Among the 250 million ha of lowlands in Sub-Saharan Africa, only 10% are estimated as appropriate sites for sustainable irrigated Sawah system development because of hydrological, topographical and pedological limitations (Wakatsuki et al., 2011). Of all lowland types, the Inland valleys are a priority because of easy water control. However, huge flood plains in the guinea savannah zone can be given priority. Its appropriate calendars and timing are selected since lowland rice yields more than upland.

The site-specific farmers' personal irrigated Sawah system development (Sawah Eco-technology) offers low-cost irrigation and water control for rice intensification with a sustainable paddy yield of 4 - 6 tons per ha. If agronomic practices are improved and applied such as the System of Rice Intensification SRI based on the Sawah systems paddy yield can be higher than 10 tons per ha. The concept and the term 'Sawah' refer to man-made improved rice fields with demarcated bunded, puddled and levelled rice yields with the water inlet and water outlet that can be connected to different irrigation facilities like canals, ponds, weirs and springs. To realize sustainable feat for the technology and increased rice production, careful site-specific selection should be conducted and Sawah development including management should be disseminated through intensive on-the–job training. This requires that self-motivated local farmers must have access to small-scale machinery such as hydro-power tillers.

Sawah Eco-technology which is part of the sawah system involves man-made improved rice fields with demarcated bunded, puddled and levelled rice fields with water inlets and water outlets which if possible can be connected to various irrigation facilities such as canals, ponds, dykes and springs (Oladele and Wakatsuki, 2011) alongside agro-chemical input and high yielding varieties (Wakatsuki et al., 2011). Thus, the three sawah inputs namely, demarcated bunded, puddled and levelled rice fields coupled with agro-chemical input and high yielding varieties has improved yield output of government institutions such as NCAM, FADAMA, ADP, APPEALS and CADP where we have an output ranging from 4 to 8 ton/ha compared to the local farmers field output which ranged from 1 to 3 tons/ha. Sawah Eco-technology was seen as an adoptable and sustainable platform for intensive rice production. Fig. 2 shows the basic structure and picture of a Sawah plot. One Sawah plot is partitioned or demarcated by appropriate bunds (ridges or leeves) based on topography, hydrology and soil type.

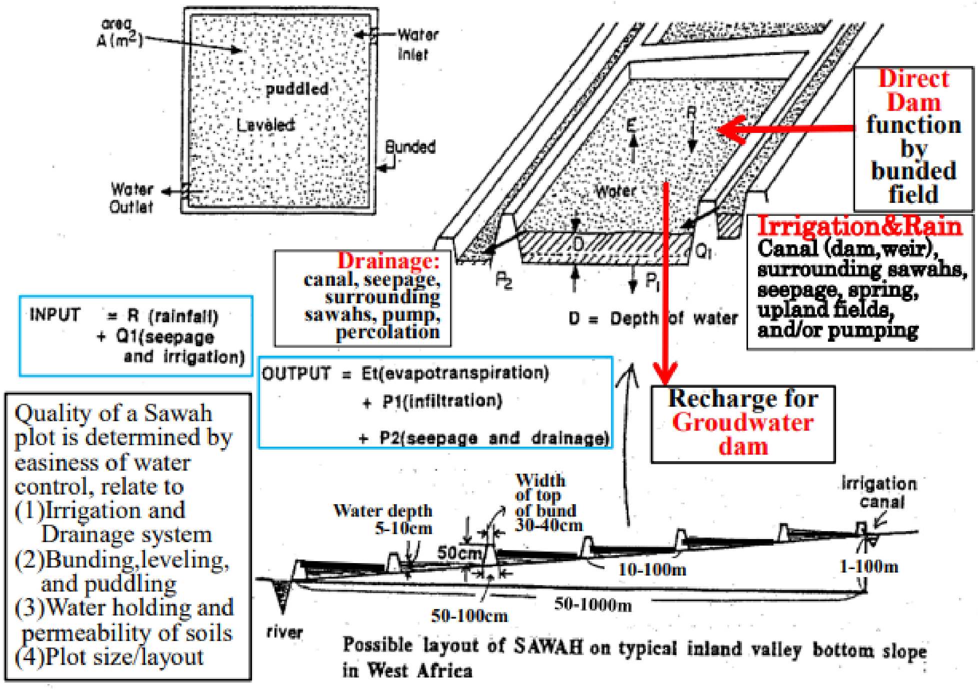

Fig. 2. Sawah Plot: A bunded, levelled, and puddled rice field with inlet of irrigation and outlet to drainage, thus control water and weeds as well as manage nutrients.

The advantages of multi-functionality in sawah rice systems, according to Wakatsuki et al. (2011) include (i) intensive, diverse and sustainable nature of productivity through weed control by water and enhancement of nutrient supply; eco-sysytem nitrogen fixation; increased phosphate availability which is a concerted effort of N-fixation; pH neutralizing eco-system to increase micronutrient availability; watershed geological fertilization: water nutrients and top soils from upland; and encouraging fish and rice, geese and sawah mutual relations; (ii) combating global warming and other environmental problems through carbon sequestration, that is, control of oxygen supply and methane emission under submerged condition, nitrous oxide emission under aerobic rice; control of flooding, soil erosion and electricity generation; watershed agroforestry by SATOYAMA approach to generate forest at upland; and denitrification of nitrate polluted water; and (iii) creation of cultural landscape and social collaborations through terraced sawah system has beautiful landscape, fair water distribution systems for collaboration and fair society.

Upon seeing the advantages of this technology, Sawah Eco-technology is faced with some barriers for its full adoption in Nigeria. Some of these barriers include (i) rice farmers shy away from adopting rice transplanting method because it requires thorough tillage practice to the extent of levelling which these farmers try to avoid during farming operation; (ii) manual labour requirement for transplanting is a bottle neck to rapid full adoption of the technology; (iii) land tenure system if it is not well secured before Sawah Eco-technology is introduced into locality conflicts and eviction abounds, (iv) the use of power tiller to carry out bunding operation require repeated passes to make appreciable bund. These repeated passes bring along the use of more energy in carrying out the task which leads to increase in soil compaction; (v) the poverty level in Sub Saharan Africa (SSA) is among the factor that retards the ease of disseminating and adopting Sawah. The unexpected idea of some rural dwellers asking for compensation before allowing new technology to be demonstrated discourages technology transfer to the local farmers; (vi) farm practices amongst different cultures of a particular locality affect the ease of adoption. An example is the rate at which a local community that is familiar with bund making during rice field preparation is easier in adopting Sawah than others that don't bund their field for rice farming; and (vii) some socioeconomic factors such as age, level of education, group dynamics, farm size, land tenure and land ownership and language barrier affect the extension of Sawah Eco-technology for farmer's adoption.

4. THE USE OF A POWER TILLER

The power tiller or the single axle tractor which could as well be referred to as the walking tractor is the only power driver tool that is effectively being used for Sawah activities in Nigeria (Ademiluyi, 2010). Fashola et al. (2006) noted that the Sawah system offers the best option for overcoming soil fertility problems through the enhancement of the geological fertilization process, conserving water resources, and the high-performance multi-functionality of the Sawah-type wetlands. The power tiller is less sophisticated and not too expensive. The power tiller has a locally manufactured frame and is equipped with an imported water-cooled diesel engine of 5.22 kW (7 hp).

Presently manufactured power tillers are designed primarily for paddy areas which are best used during operation at high tractive efficiency. The versatility of the power tiller is seen in its operation which ploughing, puddling, bunding, spraying, levelling, transplanting, harvesting and water pumping are its respective operations adapted to ensure less drudgery during rice production. This can also be referred to as the multi-purpose use of the power tiller.

Ploughing: The power tiller has a mounted rotavator which easily ploughs and turns the soil into loose tilt after the land has been cleared of virgin vegetation. Furthermore, it can be done under semi-moist or flooded conditions.

Puddling: This the further pulverization of soil into fine and smother texture. It is achieved by mounting the tiller to the machine.

Bunding: The ploughs attached to the tiller can bund the soil when the machine is operated to move in a straight line repeatedly. This eventually carries the soil to form ridges or bunds which define the perimeter of a basin.

Levelling: This operation occurs after puddling. A sizable bar made of wood is attached to the power tiller to carry soil from higher points to low points to achieve a levelled basin.

Transplanting: The transplanter could be mounted on the power tiller for motion and transplanting. It reduces the drudgery accompanied by manual motion and transplanting. The operation is time managed with high coverage of the basin with appropriate spacing for planted seedlings.

Water Pumping: The pulley of the axial water pump is connected to the V-Belt transmission unit of the power tiller as its source of power. This rotates and allows water to be pumped from the desired source. The pump must be above 10 m long to achieve an efficient water pump.

Harvesting: A mini combined harvester could be mounted in front of the power tiller to harvest and thresh the paddy for further processing and storage. Presented in Figures 3 to 11 are some of the operations performed through the use of a power tiller in the rice field.

Figure 3. Power tiller used for planting and fertilizer application

Figure 4. Power tiller used for puddling operation inside a screen house

Figure 5. Power tiller used for planting operation

Figure 6. Power tiller used for chisel ploughing operation

Figure 7. Power tiller used for haulage operation

Figure 8. Power tiller used for drilling of hole for tree planting

Figure 9. Power tiller used for potato planting

Figure 10. Power tiller used for threshing operation

Figure 11. Power tiller used for irrigation water delivery

5. CONCLUSION

The importance of making use of farm machinery and technology in rice production cannot be overemphasized. Government should intensify more efforts at their State level to help rice farmers' secure appropriate technology that could assist them in boosting rice production in their respective States to make Nigeria one of the countries in the world that is self-sufficient in rice production.

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EFFECT OF REDUCED TILLAGE, NUTRIENT AND WEED MANAGEMENT ON GROWTH AND YIELD OF SOYBEAN (*Glycin max L)*

Ariyo, E. O.[1], Olaoye, J. O.[2] and Gbadamosi, L. [3]

[1]Kwara State Ministry of Agriculture and Rural Development (hariyo19@gmail.com)
[2]Department of Agricultural and Biosytems Engineering University of Ilorin, Ilorin Kwara State
[3] Department of Agriculture and Environmental Engineering, Kwara State Polytechnic, Ilorin, Kwara State

ABRSTACT

Over-estimation of tillage requirements can result in soil degradation and high energy consumption. This study investigated the influence of Reduced Tillage (RT), Nutrient Applications (NA) and Weed Management (WM) on growth component and yield of soybean. Field experiments were conducted in 2018 and 2019 sowing seasons. Reduced tillage depths (TD) of 10, 15, 20, 25 cm; NA were applied at 0 kg/ha, Compost Poultry Manure (CPM) at 0.5 ton/ha + 50 kg/ha of superphosphate, CPM at 1 ton/ha + 75 kg/ha of SSP and WM were applied as No weeding, 3 l/ha of Pre-emergence (PE) at planting + 2.5 l/ha of post emergence (POE) at 3 weeks after sowing (WAS), 3 l/ha of PE + 3 l/ha of POE at 5 WAS, 3 l/ha of PE + 4 l/ha of POE at 7 WAS). A 4×3×4 factorial experiment in a Randomized Complete Block Design was used. Standard agronomic procedures were followed to obtain GY. Analysis of Variance was conducted on data obtained at $p \leq 0.05$. Tillage depth of 15 cm, NA of CPM at 0.5 ton/ha + 50 kg/ha of SSP and early weed control at 3-5 WAP performed best ($p \leq 0.05$) with a mean GY of 2.62 ton/ha. The study recommended that tillage depth at 15 cm with CPM of 0.5 ton/ha + 50 kg/ha of SSP and weed control at 3-5 WAP be used for soybean cultivation.

1. INTRODCUTION

Adoption of appropriate tillage systems and cost-effective crop management practices are critical to sustainable crop production, especially in soybean. Sustainable cropping requires the adaptation of farming methods that are environmentally and economically friendly. Manipulating soil for suitable seedbed may influence soil physical and chemical properties, hence, affecting plant growth and yield. In a practical term, local farmers are faced with the constraints such as; declining soil nutrients, inadequate knowledge of proper selection of cost-effective inputs (especially tillage implements and crop nutrient requirements) and untimely crop management practices, especially in weeding and harvesting (Dudje *et al*., 2009).

Studies have shown that conservation tillage systems do better than conventional tillage systems

Studies have shown that conservation tillage systems do better than conventional tillage systems for soybean productions (Dorota *et al., 2014;* Košutić *et al., 2010*). In Nigeria, adoption of conservation tillage systems as alternatives to conventional tillage systems by farmers is gaining popularity because they try to reduce the time and energy required in crop production via the use of reduced machinery and labour costs (Dorota *et al.*, 2014). However, the extent of soil tillage may influence weed growth and nutrients uptake by the crops. Hence, researchers have noted that it is necessary to select a suitable tillage practice or having the knowledge of appropriate use of primary tillage implements in order to be able to sustain continuous cultivation of crops successfully in a certain environment (Tesfahunegn, 2014).

In Nigeria, weed control in soybean (*Glycin max. L)* production is mostly carried out with the use of hoes and herbicide application. Soybean like most other crops does not have the capacity to compete with weed, especially before forming leave canopy. This is amongst the most important biotic factors that could limit its growth and yield. Most small and medium scale farmers employ both hand hoe weeding and herbicide application. The use of hand hoe is laborious and time consuming. Also, an excessive application of herbicides may lead to water and air pollution. Even though herbicide application require less labour than hoeing, it has to be appropriately carried out with the right dosage at an appropriate time during crop growth. The response of crops to herbicide application may vary with growth, especially during leaf development. At certain stages, herbicide application might result in leaf deformation and sterility (Tesfahunegn, 2014). This implies that assessing and identifying the most secure application timing is critical for soybean cultivation.

Today, the decline in soil nutrients is solved by nutrient application to the soil for plant use. The nutrients are in form of organic and inorganic manures. Nutrients are lost in the soil via inappropriate harvest, intensive tillage, weeding and could be loss through run off and soil erosion. This challenge is worsened by farmers' inability to compensate for such losses as a result of non-affordability of inorganic fertilizer. With an increase in animal farming, animal droppings or farm manures can serve as alternative to the inorganic fertilizer. More so, conservation tillage practice over time changes the soil properties and influence the way each crop responds to nutrient application. Plants respond by changing their root dispersion to parts of the soil that are more favourable.

The appropriate nutrient application strategies must then be adopted as a result of this root shift. Hence, nutrient requirement vary from crop to crop and should be applied based on crop needs for better yield. Soybean for example, requires more of phosphorus and potassium than nitrogen because it has the ability to produce up to 40% of nitrogen through Bradyrhizobia symbiosis (Dudje *et al.,* 2009). It is critical to apply nutrients appropriately in order to increase yield and return on cropping activities.

According to Shahbandeh (2022), the production of soybean in Nigeria was estimated at 467,000 MT in 2020/21 compared to 119.9 million MT and 138 million MT produced by the USA and Brazil respectively for the mentioned year. Hence, the production of soybean is abysmally low in Nigeria despite the high demands for the grain. This may be due to inappropriate cultivation that do not sustain both the crop cultivation and soil fertility.

Appropriate use of tillage implements is good for conserving soil and water resources. For example, as land slopes and climatic limitations increase, practices that complement appropriate tillage methods are required to prevent land degradation due to erosion. With this, a unanimous concession has not been reached by farmers on appropriate selection and adoption of tillage system that can reduce cost of production and providing benefits such as; lower fuel cost, reduced tillage equipment needed, lower labour requirement, reduced erosion induced by water and wind and soil moisture conservation.
Nigerian farmers frequently overestimate tillage requirements for crops that are shallow-rooted, resulting in unnecessary soil damage. More importantly, the trend of climate change in Nigeria is generating concerns that tillage efforts must be redirected to climate- focused efforts that would preserve soil and agricultural output. Crops that are economically and industrially valuable, such as soybean, are also becoming scarce due to low yields and high production costs. Hence, this study is aimed to determine the effects of tillage system, nutrient application and weed management on growth and grain yield of soybean.

2. MATERIALS AND METHODS

The experiments were conducted on the research farm site of Department of Agricultural and Biosystems Engineering, Faculty of Engineering and Technology, University of Ilorin, Nigeria, with (Latitude 08° 28' 54.5'' E and longitude 00 4° 40' 56.4'' N) and elevation 300 m above sea level. During the 2018 and 2019 growing seasons in Ilorin, Nigeria, field experiments were conducted on the soil that had been left fallow ten (10) years to determine the effects of reduced tillage system, weed management, and nutrient applications on soybean yield performance and soil properties. Table 1 shows the climatic condition of the experimental site during the growing seasons.

The experimental field area is 1.08 ha. It has a very gentle slope between 0.3 - 2 %. The slope is steady and spread over a large portion of the field. This indicates that the field is not prone to erosion and is suitable for mechanization. This observation in line with Olaoye (2002) that site slope of 5 % not prone to erosion. When compared to other ecological zones such as swamp forest, rain forest, and mangrove forest, Nigeria's derived savannah ecotone ecological zone has moderate erosion problems that do not inevitably lead to excessive floods (Olaoye, 2002). The level of mechanization and rainfall pattern are connected to soil erosion.

2.1 Experimental Design

The field design for the experiment was factorial arrangement fitted into a Randomized Complete Block Design (Figure 3.4) in three replicates. Factors such as; Tillage systems T (Reduced Tillage), Nutrients Applications (N) and Weed management (W) in 4×3×4 (a total of 48 treatments) in three replicates making 144 plots with each measuring 7 m x 8m with 1.5 inter row and 2 m main plot spacing. Olaoye, (2002), Ewulo *et al*. (2008), Gomez (2010) and Neugschwandtner *et al*. (2014), employed randomized complete block design in their studies. This may be due to its unbiased and uncomplicated field layouts.

Table 1: Agro-Climatic Condition of the Experimental Field measured during 2018 and 2019 Trials.

Month	2018 Trial Monthly Rainfall (mm)	Maximum Temperature (˚C)	Minimum Temperature (˚C)	2019 Trial Rainfall (mm)	Maximum Temperature (˚C)	Minimum Temperature (˚C)
June	315	31	23	48	28	22
July	192	30	21	137	28	21
August	265	28	21	198	29	22
September	445	30	22	160	31	22
October	115	31	22	420	32	22

2.2 Field Establishment and Management

Its layout was done using ranging poles, measuring tape and pegs. Poultry manure was measured in kg/ha and spread on each plot accordingly. The reduced tillage options at 10 cm, 15 cm, 20 cm and 25 cm depth of cuts were imposed accordingly. The tillage depths were varied as described by AMCO coy (www.amcomfg.com). The disc was adjusted that 25 % of its diameter is submerged in the soil. The angle of the blade were adjusted accordingly to accommodate the depth varied at 10, 15, 20 and 25 cm respectively. The tractor was operated at a low speed of 8 km/ha to maintain steady depth of cuts.

Soybean TDX 1448-2EB (variety that is resistance to disease and drought) were sown manually at a spacing of 25 × 75 cm and two (2) seeds per hole with eight (8) rows of plants/plot making a plant population of 144,000 plant/ha. The emerged soybean plants were thinned to two per stand and supplying was done at weeks after planting. The weeds were controlled by application of herbicides and hand picking of the broadleaf weeds and nutrients was applied as described in Table 2.

2.3 Data Collection

2.3.1 Agro-Climatic Data

The prevailing agro-climatic data (rainfall, maximum temperature and minimum temperature) at the experimental field were measured on daily basis after planting with graduated cylinder rain gauge and model 210-4421 minimum and maximum thermometer (- 45° C to 50 ° C with accuracy 0.2 ° C above 0 ° C) respectively to monitor the agro climatic condition that experiment was conducted.

Table 2: Experimental Factors for 2018 & 2019 Planting Seasons

Factors	Levels
Tillage system Reduced tillage)	T_1 = Disc plough and disc harrow at 25 cm (Reduced tillage practice) (Wlaiwan and Jayasuguya, 2013) T_2 = Disc plough 20 cm T_3 = Double tillage passes of disc harrow at 15 cm T_4 = Single pas of disc plough at 10 cm
Weed management	W_1 = No weeding as control W_2 = 3 litres of Pre-emergence at planting + Post-emergence (Fusillade forte) at 2.5 litres (0.14kg/ha) of post emergence at 3WAS (Dudje *et al., 2009*). W_3 = 3 litres of pre-emergence + 3 litres (0.17kg/ha) of post emergence at 5WAS; W_4 = 3 litres of pre-emergence + 4 litres (0.23kg/ha) of post emergence at 7WAS
Nutrient application	N_1 = No CPM application (Control) N_2= CPM at 0.5 ton/hectare + 50 kg/hectare of Superphosphate applied 4 weeks after sowing N_3 = CPM at 1 ton/hectare + 75 kg/hectare of Superphosphate applied 4 weeks after sowing

2.3.2 Crop Growth / Yield Measurements of Soybean

The crop data that were collected include; growth (percentage seedling emergence, plant height, stem girth, number of leaves, root length and number of nodules) and yield (number of seeds, seed weight per plant and grain yield) of soybean under different ploughing equipment and depth, nutrient application and weed control treatments. Samplings of crop growth were done on the $2m^2$ quadrat placed in each plot immediately after planting.

i. Percentage Seedling Emergence

Soybean plant population counts were taken immediately at two week after planting (2 WAS). The number of emerged plants was divided by the number of seeds planted to compute percentage seedling emergence, which was expressed as a percentage. Percentage seedling emergence is as expressed by Sessiz and Gursoy (2010) and as presented in Equation (3.1).

$$PE = \frac{Te}{Np} \times 100 \quad (1)$$

where;

PE = Percentage seedling emergence
Te= Total emerged seeds/m
Np = Number of planted seeds/m

ii. Plant Height, Stem Girth and Number of Leaves

The sampling for plant height, stem girth and number of leafs per plant were obtained in the quadrant (net plot) placed in each plot in 3, 6 and 9 WAP accordingly. A metre rule was used to measure plant height. Stem girth was measured using a 6" Jumlee tool digital calliper with accuracy of 0.001 in 0.02 mm and resolution of 0.0005 in 0.01 mm (sensitivity is 0.02 mm). The numbers of leaves were counted manually.

iii. Root Length and Number of Nodules

Root length and number of nodules were sampled in 5, 7 and 9 WAP by destructive sampling. Using a ruler, the length of each sampled plant's root was measured from the base of the shoot to the tip of the root (Khan *et al.,* 2017). Number of nodules were carefully counted (Gerson *et al.,* 2016).

iv. Number of Seed/Pod, Node Interface and Leaf Area Index

The number of seeds/pod was evaluated by the ratio of number of seed per plant to the number of pod per plant. According to Samia *et al.* (2012), it could be expressed as presented in Equation (2).

$$\text{Number seeds per pod} = \frac{A}{B} \quad (2)$$

where:

A= Number of Seeds/plant
B = Number of pods/plant

Plant node interface was measured with a metre ruler per plot at 10 WAS. Plant Leaf Area Index was determined at maturity stage using tracing method. Grid lines of 1cm² were plotted and the outlines of the sampled leaves (photosynthetic surface) were traced on it. The number of square centimetres was counted for each of the sampled leaf cum its ground area occupied. Hence, the Leaf Area Index (LAI) was obtained via the Equation 3 (Marshall and Warring, 1986).

$$LAI = \frac{\text{Surface area of sampled leaf (cm}^2\text{)}}{\text{Ground area occupied by the sampled plant (cm}^2\text{)}} \quad (3)$$

v. Yield/ ha

Yield was estimated per sub-sub plot in terms of tonne/ha. The harvesting was done manually per plot, threshed mechanically (locally constructed multi-purpose thresher) and manually winnowed. The weights of the threshed and winnowed soybean seeds were taken per plot using a top loading Camry manual weighing scale of 50 kg with 0.0001 g sensitivity.

3. RESULTS AND DISCUSSION

3.1 Effects of Tillage Systems, Nutrient Application and Weed Management Practice on the Growth and Development of Soybean

Tables 3, 4, 5, 6, 7, 8 and 9 show the effects of the treatments on the growth and development of soybean in terms of plant height, stem girth, number of noodles and root length. Tillage systems, nutrient application and weed management practice significantly influenced the plant height, stem girth, number of noodles and root length of soybean during the trials. Among the tillage systems imposed, T_3 (DDH at 15 cm) had the highest mean values plant height for the trials (average) of 49.39 cm and number of noodles of (20.19) while T_1 (DPH at 25 cm had highest mean values of stem girth(3.26 cm) and root length (27.74cm). Dauda and Aloko (2009) found out that tillage depths of 15- 25 cm provided greater soybean growth responses in terms of plant height, number of leaves, stem girth, and root length than no tillage or shallower tillage.

Table 3: Effects of Tillage Systems, Nutrient Application and Weed Management Practice on the Growth and Development of Soybean (2018 Trial)

Source of variance	Plant height (cm)		Stem girth(cm)	Number of noodles (no)		Root length (cm)	
	6WAP P_{value}	9WAP P_{value}	9WAP P_{value}	7WAP P_{value}	9WAP P_{value}	7WAP P_{value}	9WAP P_{value}
T	0.0001*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*
N	0.037*	0.001*	0.000*	0.061^{ns}	0.003*	0.000*	0.000*
W	0.072^{ns}	0.001*	0.000*	0.074^{ns}	0.002*	0.000*	0.000*
T×N	0.894^{ns}	0.007*	0.000*	0.153^{ns}	0.000*	0.000*	0.019*
T×W	0.934^{ns}	0.001*	0.000*	0.199^{ns}	0.002*	0.003*	0.000*
N×W	0.235^{ns}	0.003*	0.003*	0.109^{ns}	0.000*	0.005*	0.000*
T×N×W	0.119^{ns}	0.241^{ns}	0.000*	0.014*	0.000*	0.000*	0.000*

T (Tillage systems), N (Nutrient Application), W (Weed management), * (significant at $p< 0.05$), ^{ns} (non-significant at $p\leq0.05$),WAP (Week After Planting)

Table 4: Means for the Tillage Systems, Nutrient Application and Weed Management Practice of the Growth and Development of Soybean Using NDMRT (2018 Trial)

Treatments	Plant height (cm)		Stem girth (cm)	Number of noodles (no)		Root length (cm)	
	6WAP	9 WAP	9 WAP	7 WAP	9 WAP	7 WAP	9 WAP
Tillage systems(T)							
T_1 (DPH at 25 cm)	24.53^{b}	53.16^{a}	3.31^{a}	5.86^{b}	14.86^{b}	24.35^{a}	27.69^{a}
T_2 (DP at 20 cm)	21.26^{c}	52.16^{a}	3.22^{a}	4.47^{c}	10.51^{d}	19.24^{b}	18.88^{b}
T_3 (DDH at 15 cm)	28.45^{a}	54.53^{a}	3.29^{a}	7.72^{a}	19.33^{a}	20.96^{b}	27.56^{a}
T_4 (DH at 10 cm)	21.84^{c}	48.34^{b}	2.85^{b}	5.28^{bc}	13.17^{c}	18.31^{b}	19.74^{b}
Nutrient Application(N)							
$N_{1(control)}$	22.77^{b}	45.33^{b}	2.35	5.56	11.81^{b}	17.78^{b}	20.19^{c}
N_2	24.45^{a}	54.82^{a}	3.50	6.02	15.31^{a}	21.79^{a}	24.60^{b}
N_3	24.84^{a}	55.99^{a}	3.66	5.92	15.06^{a}	22.57^{a}	25.61^{a}
Weed management (W)							
$W_{1\ (control)}$	22.79	40.55^{c}	2.52^{b}	5.42	11.81^{b}	18.51^{b}	21.40^{c}
W_2	24.87	58.18^{a}	3.33^{a}	6.14	15.31^{a}	21.80^{a}	23.73^{b}
W_3	24.90	55.78^{ab}	3.46^{a}	6.14	15.06^{a}	21.58^{a}	25.41^{a}
W_4	23.52	53.66^{b}	3.37^{a}	5.64	15.83^{a}	20.96^{a}	23.32^{b}
SE	0.43	0.75	0.07	0.21	0.47	0.35	0.40

NDMRT (New Duncan Multiple Range Test), Mean values with same letters are insignificantly different at $p\leq 0.05$, WAP (Week After Planting)

Table 5: Effects of Tillage Systems, Nutrient Application and Weed Management Practice on the Growth and Development of Soybean (2019 Trial)

Source of variance	Plant height (cm)		Stem girth (cm)	Number of noodles (no)		Root length (cm)	
	6WAP P_{value}	9WAP P_{value}	9WAP P_{value}	7WAP P_{value}	9WAP P_{value}	7WAP P_{value}	9WAP P_{value}
T	0.0001*	0.0001*	0.0001*	0.001*	0.000*	0.000*	0.001*
N	0.0258*	0.001*	0.0011*	0.634^{ns}	0.001*	0.000*	0.000*
W	0.488^{ns}	0.00001*	0.0001*	0.350^{ns}	0.000*	0.000*	0.000*
T×N	0.987^{ns}	0.073^{ns}	0.014*	0.110^{ns}	0.000*	0.000*	0.0001*
T×W	0.987^{ns}	0.029*	0.037*	0.140^{ns}	0.002*	0.002*	0.001*
N×W	0.061^{ns}	0.090^{ns}	0.0025*	0.168^{ns}	0.000*	0.005*	0.000*
T×N×W	0.533^{ns}	0.088^{ns}	0.0001*	0.220^{ns}	0.000*	0.000*	0.0001*

T (Tillage systems), N (Nutrient Application), W (Weed management), * (significant at $p< 0.05$), ^{ns} (non-significant at $p\leq 0.05$), WAP (Week After Planting)

Table 6: Means for the Tillage Systems, Nutrient Application and Weed Management Practice of the Growth and Development of Soybean Using NDMRT (2019 Trial)

Treatments	Plant height (cm)		Stem girth (cm)	Number of noodles (no)		Root length (cm)	
	6 WAP	9 WAP	9 WAP	7 WAP	9 WAP	7 WAP	9 WAP
Tillage systems (T)							
T_1 (DPH at 25 cm)	24.96^a	52.01^a	3.30^a	5.89^b	15.36^b	23.46^a	27.79^a
T_2 (DP at 20 cm)	19.73^c	47.01^b	3.22^a	5.45^c	12.51^c	18.64^b	21.70^c
T_3 (DDH at 15 cm)	22.29^b	49.26^a	3.29^a	6.72^a	16.06^a	21.05^b	24.82^b
T_4 (DH at 10 cm)	22.06^b	46.90^b	2.85^b	5.33^{bc}	13.25^c	18.56^b	20.51^c
Nutrient Application(N)							
$N_{1(control)}$	21.49^c	44.05^b	2.35	5.60	10.58^b	16.58^b	19.99^c
N_2	22.60^b	50.66^a	3.50	5.90	16.70^a	20.45^a	25.50^a
N_3	22.78^a	51.66^a	3.66	6.04	16.02^a	21.57^a	25.51^a
Weed management (W)							
$W_{1\ (control)}$	21.92	39.01^c	2.52^b	5.44	11.86^b	18.51^b	21.64^b
W_2	23.15	54.08^a	3.33^a	6.06	15.19^a	21.50^a	24.23^a
W_3	22.87	50.82^b	3.46^a	5.69	15.30^a	20.76^a	24.94^a
W_4	21.08	51.26^b	3.37^a	6.19	15.20^a	20.46^a	23.81^b
SE	0.38	0.66	0.07	0.21	0.46	0.33	0.38

NDMRT (New Duncan Multiple Range Test), Mean values with same letters are insignificantly different at $p\leq 0.05$, WAP (Week After Planting)

This may due to tillage treatments (T_1 and T_3) increase pore size distribution and interconnectedness that allow soil to quickly transfer water with nutrient between soil pores for plant use. Weninger *et al*., 2019 supported the finding that tillage with high soil bulk density revealed the absence of transmissive pores.

N_3 among nutrient application treatments had the highest plant height (58.83 cm), stem girth (3.66 cm), number of noodles (15.54) and root length (25.58 cm) (average) for the trials at 9 week after sowing. Also all the weed management practice treatment are significantly different from the control (no weeding treatment). However, both W_2 and W_3 had highest soybean growth performance (27.86 %, 27.17 %, 22.48 % and 9.98 % higher than the control) in terms of plant height, stem girth, number of noodles and root length respectively. This indicates that the crop do better with early weed control.

Tillage systems (T) had significant effect on number of leaf and node interface. Nutrient application (N) and weed management practice (W) had significant effect on number leaf, leaf area index (LAI) and node interface during the trial. Among the tillage treatments, T_1 (DPH at 25 cm) had the highest mean value of number of leaf (63.11) and node interface (2.89) while T_4 (DH at 10 cm) had the lowest of number of leaf (56.21) and node interface (2.36) average for the trials at 9 week after sowing. Though, T_1 and T_3 are statistically the same at $p< 0.05$.

Nutrient treatment with higher quantity (N_3) had the highest mean number of leaf (63.35), leaf area index (1.25) and node interface (2.95) which is; 20.04%, 42.4% and 29.83% greater than the result obtained in control nutrient treatment (N_1) in terms of number of leaf, leaf area index and node interface respectively. Compost Poultry manure is a slow-release nutrient source. When compared to other manures like cow dung and pig dung, it is high in nitrogen, phosphorous, potassium, calcium, and organic matter (Zublena *et al.*, 1993). It also improves soil biological activity that speeds up the breakdown of organic nutrients into plant-absorbable forms (Rosen, 2005). Chiezey and Odunzey (2009) reported similar soybean growth responses to the combination of compost poultry manure (at 1 ton/ha) with phosphorus (inorganic) nutrient (at 26.4 kg/ha) application.

Table 7: Effects of Tillage Systems, Nutrient Application and Weed Management Practice on the Growth and Development of Soybean (2018 Trial)

Source of variance	**Number of leaf (No)**			**Leaf Area Index**	**Node Interface (cm)**
	5 WAP	7 WAP	9 WAP	9 WAP	9 WAP
	P_{value}	P_{value}	P_{value}	P_{value}	P_{value}
T	0.006*	0.000*	0.000*	0.323^{ns}	0.000*
N	0.003*	0.000*	0.000*	0.000*	0.000*
W	0.507^{ns}	0.000*	0.000*	0.000*	0.000*
T×N	0.209^{ns}	0.003*	0.101^{ns}	0.006*	0.000*
T×W	0.171^{ns}	0.000*	0.000*	0.000*	0.006*
N×W	0.299^{ns}	0.001*	0.000*	0.000*	0.000*
T×N×W	0.628^{ns}	0.002*	0.002*	0.000*	0.000*

T (Tillage systems), N (Nutrient Application), W (Weed management), * (significant at $p< 0.05$), ^{ns} (non-significant at $p\leq 0.05$), WAP (Week After Planting)

Table 8: Means for the Tillage Systems, Nutrient Application and Weed Management Practice of the Growth and Development of Soybean Using NDMRT (2018 Trial)

Treatments	Number of leaf (No)			Leaf Area Index	Node Interface (cm)
	5 WAP	7 WAP	9 WAP	9 WAP	9 WAP
Tillage systems(T)					
T_1 (DPH at 25 cm)	27.42^{a}	47.03^{a}	62.75^{a}	1.10	2.95^{a}
T_2 (DP at 20 cm)	21.94^{c}	37.92^{d}	54.97^{c}	1.05	2.30^{b}
T_3 (DDH at 15 cm)	24.78^{b}	42.97^{b}	59.97^{b}	1.09	2.85^{a}
T_4 (DH at 10 cm)	24.86^{b}	40.00^{c}	58.06^{b}	1.04	2.43^{b}
Nutrient Application(N)					
$N_{1(control)}$	22.21^{b}	30.25^{b}	50.67^{b}	0.72^{b}	2.07^{b}
N_2	26.44^{a}	46.71^{a}	62.29^{a}	1.24^{a}	2.88^{a}
N_3	25.60^{a}	48.98^{a}	63.35^{a}	1.25^{a}	2.95^{a}
Weed management (W)					
$W_{1\ (control)}$	23.75	33.08^{d}	50.92^{c}	0.79^{b}	2.06^{c}
W_2	25.47	45.92^{b}	59.11^{b}	1.11^{a}	2.98^{a}
W_3	24.08	47.14^{a}	62.86^{a}	1.17^{a}	2.81^{a}
W_4	25.69	41.78^{c}	62.19^{a}	1.21^{a}	2.69^{b}
SE	0.54	1.11	0.87	0.027	0.065

NDMRT (New Duncan Multiple Range Test), Mean values with same letters are insignificantly different at $p \leq 0.05$, WAP (Week After Planting)

Table 9: Effects of Tillage Systems, Nutrient Application and Weed Management Practice on the Growth and Development of Soybean (2019 Trial)

Source of variance	Number of leaf (No)			Leaf Area Index	Node Interface (cm)
	5 WAP P_{value}	7 WAP P_{value}	9 WAP P_{value}	9 WAP P_{value}	10 WAP P_{value}
T	0.00001*	0.0001*	0.000*	0.540^{ns}	0.000*
N	0.0001*	0.00001*	0.000*	0.000*	0.000*
W	0.425^{ns}	0.0001*	0.000*	0.000*	0.000*
T×N	0.052^{ns}	0.0001*	0.415^{ns}	0.002*	0.000*
T×W	0.0034^{ns}	0.000*	0.000*	0.0001*	0.006*
N×W	0.009*	0.001*	0.000*	0.0001*	0.000*
T×N×W	0.132^{ns}	0.001*	0.014*	0.0001*	0.000*

T (Tillage systems), N (Nutrient Application), W (Weed management), * (significant at $p < 0.05$), ^{ns} (non-significant at $p \leq 0.05$) ,WAP (Week After Planting)

Table 10: Means for the Tillage Systems, Nutrient Application and Weed Management Practice of the Growth and Development of Soybean Using NDMRT 2019 Trial

Treatments	Number of leaf (No)			Leaf Area Index	Node Interface (cm)
	5 WAP	7 WAP	9 WAP	9 WAP	9 WAP
Tillage systems (T)					
T_1 (DPH at 25 cm)	26.66[a]	45.01[a]	63.97[a]	1.09	2.82[a]
T_2 (DP at 20 cm)	22.78[c]	42.03[b]	57.89[b]	1.05	2.80[b]
T_3 (DDH at 15 cm)	2444[b]	42.97[b]	56.58[b]	1.05	2.42[c]
T_4 (DH at 10 cm)	24.69[b]	35.00[c]	54.36[c]	1.08	2.28[c]
Nutrient Application(N)					
$N_{1(control)}$	20.25[b]	30.42[c]	46.88[b]	0.73[b]	2.05[b]
N_2	25.60[a]	46.30[b]	62.32[a]	1.23[a]	2.88[a]
N_3	26.90[a]	49.18[a]	64.39[a]	1.24[a]	2.95[a]
Weed management (W)					
$W_{1\ (control)}$	23.61	32.97[d]	51.31[c]	0.80[c]	2.06[c]
W_2	25.64	45.83 [ab]	58.42[b]	1.13[b]	2.92[a]
W_3	25.36	47.36[a]	60.92[a]	1.17[a]	2.66[a]
W_4	26.72	41.78[c]	59.17[a]	1.19[a]	2.73[b]
SE	0.54	0.98	0.87	0.027	0.07

NDMRT (New Duncan Multiple Range Test), Mean values with same letters are insignificantly different at $p \leq 0.05$, WAP (Week After Planting)

3.2 Effects of Tillage Systems, Nutrient Application and Weed Management Practice on the Yield Components and Yield of Soybean

The influence of the tillage systems, nutrient applications and weed management practices imposed in this study on the yield components and yield soybean are presented in Tables 11, 12, 13 and 14 for 2018 and 2019 respectively. In 2018, the pod/plant, 1000 seed weight, and grain output were all greater than in 2019. It is possible that this is due to the reduced rainfall in 2019. This had to assure appropriate breakdown and nutrient release from organic matter. Wet soils have more mineralization than dry soils (Chiezey *et al*., 1993)

The tillage systems, nutrient applications, weed management practices; have significant effects on pod/plant (no), 1000 seed weights (g) and grain yield (ton/ha) in both trials. There are significant interaction effects among the treatment imposed for the yield components and grain yield at $p \leq 0.05$ of soybean in this study. Though, yield components are lower in 2019 trial due to the low amount of rainfall as against the 2018 trial.

Among the tillage systems, T_3 (DDH at 15 cm) had the highest mean values of pod/plant (74.78), 1000 seed weight (134.83g) and highest mean value of grain yield of 2.43 ton/ha (average for both trials), though not significantly difference from the mean values obtained in T_1 (DPH at 25 cm) at $p \leq 0.05$ with pod /plant (68.78), 1000 seed weight (131.72 g) and mean grain yield of 2.50 ton/ha. This result shows that reduced tillage between 15- 25 cm had significant higher biological yield as compared to the ones less than 15 cm may be as result of higher weed infestations in the tillage with lower depth of cut.

The fertility status of the soil is expected to benefit from poultry manure application since the manure is known to improve soil organic matter and macro-nutrient status and micro nutrient qualities of the soil (Akande and Adediran, 2004).

It is ascertained that improved soil nutrient contents caused by poultry manure addition led to increased growth, development and yield of Soybean. Increased growths of Soybean given by

Table 11: Effects of Tillage Systems, Nutrient Application and Weed Management Practice on the Yield Components and Yield of Soybean (2018 Trial)

Source of variance	Pod/plant (No)	Seed/Pod (No)	100seed weight (g)	Grain yield (ton/ha)
	P_{value}	P_{value}	P_{value}	P_{value}
T	0.0001*	0.618^{ns}	0.030*	0.016*
N	0.000*	0.007*	0.000*	0.000*
W	0.000*	0.012*	0.000*	0.000*
T×N	0.011*	0.609^{ns}	0.000*	0.000*
T×W	0.002*	0.030*	0.000*	0.004*
N×W	0.001*	0.038*	0.000*	0.000*
T×N×W	0.001*	0.031*	0.000*	0.042*

Table 12: Means for the Tillage Systems, Nutrient Application and Weed Management Practice of the Yield Components and Yield of Soybean Using NDMRT (2018 Trial)

Treatments	Pod/plant (No)	Seed/Pod	1000 seed weight (g)	Grain yield (ton/ha)
Tillage systems(T)				
T_1 (DPH at 25 cm)	68.78^{ab}	2.3	131.72^{a}	2.50^{a}
T_2 (DP at 20 cm)	61.42^{c}	2.3	127.69^{b}	2.27^{c}
T_3 (DDH at 15 cm)	74.78^{a}	2.3	134.83^{a}	2.55^{a}
T_4 (DH at 10 cm)	66.14^{bc}	2.3	131.04^{ab}	2.30^{bc}
Nutrient Application(N)				
$N_{1(control)}$	40.17^{c}	2.21^{b}	92.31^{b}	1.48^{c}
N_2	86.06^{a}	2.40^{a}	150.83^{a}	2.97^{a}
N_3	77.10^{b}	2.34^{a}	149.98^{a}	2.77^{b}
Weed management (W)				
$W_{1\ (control)}$	25.08^{c}	1.10^{d}	60.44^{c}	0.32^{c}
W_2	76.06^{a}	2.38^{b}	143.08^{a}	2.63^{b}
W_3	77.06^{a}	2.40^{a}	142.81^{a}	2.87^{a}
W_4	72.92^{b}	2.31^{c}	137.08^{b}	2.60^{b}
SE	2.44	0.026	3.07	0.41

NDMRT (New Duncan Multiple Range Test), Mean values with same letters are insignificantly different at $p \leq 0.05$, WAP (Week After Planting

Table 13: Effects of Tillage Systems, Nutrient Application and Weed Management Practice on the Yield Components and Yield of Soybean (2019 Trial)

Source of variance	Pod/plant (No)	Seed/Pod (No)	1000 seed weight (g)	Grain yield (ton/ha)
	P_{value}	P_{value}	P_{value}	P_{value}
T	0.000*	0.492^{ns}	0.037*	0.0008*
N	0.000*	0.0012*	0.0001*	0.0001*
W	0.000*	0.0008*	0.00001*	0.000*
T×N	0.005*	0.285^{ns}	0.0019*	0.0009*
T×W	0.033*	0.0011*	0.000*	0.0006*
N×W	0.0005*	0.0028*	0.000*	0.009*
T×N×W	0.0185*	0.015*	0.000*	0.001*

T (Tillage systems), N (Nutrient Application), W (Weed management), * (significant at $p< 0.05$), ^{ns} (non-significant at $p\leq 0.05$)

Table 14: Means for the Tillage Systems, Nutrient Application and Weed Management Practice of the Yield Components and Yield of Soybean Using NDMRT(2019 Trial)

Treatments	Pod/plant (No)	Seed/Pod	1000 seed weight (g)	Grain yield (ton/ha)
Tillage systems(T)				
T_1 (DPH at 25 cm)	66.89^{a}	2.25	117.00^{a}	2.19^{a}
T_2 (DP at 20 cm)	60.81^{b}	2.31	115.97^{b}	2.04^{b}
T_3 (DDH at 15 cm)	68.31^{a}	2.33	119.69^{a}	2.30^{a}
T_4 (DH at 10 cm)	57.86^{bc}	2.21	115.92^{b}	2.02^{c}
Nutrient Application(N)				
$N_{1(control)}$	42.10^{c}	2.19^{b}	93.77^{b}	1.38^{c}
N_2	76.40^{a}	2.38^{a}	129.13^{a}	2.53^{a}
N_3	74.60^{b}	2.34^{a}	128.54^{a}	2.51^{b}
Weed management (W)				
$W_{1\ (control)}$	20.08^{c}	1.13^{c}	55.56^{d}	0.37^{c}
W_2	70.60^{a}	2.42^{a}	128.61^{a}	2.23^{b}
W_3	70.39^{a}	2.35^{a}	123.22^{b}	2.49^{a}
W_4	69.47^{b}	2.33^{b}	121.31^{c}	2.47^{b}
SE	2.30	0.028	3.02	0.35

NDMRT (New Duncan Multiple Range Test), Mean values with same letters are insignificantly different at $p\leq 0.05$, WAP (Week After Planting)

1ton / ha and 75 kg of SSP /ha nutrient applied relative to 0.5 ton/ ha and 50 kg of SSP manure did not translate into grain yield can be adduced to dilution effect of excess organic matter and high availability of N which led to vegetative growth at the expense of grain filling. This is explained by the dilution effect of excess N given by 1 ton / ha of FYM. Ewulo *et al.,* (2008) explained that poultry manure above 25 ton/h did not translate into fruit yield in tomato. Rosen and Bierman (2008) reported that too much ammonium produced from excessive poultry manure application reduces the amount of adenosine triphosphate (ATP), which permits energy to be released from photosynthesis for grain yield.

4. CONCLUSION

It is important that farmers adopt management practices that are directed at achieving a self-sustaining system of the soil and sustainable yield of soybean. From this study, reduce tillage system, T_3 (DDH at 15 cm) (double harrowed at depth 15 cm) is recommended for gentle slope arable land with sandy loam soil in ecotone guinea savannah for its ability to produce high yield and conserve soil nutrient. Minimum application of compost farm yard manure at the rate of 0.5 ton/ ha and early control of weed before the 5th week after sowing is highly recommended for higher yield of soybean.

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EXPERIMENTAL DETERMINATION OF SOIL PROPERTIES RELATED TO TRACTION ON AN UNPAVED *ILE-APA* FARM ROAD

Tanam U. I.
Department of Environmental Management, Bingham University, Karu – Nigeria
Email: tanam.isaac@binghamuni.edu.ng,

ABSTRACT

Ile-Apa is a farming community in Kwara State, Nigeria. Loss of manhours resulting from loss of traction has been a major problem for farm vehicles travelling in and around *Ile-Apa*. This makes it difficult to convey farm inputs to the farm during certain periods of the year. Due to the heterogeneity of agricultural soils, it would be inappropriate to use soil data from different locations to design or select tractive devices for this community. It became necessary to determine soil parameters related to traction on the unpaved road in, and around the *Ile-Apa* community. Experimental methods were used to determine soil cohesion (C), internal angle of friction (ϕ), wet basis moisture content (Mc), void ratio (e), porosity (n) and bulk density (ρ). Results obtained showed that C, ϕ, Mc, e, n and ρ were 1.4 N/cm^2, 34.84°, 44.92%, 1.213, 0.548 and 1.768 g/cm^3 respectively. These indicated that the soil in the area lacked sufficient strength to support heavy vehicles during rainy periods. Appropriate tractive devices must therefore be carefully selected to avoid loss of manhour and damage to both soil and vehicle.

Keywords: Traction, Unpaved Road, void ratio, Porosity, Shear stress

1.0 INTRODUCTION

Traction is the force developed from the interaction between a tractive device and a tractive medium to facilitate motion required to move a load. This force is often less than tractive effort due to energy losses, especially from rolling resistance (Fenyvesi *et al*., 2002 Vedantu, 2023). Offroad tractions are common in the military, road construction, and agriculture. The tractive medium in these environments is the soil.
Soil trafficability is the ease with which a tractive device can trafficate a given tractive medium without damage to the device or the medium. Mueller *et al.* (2011) defined it as the capability of the soil to provide traffic support for agricultural machines without degrading the soil. Agricultural soils, however, lack sufficient strength to bear the weight of most traffic devices. When loaded, they deform plastically in shear, leading to wheel slip. Loading could be in pulling or pushing an implement or simply travelling over the soil. Abubakar *et al.* (2022) explained that wheel slip occurs when the horizontal force of the wheel overcomes the internal shear strength of soil in the wheel/soil contact planes, thereby displacing the soil in the opposite direction of travel of the wheel. Ajewole and Fayose (2022) reported that about 20% to 55% of the total energy available to the tractor is wasted at the interaction of the tractive device and soil. Reduction in wheel slip can lead to considerable savings in fuel consumption, tyre wear and machine maintenance, as well as increase in attractive efficiency (Abubakar *et al.,* 2022; Zoz and Grisso, 2003).

Agricultural soils are heterogeneous. Therefore, data from one location may not apply to another. Knowledge of the soil condition in a specific location is very important in the design or selection of the tractive device that may interact effectively in that location. Several attempts have been made to study tractor wheel slip to minimize traction losses resulting therefrom (Abubakar *et al.,* 2022). However, none of these attempts took into account the location of these studies. Abubakar *et al*. (2022) citing Ani *et al.* (2004) stated that soil condition is among the factors influencing tractor traction performance. Abubakar *et al.* (2022) further listed the soil conditions and included soil moisture content, bulk density, soil texture, and shear strength.

As a result of the heterogeneity of agricultural soils, design of tractive devices and their performance is often based on experimental approach rather than analytical, with soil material collected from the location of intended use. The purpose of this work, therefore, was to experimentally determine the parameters of soil related to traction around *Ile-Apa*, a farming community close to Ilorin, the Kwara State capital.

2. MATERIALS AND METHOD

2.1 Study Area

Ile-Apa is located in Ilorin-South Local Government Area of Kwara State, Nigeria, on latitude 8° 26′ 6″ North and longitude 4° 40′ 52″ East at an altitude of 397 m above sea level. The community has a rural setting with the majority of inhabitants farmers. The road selected for this work is among farm roads, one linking *Ile-Apa* to the University of Ilorin. Figure 1 is an aerial map of *Ile-Apa* showing the selected road. Soil properties determined were soil cohesion (C), angle of internal friction (ϕ), moisture content (Mc), void ratio (e), porosity (n), and bulk density (ρ).

Figure 1: Aerial Map of *Ile-Apa* showing research selected road
Source: Google Maps (2023).

2.2 Determination of Soil Cohesion and Angle of Internal Friction

The translational (direct) shear box method was used to determine the apparent cohesion and angle of shearing resistance of the soil. Saturated soil samples for the test road were collected from random locations along the selected unpaved farm road, prepared into a cube, 0.061m^3, and placed in the box. A normal force (P) of 88.94N was exerted directly on the soil. A slow-running electric motor was used to apply a varying force tangential (F) on the upper half of the box at a constant rate. The force, F, was read directly from a proving ring while soil deformation (x) was simultaneously read from the dial gauge. Values of shear stress (τ) at each reading of F were determined by Equation 1.

$$\tau = \frac{F}{A} \qquad 1$$

where F is the A is the area of the shear plane = 3.721 x 10^{-3}m^2.

The procedure was repeated with different normal forces and shear stress at failure and recorded. The values of shear stress (τ) were then plotted against deformation (x) to determine the maximum shear load. The relationship between soil maximum shear strength (τ_f) and shear stress (σ′) is given by Sitkei (1986), Verruijt (2018) and Roy (2022) as:

$$\tau_f = C' + \sigma' tan\phi' \qquad 2$$

Where C´ is soil cohesion and ϕ´ is angle of internal friction. Graphical method was adopted to estimate the values of C´ and ϕ´.

2.3 Determination of Soil Moisture Content, Void Ratio, Porosity, and Bulk Density

The oven method described by Tanam and Olaoye (2022) was used to determine the moisture content (Mc_{db}) (dry basis). Moisture content was determined using Equation 3:

$$Mc_{db} = \frac{m_1 - m_2}{m_2} \qquad 3$$

Where m_1 is the mass of the saturated soil and m_2 is the mass of the oven-dry soil.

Since the soil was saturated, the volume of water removed was equal to the volume of void in the soil. Void ratio (e) was obtained by Equation (4).

$$e = \frac{V_v}{V_s} \qquad 4$$

where V_v is volume of void and V_s is volume of solid soil particles.

The density of water (ρ_w) was taken as 1g/cm^3 and soil-specific gravity was taken as 2.7. Therefore, density soil solid (ρ_s) = 2.7ρ_w = 2.7gcm^{-2}. Dividing the mass of dry soil by ρ_s produced the volume of the dry soil.

Porosity (n) was determined from Equation 5.

$$n = \frac{V_v}{V} = \frac{e}{e+1} \qquad 5$$

where V is the total volume of soil, m^3.

Bulk density was obtained as the ratio of the mass of the oven-dry soil to its total volume, expressed as Equation (6).

$$\rho = \frac{m_1 - m_2}{V} \qquad 6$$

3. RESULTS AND DISCUSSION

3.1 Cohesion and Angle of Internal Friction

Figure 2 shows a graph of the series of shear stress and their corresponding deformation. Figure 2 showed that the first soil failed at a shear load of 17.5 kN with a normal load of 0.089 kN.

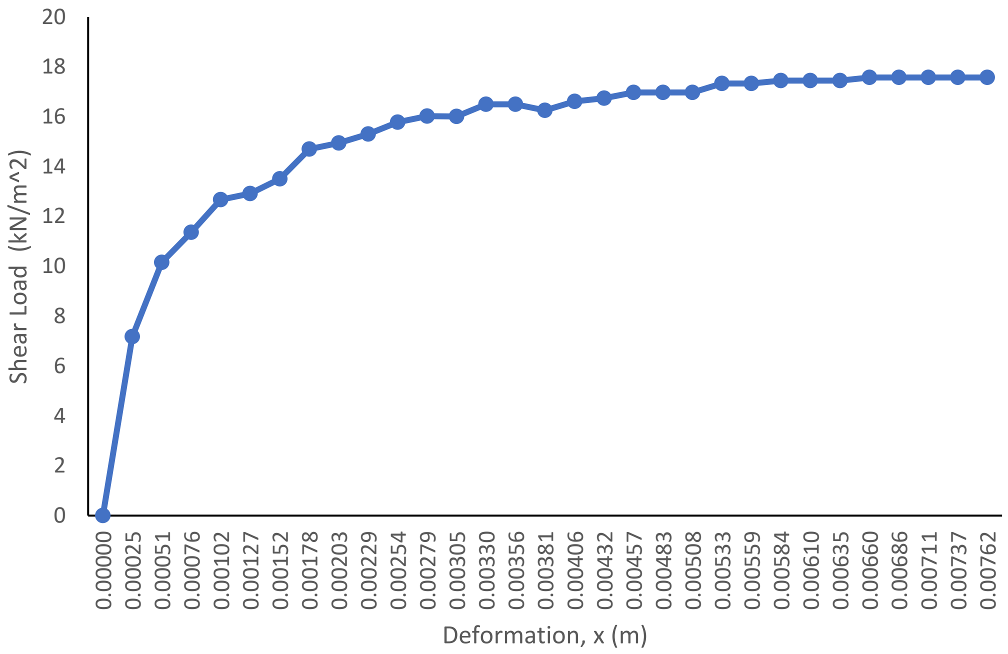

Figure 2: Graph of shear load against deformation.

It was observed the rate of deformation was lower at lower forces than at higher forces and increasing normal compressive load increased the maximum shear stress at failure. This observation is similar to that observed by Hu *et al*. (2020). The deformation was observed to be partially elastic with the possibility of returning to its original position when load is removed. However, at higher loads, the deformation became plastic and even brittle (Hu *et al*., 2020). For each soil sample tested, deformation continued even when no further force was applied beyond the maximum shear load. This showed that the soil had failed at that point. Deformation continued even when the tangential force was decreased. Table 1 is a summary of normal stress and shear stress for all soil samples.

Table 1: Summary of shear stress and normal stress from the translational shear test.

Normal Stress, σ (kN/m^2)	τ_{max} (kN/m^2)
23.91	17.57
29.83	19.84
41.92	28.87
47.84	33.47
53.75	37.54

Table 1 shows that the maximum shear stress was almost perfectly directly related to the normal stress with a positive correlation coefficient of 0.997. Increasing normal load led to an increase in shear stress at failure. Figure 3 is a graphical representation of the result. The intercept of the curve on the shear stress axis represents the soil cohesion (C) while the slope represents the angle of shearing resistance of the soil (ϕ).

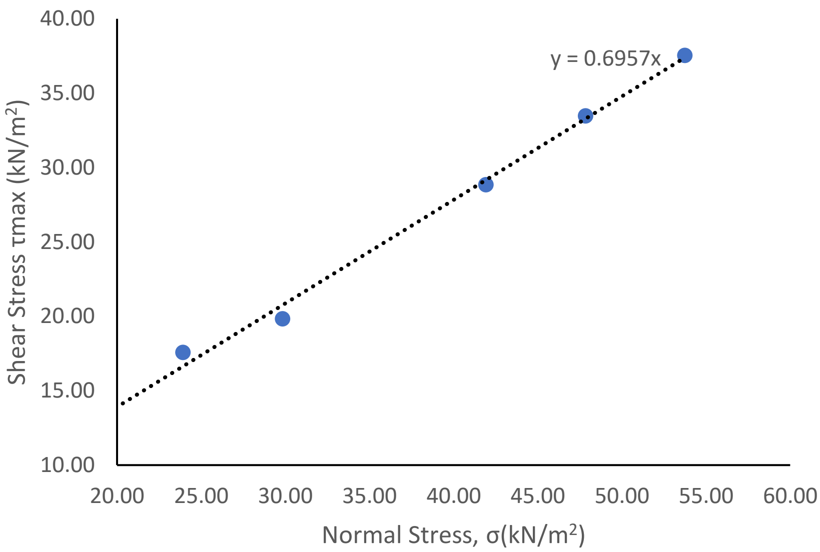

Figure 3: Graph of Shear stress against Normal stress showing the line of best fit.

From Figure 3, C was found to be 14.00 kN/m^2 or 1.4 N/cm^2 and the slope was obtained as 0.6957, giving an angle of internal friction of 34.84°. For the soil in *Ile-Apa* therefore, the relationship between the shear stress and normal stress may be expressed as Equation 7.

$$\therefore \tau = 1.4 + \sigma tan\, 34.84 \qquad 7$$

The low value of soil cohesion indicates that the soil is only slightly cohesive, representing a low clay content, whereas the observed high gradient is an indication that the soil is highly frictional, an indication of a high sand content. The soil along the unpaved *Ile-Apa* farm road may therefore be described as frictional-Cohesive and may be classified as sandy clay soil.

3.2 Moisture Content, Void Ratio, Porosity and Bulk Density

Equation 3 was used to determine the soil moisture content. Mass of the saturated soil was found to be 1526 g. Mass of the oven-dry soil was 1053 g. Moisture content (dry basis) was evaluated at 44.92%. With a moisture content of over 40%, trafficability is hampered by excessive wheel slip. This agrees with the findings of Abubakar *et al.* (2022), which showed that wheel slippage generally increased with increase in moisture. Abubakar *et al.* (2022) showed that a moisture content of 25% produced a wheel slippage of over 20% depending on the soil type.

The volume of the dry soil was found to be 390 cm^3. Applying this to Equation 4, void ratio (e) was calculated to be 1.213. This value is above average for typical soil which varies from 0.3 – 2.0 (Hillel, 2003). The implication is that soil compressibility is high. Therefore, when a heavy wheel load traverses the study road, there is a high chance of wheel sinkage, causing adjacent soil displacement. Trafficability is therefore impaired. Equation 5 showed that porosity (n) was 0.548, while Equation 6 returned a bulk density (ρ) of 1.768 g/cm^3. Again, the high value of porosity is an indication of possible soil compaction when a heavy vehicle travels over it, thereby causing damage to the soil and the vehicle, with heavy loss of manhours. *Ile-Apa* should therefore be avoided at the peak of rainy seasons when the soil is saturated.

4 CONCLUSIONS

Experimental values for the soil parameters related to traction showed that the *Ile-Apa* road lacks sufficient strength to support heavy loads when wet. Soil cohesion was found to be 1.4 N/cm^2 with a coefficient of internal friction of 34.84°. Moisture content, void ratio, porosity and bulk density were 44.92%, 1.213, 0.548 and 1.768 g/cm^3 respectively. A low load-bearing capacity would cause damage to the soil as the failure rate is quite high. There would be heavy loss of energy and manhours due to loss of traction. This road must therefore be avoided when rains are high, else, the road should be improved or appropriate tractive devices should be employed. Since this road may not avoided completely as farmer must continue with farming operations, it would be necessary to determine the optimum levels of these parameters with a view of advising offroad vehicle owner on the best period to engage the road.

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TRENDING MULCHING TECHNOLOGIES AND BENEFITS IN SOIL AND WATER CONSERVATION: A DISCOURSE FOR ADOPTION IN NIGERIA

Amool, Shagbaor Hycent[1], Agidzi Donald[2]
[1-2]Department of Agricultural and Environmental Engineering, University of Agriculture, Makurdi, Benue State. Nigeria
Corresponding mail: amoolhycent@gmail.com

ABSTRACT

In Nigeria, there are many problems in agricultural production as a result of the effect of the change in climatic conditions and the lack of precipitation, as well as the malnutrition and maintenance procedures applied by producers. Inadequate soil fertility and water generally cause reductions in crop yield. As a result of the high temperatures seen in summer months, the losses in soil fertility through evaporation create stress conditions for the plant as well as low yield. This paper is a review of research and development associated with application, methods, and amounts of mulch types-crop residues, chemical soil stabilizers, and feedlot wastes (manure)-required to control soil degradation (majorly erosion and water management) in Nigeria. Mulching has become an important practice in modern field production. Mulch paper reduces the application of chemical fertilizer and herbicide, weed control and maintain the land temperature. Under natural conditions, residues such as fallen leaves, branches, etc. form a natural mulch cover on the soil surface in the area covered with vegetation. This article reviews the published research on mulches and discusses the opportunities that they have in solving the problem of agriculture in Nigeria such as improvement in soil moisture conservation, reduction in soil erosion and nutrient losses, suppression of weed growth, reduction in the need for herbicides or manual weeding, enhancement in soil fertility and organic matter content, moderation in soil temperature and prevent extreme fluctuations, and increment in crop yield and quality by providing favourable conditions for crop growth, reducing pest and disease incidence, and improving crop appearance and marketability.

1.0 INTRODUCTION

The environment, agronomic productivity, food security, and quality of life are all impacted by land degradation, which was a major global concern during the 20th century and continues to be crucial in the 21st (Eswaran *et al*., 2001). Biological deterioration of natural resources, such as the decline in soil biodiversity, chemical deterioration such as nutrient depletion, physical deterioration such as compaction, and erosion are all examples of soil degradative processes (Lal, 2001). Topsoil loss due to wind or water action is another.

Human-caused soil deterioration is a prevalent occurrence in Nigeria, West Africa. According to the UN Food and Agriculture Organization's 2005 assessment, it is mild for 37.5% of the region (342,917 km^2), moderate for 4.3% (39,440 km^2), high for 26.3% (240,495 km^2), and extremely high for 27.9% (255,167 km^2). The most common kind of soil deterioration in the nation is soil erosion, which has long been acknowledged as a severe issue (Stamp, 1938). In 1989, 231,000 km^2 in the north and 693,000 km^2 in the south were already deteriorated, primarily due to runoff-induced soil loss. While rill and gully erosion are frequent in the eastern portion of the country and along rivers in northern Nigeria, sheet erosion predominates throughout the whole nation (Ologe, 1988; Igbozurike, 1989).

Disturbance and a natural process known as landscape formation result in the redistribution of soil through erosion and deposition. The traditional shifting agriculture technique has been supplanted in recent decades by more intensive but generally unstable cropping systems, which has substantially hastened the process (Lal, 1993a). The need to expand food production to feed the world's population is still the primary driver of land use intensification. For instance, according to the Federal Republic of Nigeria (2007), the population of Nigeria increased from 115 million in 1991 to 140 million in 2006.

Particularly in sub-Saharan Africa, where the soil's capacity for resilience is constrained, the expansion of agriculture into marginal areas, deforestation, the shortening or elimination of fallow periods, inappropriate farming practises, and low input levels invariably have a number of environmental and economic impacts. Agriculture is expanding, which lowers productivity and creates localised resource degradation. For instance, Mbagwu *et al*. (1984) found that in some root-restrictive shallow soils of southern Nigeria, soil erosion results in a yield drop of between 30% and 90%. Off-site issues, including reservoir siltation, are also frequent results of soil loss. Soil erosion has a number of negative effects, including low agricultural production, food insecurity, low rural population income, and poverty. To sustain the functions of the soil and help provide food security for the present and for future generations, it is crucial to prevent soil loss through improved management and the conservation of natural resources (Ehui and Pender, 2005).

In Sub-Saharan Africa (Fournier, 1967; Greenland and Lal, 1977; Quansah, 1990; Kayombo and Mrema, 1998; Ehrenstein, 2002) and Nigeria (Lal 1976a, 1990), research on soil conservation has been performed for a long time. Various initiatives have led to the development of both off-farm strategies, such as mechanical or biological soil conservation technologies, as well as so-called on-farm strategies, including agronomic measures, soil management, and mechanical approaches. This paper provides a comprehensive and updated review of the current state of knowledge and practice on mulching as a soil and water conservation measure in Nigeria. The paper specifically:

- Highlights the benefits and challenges of using different types of mulches for different crops, soils and climates in Nigeria.
- Identifies the gaps and opportunities for further research and development on mulching technologies and their adoption among farmers.
- Provides recommendations and guidelines for policy makers, extension agents, researchers, educators and farmers on how to promote and implement mulching technologies effectively and sustainably.

The paper can serve as a valuable source of information and reference for various stakeholders involved or interested in soil and water conservation in Nigeria. It can also contribute to the advancement of science and innovation on mulching as a key component of integrated soil fertility management and climate-smart agriculture.

2.0 HISTORY OF SOIL CONSERVATION IN NIGERIA

The British government focused on managing natural resources during colonial times since there was a lot of interest in growing commercial farming operations. The first essay on soil conservation in northern Nigeria was written by Stebbing (1938), and Longtau *et al*. (2002) documented the use of terraces in various Jos Plateau locations in the past. Large-scale soil loss management programmes were launched, particularly in regions with strong agricultural potential, but many of them failed because the imported technology was not accepted later on by local farmers and had little application in the tropics.

Soil conservation has a long history in Nigeria, dating back to the pre-colonial times when indigenous farmers practiced various techniques to conserve soil and water resources. Some of these techniques included ridging, mulching, constructing earth bunds and terraces, multiple cropping, fallowing and planting trees. These techniques were based on local knowledge, experience and adaptation to the prevailing conditions (Junge *et al*., 2011a).

During the colonial period, the British government initiated several large-scale projects on soil loss control, such as contour plowing, contour ridging, bench terracing and gully reclamation. However, many of these projects failed or were abandoned due to lack of relevance, acceptance, maintenance and funding. The imported technologies were often unsuitable for the tropical soils, crops and climates, and did not consider the socio-economic and cultural aspects of the local farmers (Junge *et al*., 2011a).

After independence, more emphasis was placed on soil fertility issues rather than soil erosion control. The use of chemical fertilizers, improved seeds and irrigation increased crop production but also increased soil degradation. The oil boom in the 1970s provided some funds for soil conservation schemes but these were also limited by poor planning, implementation and evaluation. The oil bust in the 1980s further reduced the funds and the interest in soil conservation (Junge *et al*., 2011b). The effectiveness of soil conservation programmes was further hampered by declining funding at the conclusion of the 1980s oil boom (Slaymaker and Blench, 2002).

In recent decades, there has been a renewed awareness and concern about soil conservation in Nigeria, especially in the face of population growth, land use intensification, climate change and environmental degradation. Several initiatives have been undertaken by various stakeholders, such as government agencies, research institutions, non-governmental organizations (NGOs), donor agencies and farmers' groups. Some of these initiatives include:

- The National Erosion Control Programme (NECP), launched in 1986 by the Federal Ministry of Agriculture to address the problem of gully erosion in southeastern Nigeria.
- The National Special Programme for Food Security (NSPFS), launched in 2002 by the Federal Ministry of Agriculture in collaboration with the Food and Agriculture Organization (FAO) to improve food production and rural livelihoods through integrated land and water management.
- The Sustainable Land Management Project (SLMP), launched in 2009 by the Federal Ministry of Environment in collaboration with the World Bank to combat land degradation and desertification in northern Nigeria.
- The International Institute of Tropical Agriculture (IITA), established in 1967 as a research center for tropical agriculture with a focus on improving crop production and natural resource management in sub-Saharan Africa.

2.1 Role of IITA in Soil Conservation Research

IITA has been one of the leading institutions in conducting research on soil conservation in Nigeria and other African countries. IITA has developed and evaluated various technologies for soil conservation, such as:

• Mulching with organic materials such as crop residues, grasses or legumes to conserve soil moisture, suppress weeds, improve soil fertility and reduce erosion.

• Cover cropping with legumes such as mucuna or lablab to provide mulch material, fix nitrogen, smother weeds and improve soil structure.

• Conservation tillage with minimum or zero tillage to reduce soil disturbance, maintain crop residues on the surface, enhance water infiltration and retention and reduce runoff and erosion.

• Agroforestry with woody perennials such as shrubs or trees to provide mulch material, shade, fodder or timber while improving soil fertility, water balance and microclimate.

IITA has also conducted socio-economic studies on the adoption and impact of soil conservation technologies among farmers. Some of the factors that influence adoption include availability, affordability, profitability, compatibility, simplicity and observability of the technologies. Some of the impacts include increased crop yield and quality, reduced labour and input costs, improved food security and income generation.

Some of the papers published by IITA on soil conservation research include:

- Abaidoo *et al.* (2000). Rotation effects of grain legumes and fallow on maize yield nutrient uptake dynamics of weeds.
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Soil conservation is an important issue for Nigeria's agriculture and environment. Mulching is one of the effective measures for soil conservation that can provide multiple benefits for crop production and soil health. Soil conservation has a long tradition in Nigeria but also faces some challenges that need to be addressed. IITA has played a significant role in developing and promoting soil conservation technologies through research and extension activities. The Federal Government of Nigeria, which had budgeted roughly half a million US dollars for soil erosion projects around the nation in 2007, acknowledged the significance of this environmental problem even in modern times (Junge *et al.*, 2011a).

3.0 GLOBAL TRENDS IN MULCHING TECHNOLOGY

The word mulch was probably derived from the German word "*molsch*" meaning soft to decay, which apparently referred to the use of straw and leaves by gardeners as a spread over the ground as mulch (Jacks *et al.,*1955). Mulches are used for various reasons in agriculture but water conservation and erosion control are the most important objectives particularly in arid and semi-arid regions. Mulching is the process or practice of covering the soil/ground to make more favourable conditions for plant growth, development and efficient crop production. Mulch technical term means 'covering of soil'. While natural mulches such as leaf, straw, dead leaves and compost have been used for centuries, during the last 60 years the advent of synthetic materials has altered the methods and benefits of mulching. The research as well as field data available on effect of synthetic mulches make a vast volume of useful literature.

3.1 Plastic Mulch Covers

In comparison to bare soil, plastic covers used as mulch material improve soil warming and boost seed germination, vegetative growth, and root development of seedlings. The development of weeds is stopped, and labour costs are decreased, by the plastic mulch layer. With this inorganic mulch cover, the soil surface does not dry up or develop a cream layer. The plastic mulch covers prevent water from the soil top from evaporating, provide water savings, and hence maintain soil moisture (Figure 1). Bajad *et al.* (2017) in a study titled 'The effect of different planting times and mulching materials on flower quality' conducted in China, M0-no mulch, M1-Black plastic mulch, M2-Silver plastic mulch, M3-Clear plastic mulch, M4- Pine needle cover and M5- Grass cover materials were used. Plant height (84.48 cm), plant width (48.39 cm), number of flowers per plant (47.89), flowering time (51.53 days), flower diameter (4.73 cm), fresh weight (291.67 g), flower yield per plant (134.73g), the best results were obtained with the use of silver plastic mulch. Xiao-Yan *et al.* (2000) in semi-arid regions of China; in their studies on corn plant, they followed the soil moisture and water use efficiency by applying gravel mulching and plastic mulch combinations on the ridges and furrows. On bare ridges, the average runoff efficiency is 7%; The runoff efficiency on the ridges covered with plastic cover was 87%. In terms of soil moisture retention, plastic-covered ridges and gravel-covered furrows outperformed bare ridges and furrows (Xiao-Yan *et al*., 2001). Ridges and furrows were used in conjunction with plastic mulching and rainwater in the cultivation of maize under semi-arid conditions. In the plastic-covered ridges and furrows, the yield of maize increased by 4.010 to 5.297 kg/ha in comparison to the control subject.

Figure 1**.** Use of Black Plastic Cover in Strawberry Cultivation
Source: Kuzucu (2021)

In addition to these advantageous applications, plastic coverings have also been utilised successfully in soil moisture conservation initiatives to boost agricultural output effectiveness. By directing runoff into the plant root zone, they were tested to lessen the negative impacts of dryness in plants growing in dry environments (Figure 2) (Calik, 2020). In Nigeria and most sub-Saharan African countries, plastic covers are rarely used to collect and conserve rainwater. When using plastic mulch, exposed soil is not only protected from weed damage and sediment loss from the surface. Mulch covers are practical tools for preventing soil erosion and promoting plant growth by preserving soil moisture. Yuan *et al.* (2003) looked at how varying ridge and furrow widths and combinations of bare and plastic mulch cover applications affected the productivity of potatoes in semi-arid regions. The application of plastic mulch with a 0.45 m ridge and 0.60 m furrow, fed only by rainwater, resulted in the study's maximum potato output. Very effective soil moisture conservation has been accomplished with the help of this technique.

Figure 2. Plastic Mulch Cover for Rainwater Containment
Source: Kuzucu (2021)

A plastic mulch cover was utilised to keep soil moisture in a sloping vegetable farm that was built in dry conditions in order to promote the growth and development of new plants. An image of a farm's rainwater harvest is shown (Figure 2), where plastic cover was utilised to boost runoff and store rainfall in the root zone of the plants. Plastic mulch coverings are the most popular mulch cover in many industrialised nations, and they provide the best results in preventing erosion. Utilising plastic mulch cover, numerous experiments on stormwater containment have been carried out. In semi-arid and loess plateaus of China, Feng-min *et al.* (2004) examined the effects of pre-sowing irrigation, plastic film application, and mulch treatment on yield in summer wheat. The plots with plastic mulch covers produced the highest grain yield. Xiao-Yan *et al.* (2006), in their study on the development of the Tamarix tree in semi-arid loess soils in China between 2002 and 2004, examined the effects of rainwater storage on soil moisture and plant growth. The trial's test groups included controls, embankments, plastic mulch, bare ridges and furrows, ridges and furrows covered in plastic, and ridges and furrows coated in gravel. The combination of the plastic-covered ridge and the gravel-covered furrow resulted in higher soil moisture retention (18–137 mm more) than the control. In terms of plant growth metrics, mulch applications boosted height by 70%, crown diameter by 57%, and trunk circumference by 79% when compared to control. According to the results of many studies; Yuan *et al.* (2003), Feng-Min *et al.* (2004), Xiao-Yan *et al.* (2006) and Hira *et al.* (1990), reported that by reducing evaporation with plastic cover applications, the need for water of the plant is partially met and water saving can be achieved.

3.2 Stone – Gravel Mulch Covers

Stone and gravel mulch covers act as a protective layer over the soil's surface, offer shading, and maintain soil moisture. Particularly in sloped sites, stone coverings provide good soil and containment. Studies have shown that stone mulch covers reduce the amount of silt that is lost from the soil's surface. It should be highlighted that these stone mulch covers offer great protection and can be utilised to reduce erosion (Fig. 3). Figure 3 contains images from rain water collecting studies carried out in orchards where the plant's root zone was covered in stone mulch and runoff water was collected there. Projects designed to capture rainwater in the soil have successfully utilised a variety of stone mulch covers. Although stone and gravel mulch covers can effectively prevent erosion, they are not very good at controlling weeds. Although scarce, there are holes between the stones, and weeds are sprouting up in them. Xiao-Yan *et al.* (2008) tracked the growth and development of the shrub Caragana korshinskii under dry conditions using a plastic and gravel mulch cover to collect rainwater from the slopes. Combinations of plastic cover and gravel cover effectively held precipitation in the soil relative to the control in semi-arid parts of China, and the plant took advantage of this to demonstrate good development.

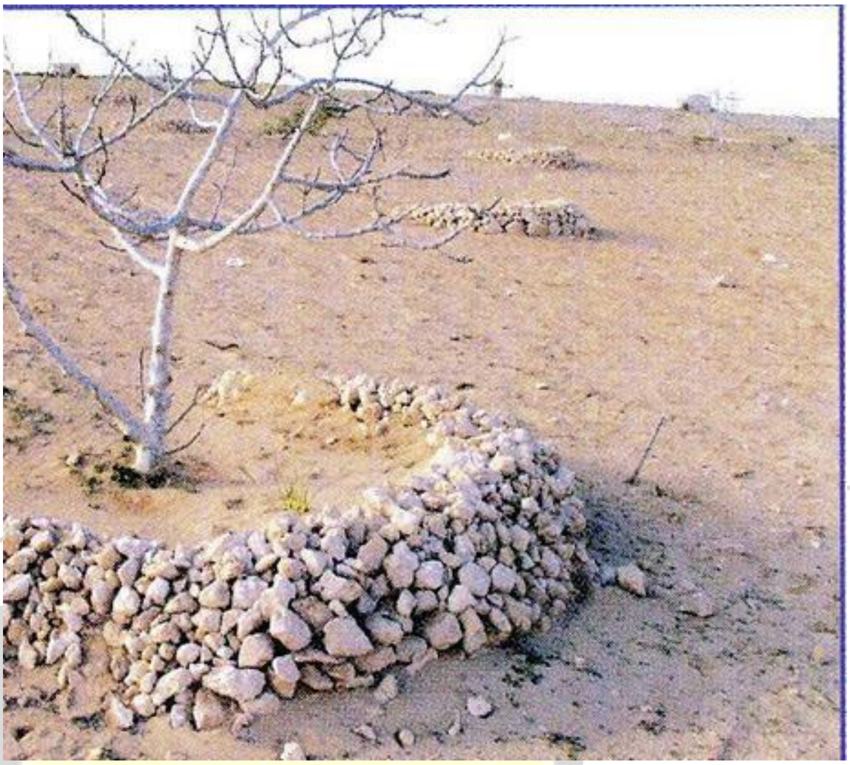

Figure 3. Stone Mulch Cover for Rainwater Containment for Fruit Trees
Source: Kuzucu (2021)

Sometimes, stone and gravel mulch covers can be designed in various ways to reduce the slope in the direction of the slope of the land, the purpose of these applications; collecting rain water, giving it to the plant and at the same time stopping the flow of precipitation that may cause erosion. Figueiredo *et al.* (1998), reported that stone mulch cover increases infiltration, while reducing soil losses caused by runoff and leaching and splashing. Wang *et al.* (2011), investigated the effects of pebble-stone mulch, plastic mulch, rainwater harvesting at different rates of furrows and ridges on watermelon yield and water use efficiency in the semi-arid region of China. In the research, the highest yield was obtained in the subject where the ridge: furrow and ridges are covered with plastic cover and the furrows are covered with stones and gravel in the ratio of 1:1. In the study, it was determined that evaporation decreased by 56-58% with the application of stone and gravel mulch, by 74% with the application of plastic mulch, and the surface flow efficiency was also increased.

Stone and gravel mulch covers can be used successfully for fruit trees and ornamental plants in arid areas with insufficient rainfall. It has been reported by many studies that stone mulch covers provide soil erosion control. Serpantie *et al.* (1992), in the study they carried out in the North Yatenga Region of Burkina Faso, in arable arable land, in wooded areas leveled with stone banks, in order to preserve rainwater in the soil, the highest soil moisture storage was obtained from the application of a 20% sloped stone bank. has been done. As a result of the same application; tree height increased by 70%. The amount of product increased from 1.69 tons/ha to 6.39 tons/ha. Subjects covered with mulch produced the best results compared to the control subject. The use of a one-inch layer in stone mulch covers using pebbles, pebbles, crushed stones provides great success in controlling weeds (Sanders, 2001). Stone mulch covers are successfully applicable and inexpensive materials for water and soil erosion control on sloping lands. Since the flowing water and the sediments carried by the water can stop between the stones, they provide good erosion control in areas with bare surfaces (Kuzucu, 2013 and Poesen, 1999). Taysun (1986) in laboratory conditions, compared the straw mulch, PVA and stone cover applied on the erosion plots placed on 9% slope for erosion control, and it was determined that the stone cover mulch was more successful in erosion control.

3.3 Straw – Straw Mulch Covers

In fields, vegetable gardens, orchards, greenhouses, and under trees, grain straw and straw or stubble mulch covers are utilised. They quickly disintegrate after starting to decay and mixing with the soil. They enhance the soil's physical composition. Particularly in arid agricultural settings, straw mulch covers keep natural rainwater from evaporating from the soil surface (Figure 4). This mulch cover application uses organic materials, which degrade over time and require replacement. Straw straw mulch is an effective mulch for weed control, soil moisture retention, and erosion prevention. By keeping the soil temperature constant, this mulch cover also boosts microbial activity. The plant is shielded from excessive heat and cold by it.

Figure 4. Straw-Straw Mulch Cover
Source: Kuzucu (2021)

Orzolek and Lamont (2015), reported that stubble and straw covers had insufficient nutrient content. Wang *et al.* (2008), used storm water conservation and mulching techniques in corn cultivation in the semi-arid and loess plateaus of China. With the plastic mulch, sand-gravel mulch and straw mulch used, higher yields were obtained compared to the control issue. Especially since evaporation is minimized with mulch covers, irrigation water is saved. The study's findings indicated that before beginning the application, producers should consider the economics of using these mulch covers. Saucke and Doring (2004) when straw mulch was utilised to cultivate potatoes, less weed growth and aphid damage to the plant were seen. Straw mulch has been shown to limit the spread of viruses in organic seed potato farming, while it hasn't been shown to increase yield. However, when applied to regions with an 8% slope during a rain simulation, straw mulch has been shown to minimise erosion by 97% when compared to bare ground, (Doring *et al.,* 2005).

3.4 Tree Bark, Plant Waste Mulch

Wood shavings are a good mulch layer that may be utilised in landscaping and crop production. It takes a while for it to disintegrate, and occasionally it might even make fungi more active. In addition to coverings that take a while to decompose, dry leaves, bark, and ground-dry pruning leftovers can be employed at the base of perennial plants. Jayawardana *et al.* (2019)

looked at the effects of several natural and synthetic mulching materials on weed control. Synthetic canopy, polyethylenes, and palm empty fruit bundles were used as synthetic mulch covers and contrasted with the control issue. In comparison to control, all mulch applications offered weed control and lower labour expenses. The mulch cover made of palm fruit bunches provided good weed control, prevented environmental pollution as it is a natural waste material and was successful.

Long-term soil moisture retention is achieved with mulch made from tree bark. Because of its attractive appearance, it is utilised in landscaping as a natural plant. Tree bark can be utilised all year round as a mulch covering in gardens and parks. Under natural circumstances, mulch can be made from sawdust, leaves, bark, and pruning waste (The Royal Horticulture Society, 2008). Dry leaves can be found in native forest regions and used as mulch; they have been shown to add nutrients to the soil when they decompose at the surface (David, 2007).

3.5 Paper, Cardboard and Newspaper Mulch

This type of mulch, like other covers, preserves the soil water, meets the water need of the main product and provides weed control. They are applied by laying on the soil surface at a determined thickness and can be renewed as they rot (Figure 5). Newspaper mulch cover controls weeds in its use; It reduces labor costs, saves time in crop production and is biodegradable over time, beneficially used in vegetable gardens (Ashriif and Thornton, 1965 and Lal, 1974). Ojasvi *et al.* (1999), in their water harvesting studies on jujuba trees under arid conditions in India; They covered the surfaces of the micro-basin with different waste materials such as marble pieces, stone and paper. As a result of the two-year study, the effects of these practices on the cultivation of jujuba trees were found to be significant. Covered micro-catchments retained higher soil moisture than the control subject. The plant height of the subjects covered with stone and marble pieces was 40-48% higher than the control subjects.

Figure 5. Paper and Cardboard Mulch
Source: Kuzucu (2021)

3.6 Surface Coating Processes

Another type of covering method in dry locations involves making the surface impervious. They are used to guide rain that falls in dry areas to the plant by limiting evaporation from the surface. At the soil surface, these applications reduce soil and water erosion (Figure 6). For proper runoff and to keep precipitation in the soil, paraffin was applied to the microbasin's surface. It is a programme developed at the Turkish-based ICARDA (International Centre for Agricultural Research in the Dry Areas).

Figure 6. Paraffin Application Providing Impermeability on the Soil Surface
Source: Kuzucu (2021)

It is formed by surrounding the lozenge-shaped parcels (negarim-type microcatchments) created to collect rainwater with earthen banks. Plants are planted in the lower part of these micro-catchments in the direction of slope (Figure 6). In light textured soils with high permeability, surface hardening paraffin and similar applications are applied around the trees to keep the rain water in the plant root zone. This application is used in arid areas where the slope is 1–5% and the annual precipitation is around 100–400 mm. The main purpose here is to combat drought by increasing plant production, and to rehabilitate abandoned and poorly productive areas. However, these local water conservation practices have been reported to have been successful at low cost and have been accepted by local farmers and agronomists (Critchley *et al.* 1992).

3.7 Surface Compaction Operations

It is necessary to collect the limited amount of precipitation falling in areas with insufficient precipitation and to preserve it in the soil profile. In the Negarim microcatchment technique, the surface compaction application parcel prepared to deliver rain water to the plant root zone and to maintain soil moisture is given (Figure 7). Xiao-Yan and Jia-Dong (2002), conducted low-cost micro-catchment applications under economic conditions in the semi-arid regions of Southwest China, in areas with volcanic soils. The efficiency of precipitation-runoff efficiency was determined under natural precipitation conditions on the compacted soil surface. In the study, the surface compacted basins; It was prepared from a mixture of fine sand, laterite and loess in 1:1:1 ratios in a uniform manner. While the runoff efficiency of the total rain was 33% in the compacted plots, it was 8.7% in the untreated control plots. Compacted surfaces have a low infiltration rate and show great potential for rainwater transmission. However, in areas where soil erosion is seen as a problem, it has been reported that the application of surface compaction for erosion control is not very successful. It has been observed that the compressed surfaces are deteriorated and transported by erosion in heavy rains. Contour ridges are levees built in sloping and arid areas. The part above the ridges is vegetative production, the rest is mostly by surface compaction or supported by mulch covers, accumulating rainwater and directing it to the planted area.

With this process, while soil moisture is maintained, agricultural production is supported at the same time. Wang *et al.* (2007), investigated the effects of rainwater harvesting in ridges and furrows on runoff efficiency and potato yield in the arid region of China. Soil moisture was provided in the potato production area by applying surface compaction on the ridges, plastic mulch cover and flat sowing. The average runoff efficiency was 91-94.3% for plastic film covered ridges and 24.6-28.8% for compressed ridges. Tuber yield in plastic ridges increased by 158-176% compared to control, while potato yield increased by 14.9%-28.4 percent with surface compaction application compared to control. With the application of plastic mulch cover and surface compaction, soil moisture retention was significantly higher than the control.

Figure 7. Soil Surface Compaction and Contoured Ridges
Source: Kuzucu (2021)

With surface compaction applications, soil moisture is maintained while weed control is also ensured. Oweis and Taimeh (1994), compared three different practices for soil water conservation in agricultural holdings located in arid regions of Syria. Plots with plastic cover and surface compaction applications retained soil water more successfully than plots without mulch cover and without surface compaction. Calik (2020b), climate characteristics are the most important determinant of the products to be grown in a region. Lack of precipitation and drought cause low productivity in areas where irrigation is not available and cause economic damage. For this reason, the controlled and recyclable use of water should be supported by training our farmers on practices such as the reuse of wastewater, directing producers to modern irrigation techniques, and the use of rain water that saves water (Gunes, 2018). Kuzucu (2013) compared traditional practice (control), plastic mulch, stone mulch, straw-straw mulch covers and surface compaction applications for pistachio trees under dry conditions in order to collect rainwater, accumulate it in the soil and provide erosion control. In this study, water conservation and yield success were plastic mulch, straw-straw mulch, surface compaction, stone mulch and conventional application, respectively.

Plastic mulch and stone mulch cover have been successful in erosion control. In this garden, which has a 6% slope, the sediments carried by the surface flow were stopped by hitting the stones in the stone mulch application. Stone mulch, which was found to be very successful in erosion control, was determined as the most economical mulch cover. While weed control was achieved well in plastic mulch, straw-straw mulch and surface compaction applications, weed problems were experienced in the parcels covered with stone mulch. The mulch covers in this study, in which the advantages and disadvantages of each of the mulch covers were determined, were found to be more successful than the traditional application in all aspects.

4.0 EFFECT OF MULCHING ON SOIL AND WATER CONSERVATION

4.1 Mulching in improvement of soil health: Knowledge of the physical properties of soil is essential for defining and/or improving soil health to achieve optimal productivity for each soil/climatic condition. This envisages that for increasing crop production, soil must be maintained in such a physical condition so as to allow adequate crop growth. Unless the soil physical environment is maintained at its optimum level, the genetic yield potential of a crop cannot be realized even when all the other requirements are fulfilled. No doubt, if these soils are managed properly for good physical health, the yield potential of different crops can be increased significantly.

4.2 Soil temperature: Soil temperature under plastic film is usually higher and also it is based on the color of the plastic mulches. The black plastic-film mulched plots had significantly lower soil temperature (1 to 2.8^0 C) than the clear plastic-film mulched plots. Because much of the solar energy absorbed by black plastic-film mulch is lost to the atmosphere through radiation and forced convection (Schales and Sheldrake,1963). Anikwe *et al*., (2007) observed that the unmulched plots had the lowest soil temperature (about 1-3.8^0 C lower) at different times since planting compared to plastic film mulched plots. Among different mulching techniques plastic film mulching increases soil surface temperature by influencing the heat balance and thus increased the soil temperature and it also positively influenced the crop emergence (Aniekwe *et al*., 2004).

4.3 Soil water content

The black polyethylene mulch maintained high soil water contents compared to the control (no mulch) and the bare soil treatments (Li *et al*., 2001). Improvement of the water use efficiency by better utilization of soil water appears to be the best way to increase grain yield in the semiarid areas (Zhao *et al*., 1995). The main methods of increasing the water use efficiency include reducing soil water evaporation, and exploiting deep soil water so as to support shoot biomass accumulation and optimize the dry matter allocation by selectively increasing the reproduction (Li *et al*., 1997, 2000; Li and Zhao, 1997). The plastic film mulch was promoted root growth and that more roots were distributed in mid- and deep-soil, so that the plant can uptake water from the deep soil and increase the grain yield (Kwabiah, 2004).

4.4 Nutrient availability

The decomposition of organic residues under plastic mulch adds organic acids to the soil resulting in low soil pH, which may increases the bioavailability of micronutrients (Mn, Zn, Cu, and Fe). This was also evident from the increased Fe and Zn content in soil under plastic mulch (Tisdale *et al*., 1990). The mineral N content (NO3 and NH4+) in soil is high due to mineralization of organic N with time, thereby; it increases the availability of soil nitrogen. Breakdown of organic material release soluble nutrients like NO_3, NH^{4+}, Ca^{2+}, Mg^2+, K+ and fulvic acid to the soil intern increases the soil nutrient availability under plastic mulch.

4.5 Crop growth parameters

Plastic mulch induces the early crop emergence, so that it increased the biomass production at early stages of the crop growth. Li *et al.* (1999) reported that plastic film mulching leads to earlier seedling emergence and earlier spike differentiation, which help to develop more spikelets and more grains per spike in wheat. The improvement in soil moisture and topsoil temperature under plastic mulch hastened seedling emergence by 8 days on average in wheat. Plants in mulching treatments entered the maturation phase sooner and their maturation period was longer. This change is favorable to partition assimilate that is stored in vegetative organs, thus facilitating development of the reproductive organs of wheat plants. It increases the duration of reproductive period so the yield will be maximized (Li *et al*., 2004).

4.6 Effect of mulching on weed control

The principal aim of mulching is to cut off the light to the weeds and to suppress their growth. Mulching is a beneficial practice for weed control that can also improve crop production and soil health. Mulching can reduce weed seed germination, shade and hinder emerging weeds, enhance crop growth and competitiveness, and reduce herbicide or cultivation needs. Mulching is a practice that can help reduce weed problems by covering the soil surface with organic or inorganic materials. Mulching can provide several benefits for weed control, such as reducing weed seed germination by depriving them of light and oxygen, shading and physically hindering emerging weeds by creating a barrier between them and the crop (Junge *et al.* 2011b).

4.7 Biodegradable mulches

Carrubba and Militello (2013) presented some environmentally friendly techniques for weed management, which proved to be efficient to increase seed yields of coriander, fennel and psyllium. Although biodegradable films used in experiment positively affected yields, they were not capable to suppress weeds. Organic agriculture also uses some degradable inorganic materials, such as gravel, which has been used as mulch from almost forty years now (Fairborn, 1973). Besides the thickness of this mulch, the gravel different grain size is also examined (Qiu *et al*., 2014). Wang *et al*. (2014) investigated implementation of gravel-sand mulches in watermelon production and reported how it influences the soil temperature. There are reports on application of many other organic mulches, such as composted pine bark in Allium aflatunense (Laskowska *et al*., 2012) or pine bark mulch in Salvia splendens (Blażewicz-Woźniak *et al*., 2011). Sawdust was recommended as effective mulch for acid-loving plants, such as calla (Wright and Burge, 2010) or blueberries (Haynes and Swift, 1986). Straw and other organic mulches, similarly to composting process, decompose over time through mineralization process, thus forming humus. Apart from its primary use as organic fertilizers, compost positively contribute to the soil structure and is frequently used for production of various substrates and mulches (Matković *et al*., 2015).

4.8 Non-biodegradable film mulches

Different polypropylene (PP) black films were tested for efficiency in weed control and the results proved significant increase in the plants height (Fontana *et al*., 2006). Normally, black and other film colours are used in a cultivation of strawberry and watermelon, since they need higher soil temperatures for attaining desired sweetness. Polara and Viradiya (2013) presented superior yield and quality features of watermelon produced on silverblack PE film, although it is quite known that conventional PE films create a big trouble to the environmental. With regard to this, Costa *et al*. (2014) compared efficacy of PE film with five biodegradable films and proved no significant differences in productivity and quality of strawberry.

The influence of different mulch types on crop yield might be positive or negative, related totheir weed suppression effect. Many researchers proved positive effects of mulching on crop growth and the obtained yield quantities and qualities (Ramakrishna *et al*., 2005). Regardless the colour, nonbiodegradable PP and PE films mulches proved to be the most efficient in preventing of germination of seeds of the most weeds and their further growth, though they are also helpful in preventing loss of the moisture from the soil and in balancing of its temperature (Momirović *et al*., 2010). Their application frequently bring about many other benefits, such as reduction of the run-offs, increase in rain water penetration, control of erosion, correction of the chemical balance of the soil and reduction of pest and disease damages. However, they also have some environmental disadvantages, related to the removal and handling of their waste (Briassoulis, 2006).

4.9 Mulches and insect pest and disease management

Polyethylene mulches have been used to potential decrease in insect and disease pests (Lamont, 1993). The influence of mulches on plant microclimate and energy balance is a function of transmittance, absorbance, and reflectance of solar radiation (Ham *et al*., 1993; Lamont, 2005; Tarara, 2000). Host-seeking behavior of thrips can be disrupted by incorporating ultraviolet reflectance, thereby reducing thrips numbers on and around host plants (Brown and Brown, 1992; Kirk, 1997; Kring and Schuster, 1992; Scott *et al*., 1989; Stavisky *et al*., 2002). The use of highly ultraviolet-reflective aluminized mulch as a bed covering provides this reflectance to disrupt initial flights of thrips into a field (Brown and Brown, 1992; Kring and Schuster, 1992; Scott *et al*., 1989).

5.0 ADOPTION OF TRENDING MULCH TECHNOLOGIES IN NIGERIA: WAY FORWARD

In Nigeria, mulching has been traditionally practiced by farmers using locally available materials such as crop residues, grasses, leaves and stones. However, these materials are often scarce, decompose rapidly or compete with livestock feed. Therefore, alternative sources of mulch have been explored, such as cut-and-carry systems and alley cropping systems.

Cut-and-carry systems involve growing perennial grasses or legumes on separate plots and transporting them to the crop fields for mulching. This system can provide large amounts of mulch material, but it also requires high labour input, land allocation and transportation costs.

Moreover, the cut-and-carry system may not be sustainable in the long term due to soil nutrient depletion and erosion on the mulch source plots.

Alley cropping systems involve growing woody perennials such as shrubs or trees in rows or hedges and pruning them periodically to provide mulch material for the intercropped crops. This system can provide multiple benefits such as soil fertility improvement, erosion control, microclimate modification and additional income from timber or fodder. However, alley cropping systems also have some drawbacks, such as high labour demand for pruning and weeding, competition for light, water and nutrients between the woody perennials and the crops, and slow decomposition of some mulch materials.

Another alternative source of mulch is plastic film, which is widely used in many countries for crop production. Plastic film can provide several advantages over organic mulches, such as higher soil temperature, lower weed pressure, higher crop yield and quality, and more efficient use of soil nutrients. However, plastic film also has some disadvantages, such as high cost, non-biodegradability, disposal problems and environmental pollution.

5.1 Challenges of Adoption of Trending Mulch Technologies in Nigeria

The adoption of trending mulch technologies in Nigeria faces several challenges that need to be addressed. Some of these challenges are:

- Lack of awareness and knowledge among farmers about the benefits and methods of using different types of mulches.
- Lack of availability and accessibility of suitable mulch materials or plastic films in local markets or from extension services.
- Lack of affordability and profitability of using mulch technologies due to high initial investment, maintenance and disposal costs.
- Lack of appropriate machinery and equipment for applying and removing plastic films or organic mulches.
- Lack of supportive policies and incentives from the government and other stakeholders to promote the use of mulch technologies.
- Lack of research and development on the adaptation and improvement of mulch technologies to suit local conditions and preferences.

5.2 Way Forward to Ensure Adoption of Modern and Trending Mulching Technologies in Nigeria

To ensure the adoption of modern and trending mulching technologies in Nigeria, the following actions are suggested:

- Conduct awareness campaigns and training programs for farmers on the benefits and methods of using different types of mulches.
- Establish demonstration plots and farmer field schools to showcase the performance and profitability of various mulch technologies.
- Facilitate the supply and distribution of suitable mulch materials or plastic films at affordable prices through cooperatives, agro-dealers or extension services.
- Provide subsidies, credits or grants to farmers to purchase or rent machinery and equipment for applying and removing plastic films or organic mulches.

- Develop and implement policies and regulations that encourage the use of mulch technologies and discourage the use of non-biodegradable plastic films.
- Support research and innovation on the development and evaluation of new types of biodegradable plastic films or organic mulches that are compatible with local crops, soils and climates.

Mulching is a beneficial practice for crop production in Nigeria, but it also faces some challenges that limit its adoption. Different types of mulch technologies have been developed to overcome these challenges, such as cut-and-carry systems, alley cropping systems and plastic films. However, these technologies also have some drawbacks that need to be addressed. To ensure the adoption of modern and trending mulching technologies in Nigeria, a combination of technical, economic, social and policy interventions is required.

6.0 CONCLUSION

In the present scenario of globalization and health consciousness demand for horticultural crops has increased world over. Under plastic mulch, soil properties like soil temperature, moisture content, bulk density, aggregate stability and nutrient availability improved. Plant growth and yield are also positively influenced by the plastic mulch due to the modification of soil microclimate. Even though it has many advantages, high initial cost, removal and disposal of plastic materials are some of the limitations experienced by the farmers. To overcome these limitations photo and biodegradable plastic mulches can be effectively used for sustaining the productivity as well as controlling environmental pollution due to the use of plastics.

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OVERVIEW OF TILLAGE PROCESSES INVOLVED IN NIGERIA RICE PRODUCTION USING SAWAH ECO-TECHNOLOGY SYSTEM

[1]Ademiluyi, Y. S., O. A. Oyelade[1], O. T. Dada-Joel[1], U. C. Onyemize[1], O. N. Okoro[1], K. C. Eneh[1], J. A. Oyedokun[1], S. C. Obiakor[1], T. Wakatsuki[2] and A. R. Kamal[1]
[1.] National Centre for Agricultural Mechanization (NCAM), Ilorin, Kwara State.
2. Shimane University, Matsue, Japan

ABSTRACT
Tillage is considered as a unique process that is needed for the optimum performance of rice production in Nigeria using Sawah eco-technology system. Sawah eco-technology involves man-made improved rice fields with demarcated bunded, puddled and levelled rice fields with water inlets and water outlets which if possible can be connected to various irrigation facilities such as canals, ponds, dykes and springs. This system coupled with the use of agro-chemical input and high yielding varieties improves rice farming. It is the basic infrastructure without which other components for achieving rice green revolution becomes meaningless. The traditional system used for rice production in Nigeria which is bedeviled with low productivity and poor tillage practice can no longer meet the demand of the teeming population who loves eating rice. The main tillage processes involved in Sawah eco-technology in this study include bunding, ploughing, harrowing, puddling and levelling. The specialized tillage operation involved in this system include furrow opening and poldering. Despite the contribution of Sawah eco-technology to rice farming in Nigeria, one of the salient factors retarding the ease of disseminating and adopting the technology in Nigeria and other sub-Saharan African countries is the poverty level among our rice farmers. For Nigeria to retain her position as the leading producer of rice in Africa, the Sawah eco-technology system needs to be promoted in Nigeria as it entails optimum application of machinery for the management of the soil nutrient and water leading to a remarkable yield increment as a result of its adoption in different localities in Nigeria. NCAM played a foundational role in Kebbi State rice revolution, the previous administration played a pivotal role by the launching of Anchor Borrowers Progrmme. This paper strongly recommend among others that other state governments in Nigeria should borrow a leaf from Kebbi State government who worked in collaboration with the Federal Government team led by NCAM in providing an enabling environment for the spread and adoption of the technology by the State farmers.

Keywords: tillage, sawah, eco-technology, rice, production, processes

1. INTRODUCTION
Rice is the only cereal that is grown across most regions in the world (Isiaka et al., 2008). Rice is one of the three most staple food among maize and cassava in Sub-Sahara Africa (Naoyoshi, 2011) where its consumption keeps increasing due to population growth, urbanization and change in consumer habits. Research into sustainable rice production has thus evolved to satisfy its increasing consumption**.**

Nigeria is the leading consumer and largest producer of rice in Africa, however, it is one of the largest rice importers in the world. Many years back, Imolehin and Wada (2000) noted that rice in terms of area of land under food crop production in the country, rice ranks sixth after sorghum, millet, cowpea, cassava and yam. According to Ojehomon et al. (2009), farmers term rice both a food and a cash crop which contributes to smallholders revenues in the main producing areas of Nigeria. Out of a total land area of 70 million hectares available for land cultivation in Nigeria, rice is grown on approximately 3.7 million hectares representing 10.6% of the 35 million hectares of land under cultivation. Seventy seven percent (77%) of the farmed area of rice is rain-fed out of which 47% is lowland while 30% is upland.

The term sawah according to Wakatsuki et al. (2009) is a man-made, improved rice-growing environment with demarcated, bunded, leveled and puddle fields, for water control. Sawah is soil based eco-technology. In a simpler form the term Sawah refers to leveled, bunded and puddled rice field with water inlet and outlet to control water and manage soil fertility, which may be connecting irrigation and drainage facilities including Sawah to Sawah irrigation and drainage. Thus to effectively apply these scientific technologies, farmers have to develop typical sawah or similar alternatives which can conserve soil properties and control water.

Sawah eco-technology involves man-made improved rice fields with demarcated bunded, puddled and levelled rice fields with water inlets and water outlets which if possible can be connected to various irrigation facilities such as canals, ponds, dykes and springs (Oladele and Wakatsuki, 2011) alongside agro-chemical input and high yielding varieties (Wakatsuki et al., 2011). Thus, the three sawah inputs namely, demarcated bunded, puddled and levelled rice fields coupled with agro-chemical input and high yielding varieties has improved yield output of government institutions such as NCAM, FADAMA, ADP, APPEALS and CADP where we have an output ranging from 4 to 8 ton/ha compared to the local farmers field output which ranged from 1 to 3 tons/ha. Sawah eco-technology was seen as an adoptable and sustainable platform for intensive rice production.

The three essential components of sawah are (i) the demarcation of field by bunding which is based on topography, hydrology and soil. This may be achieved by attaching a mouldboard to the power tiller or tractor for the creation of demarcations and bunds; (ii) puddling is an operation that is achieved through attaching a puddler to a power tiller or tractor for preparing the soil for easy acceptance of rice seedling when transplanted; and (iii) controlled water management by creating room for the inflow and outflow of water.

The previous administration has done so much on rice production in Nigeria through the launching of the Anchors Borrowers Programme where the Sawah eco-technology system used for rice production was first demonstrated in Kebbi State. This paper tends to discuss on the tillage processes involved in Nigeria rice production using Sawah eco-technology system.

2. TILLAGE PROCESSES INVOLVED UNDER SAWAH PRODUCTION

Sustainable personal or co-operative irrigated fields for rice production usually encourage small scale, sustainable machinery which in most times involves the single axle tractor or the power tiller. Most farm implement can be coupled to the power tiller for tillage operations in lowland and upland fields. However, lowland field is much preferred due to soil fertility and water availability. The power tiller is driven using the cage wheel to avoid mechanical hindrance in the soil.

Land preparation starts with the complete removal of all vegetation which may be buried completely to avoid re-growth through pulverization of the soil to destroy soil lump for proper levelling off the field. Some of the activities that take place during sawah rice field preparation include bunding, sloughing, harrowing, puddling and levelling,

2.1 Bunding

This is the demarcation of fields into basins with the assistance of field topography by taking advantage of gradient variations to group closely related portions. Standard bunds should be of 50 cm width by 50 cm height using a moldboard severally in vertical motion to achieve good bunds. However, standard bunds are created for major sawah demarcation while small bunds are created for sub-sawah demarcations. Furthermore, the creation of bunds creates canals and drainages in the sawah field. It is also constructed to submerge the field for easy levelling. Fig. 1 shows the picture of bunding operation carried out during rice farming at Lake Chad basin.

Fig. 1. Picture of bunding operation during rice farming at Lake Chad basin

2.2 Ploughing

The objectives of this activity are to bury the previous vegetation, loosen, overturn and aerate the soil, and bring leached nutrients back to the surface. Ploughing should be done 2 to 4 weeks before sowing or planting so as to give time for vegetation to rot and the acids to be neutralized. Land preparation is tedious and so it is frequently mechanized. Ploughing operation are encouraged in virgin land operations to further soften the soil for further tillage operation. Ploughing should be done at about 10 cm to 20 cm depth of top soil without water. Fig. 2 shows the picture of ploughing operation carried out during rice farming at Lake Chad basin.

Fig. 2. Picture of ploughing operation during rice farming at Lake Chad basin

2.3 Harrowing

Harrowing is the process of breaking up clods and smoothening of the soil that is suitable for planting seeds. It can be done in dry or wet conditions after rain or irrigation. Harrowing should be done with hoes, ox-driven harrows in water or tractor-disk harrows. It should be done until all debris are completely buried. Fig. 3 shows the picture of harrowing operation carried out during rice farming at Lake Chad basin.

Fig. 3. Picture of harrowing operation during rice farming at Lake Chad basin

2.4 Puddling

Puddling is the process of further making the soil softer after harrowing. It serves to soften the soil for transplanting only under flooded conditions, creates a semi-hard pan for reducing percolation and help make levelling easier. Puddled fields should not be allowed to stand for long before sowing or transplanting. Puddling could be done when the field is flooded, by foot, with the use of cattle, hoes, cage wheels and rotavators or by repeated wet harrowing. Puddling should be done a day to planting or sowing. Puddling operation involves attaching puddlers to the power tiller to further till the soil when submerged in water to create a slurry mixture of soil and water that is best suited for transplanting rice seedlings. The puddling operation prepares the field for proper soil and rice attachment. Puddling to an extent helps in levelling the basin. Fig. 4 shows the picture of puddling operation carried out during rice farming at Lake Chad basin.

Fig. 4. Picture of puddling operation during rice farming at Lake Chad basin

2.5 Levelling

Levelling is the process of making a field surface relatively uniform and flat. The objective of levelling in land preparation is to produce a flat field where water management and nutrient distribution can be made easier. It involves the movement of soil from high (exposed) spots to low spots. This result in a smooth, level area before sowing or planting. This further promotes the equal submergence and reduces weed infestation in the basin. Fig. 5 shows the picture of levelling operation carried out during rice farming at Lake Chad basin.

Fig. 5. Picture of levelling operation during rice farming at Lake Chad basin

2.6 Specialized Tillage Operation practiced in Sawah Eco-technology System

2.6.1 Furrow opening

Furrow opening is an operation that involve creating a channel for water to flow out of a waterlogged field and conversely also to lead water into a field for the purpose of irrigation. This is usually achieved through the use of (i) a specialized outward sweeping double disc or mouldboard implement designed for the purpose of furrow opening or (2) improvising a mouldboard ridger mounted on a power tiller or a tractor. Fig. 6 shows the picture of furrow opening operation carried out during rice farming in Amayi Igbere of Abia State.

Fig. 6. Picture of furrow opening operation during rice farming in Amayi Igbere of Abia State

2.6.2 Poldering

A fertile tract of flat, low-lying land reclaimed from a body of water by the use of water supply and continuous puddling of adjacent leeves to achieve soil movement inward and water movement outward. This operation takes advantage of thixotropy, a time dependent shear thinning property of the soil becoming less viscous when subjected to an applied stress resulting to temporarily fluid when continuously puddled (shaken and stirred). Fig. 7 shows the picture of the stages involved during poldering operation carried out during rice farming at Lake Chad basin.

Fig. 7 a.) pre-intervention; b.) during poldering; c.) soil and water interface; and d.) levelled basins ready for rice seedling transplant

3. ADVANTAGES OF SAWAH ECO-TECHNOLOGY OVER TRADITIONAL SYSTEM OF RICE PRODUCTION IN NIGERIA

Sawah eco-technology encourages the multi-functionality of sawah systems in a watershed. Lowland sawah can produce at least 4 tons/ha of rice paddy with the application of chemical fertilizer as compared to the traditional upland rice with maximum yield which ranges from 1 to 3 tons/ha. Sustainable productivity of sawah based rice farming is therefore more than 10 times higher than that of upland slash and burn rice. The advantages of multi-functionality in sawah rice systems, according to Wakatsuki et al. (2011) include:

1. Intensive, diverse and sustainable nature of productivity through weed control by water and enhancement of nutrient supply; ecosysytem nitrogen fixation; increased phosphate availability which is a concerted effort of N-fixation; pH neutralizing eco-system to increase micronutrient availability; watershed geological fertilization: water nutrients and top soils from upland; and encouraging fish and rice, geese and sawah mutual relations.
2. Combating global warming and other environmental problems through carbon sequestration, that is, control of oxygen supply and methane emission under submerged condition, nitrous oxide emission under aerobic rice; control of flooding, soil erosion and electricity generation; watershed agroforestry by SATOYAMA approach to generate forest at upland; and denitrification of nitrate polluted water.

3. Creation of cultural landscape and social collaborations through terraced sawah system has beautiful landscape, fair water distribution systems for collaboration and fair society.

4. SUCCESS STORY OF SAWAH TECHNOLOGY IN NIGERIA

Sawah Eco- technology has been extended to more than 18 States of Nigeria with over seven hundred (700) local farmers trained to adopt the technology and over eighty (80) ha of lowland utilized for rice production. Presented in Table 2 are some of the achievements made while training farmers in different locations in Nigeria on the use of Sawah eco-technology for effective rice production. It can be deduced from Table 2 that the level of training received by these rice farmers irrespective of their locations had positive impact on rice yield.

Table 2. SAWAH Activities from 2015 to 2021

S/No.	State	Description	Location	No. of farmers trained	AYBT (t/ha)	Year	AYAT (t/ha)
1	Niger	ESTRASERIF	Rani	20	3.5	2015	5
2	Niger	ESTRASERIF	Ubandoma	25	3.5	2015	5
3	Kogi	ESTRASERIF	Koriko, Sarkin Noma.	20	2.5	2015	4
3.	Nasarawa	OJCB	Maraba,Tundun Kauri	8	3	2016	4.5
4	Nasarawa	OJCB	Shabu Azuba,	25	2.2	2016	3
5.	Niger	ESTRASERIF	Gbajigi	24	3	2017	4
6	Akwa-Ibom	PPP	Ini	21	-	2017	5
7	Akwa-Ibom	State Government	Nung Obong	31	2	2017	4
8.	FCT	Fadama	Yaba	18	1.8	2017	4
9.	Kano	Sasakawa	Bunkure, Kura	25	3.5	2017	4.2
10	Kebbi	ESTRASERIF	Kamba	20	3	2017	5
11	Kano	ESTRASERIF	Bagwai	20	3.5	2017	6
12.	Benue	ESTRASERIF	Tse-Abata	20	3.2	2017	6.5
13	Kwara	Landmark University	Omu-Aran	10	2.1	2018	4
14	Katsina	ESTRASERIF	Ajiwa	20	3	2017	4.6
15.	Ebonyi	ESTRASERIF	Uburu	15	3.5	2017	7
16.	Nasarawa	ESTRASERIF	Asakio	28	2.7	2017	3.5
17	Kwara	Landmark University	Omu-Aran	12	2.5	2018	4
18	Niger	ESTRASERIF	Gbajigi	27	3	2017	4.3
19.	Benue	ESTRASERIF	Apir	20	2.7	2018	6.5
20.	Akwa-Ibom	ESTRASERIF	Ikot Esen	20	3	2018	7
21	Anambra	ESTRASERIF	Ogboji	20	3.5	2018	6
22.	Osun	ESTRASERIF	Iwo	20	2.5	2018	5.5
23	Osun	ESTRASERIF	Osogbo, Gbonmi	25	3	2018	5.5
24	Taraba	ESTRASERIF	Mutum Biyu	25	3.5	2018	6.5
25	Kwara	ESTRASERIF	Lafiagi	20	3	2019	5.5
26	Kwara	ESTRASERIF	Shonga	35	3	2019	6
27.	Imo	ESTRASERIF	Mbaise	25	2.5	2019	5
28	Oyo	ESTRASERIF	Igbo Adan	20	3	2019	6
29.	Oyo	ESTRASERIF	Palapala	6	2.7	2019	5
30	Sokoto	ESTRASERIF	Goronyo	25	3	2019	5.5
31.	Ekiti	ESTRASERIF	Aishegba	25	2.5	2020	5
32.	Abia	ESTRASERIF	Ibeku	21	2.2	2020	4.5
33.	Niger	ESTRASERIF	Sheshibekun	23	3.5	2020	6
34.	Ogun	ESTRASERIF	Ifasa, Sawonjo, Igbogila	20	3	2020	5.5
35.	Ondo	ESTRASERIF	Awujale	25	3.2	2021	4.9
36	Ondo	ESTRASERIF	Okuta Elerin	25	3.3	2021	5.3

37	Ondo	ESTRASERIF	Akure North Secretariat	25	3.0	2021	5.0
38	Enugu	ESTRASERIF	Nnewe	25	2.7	2021	4.5
39	Benue	ESTRASERIF	Makurdi	25	3.2	2021	5.6

Keynote: AYBT = Average Yield before Training; AYAT = Average Yield after Training; OJCB = On-the-job capacity building; ESTRASERIF = Expansion strategy for Sawah Eco-Technology and Rice Farming; PPP = Public Private Partnership project

5. CHALLENGES OF SAWAH ECO-TECHNOLOGY FOR RICE PRODUCTION IN NIGERIA

The dissemination of the Sawah Eco technology in Nigeria has encountered the following challenges.

1. Rice farmers shy away from adopting rice transplanting method because it requires thorough tillage practice to the extent of levelling which these farmers try to avoid during farming operation.
2. Manual labour requirement for transplanting is a bottle neck to rapid full adoption of the technology.
3. Land tenure system if it is not well secured before sawah eco-technology is introduced into locality conflicts and eviction abounds.
4. The use of power tiller to carry out bunding operation require repeated passes to make appreciable bund. These repeated passes bring along the use of more energy in carrying out the task which leads to increase in soil compaction.
5. Poldering which is a specialized tillage operation is only applicable to an ecology of receding lakes, senile rivers, bank of dams and deltas which are not widespread.
6. Furrow opening which is also part of the specialized tillage operations carried out in Sawah eco-technlogy system require expertise in depth control to avoid damage to the soil through erosion.
7. The poverty level in Sub Saharan Africa (SSA) is among the factor that retards the ease of disseminating and adopting Sawah. The unexpected idea of some rural dwellers asking for compensation before allowing new technology to be demonstrated discourages technology transfer to the local farmers.
8. Farm practices amongst different cultures of a particular locality affect the ease of adoption. An example is the rate at which a local community that is familiar with bund making during rice field preparation is easier in adopting Sawah than others that don't bund their field for rice farming.
9. Some socio economic factors that affect the extension of Sawah eco-technology for farmer's adoption include:
   - i. Age: The youth are more inclined to adopt the technology than the aged farmer.
   - ii. Level of education: The higher the level of education of farmer the easier it is to adopt the technology.
   - iii. Group dynamics: The extension of Sawah eco-technology is easier done through cooperatives and associations.
   - iv. Farm size: An appreciable size of land attracts dissemination of technology than smaller fields.
   - v. Land tenure and Land Ownership: This is one big challenge often encountered in areas where there is limited land supply appropriate for low land cultivation. Entry of Sawah Ecotechnology project to a community often lead to a tremendous increase in the value of such land and its neighbouring properties. The high prospect of gains makes the landlords to hike the value of the property wherever there is no prior agreements

vi. Location of Sawah plot: Close distance of plot to farmer encourages farmer input to the technology at every point in time during dissemination than plots that are far from farmer.
vii. Cost of use and Maintenance of Power Tiller: Proper skill in the use of power tiller increases the durability of the machine as well as appropriate maintenance culture (Ademiluyi et al., 2008). Whereas lack of skill will lead to quick damage and high cost of adoption.
viii. Language Barrier: In Nigeria, the multi lingual nature makes it difficult for a researcher or an expert from another part of the country to transfer technology because there is no universal way to describe Sawah (Wakatuki et al., 2008).

6. CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

This paper takes a good look at the tillage processes involved in Nigeria rice production using Sawah eco-technology and from all indications there is need to scale-up Sawah eco-technology for ease of adoption by enthusiastic Nigerian rice farmers through application of versatile new model power tillers, mini transplanters, sustainable solar water pumps and mini modular processing plants that is attractive to teeming youth of Nigeria.

6.2 Recommendations

Sawah eco-technology is gradually generating interest in Nigeria over the traditional system of producing rice. In an attempt to encourage rice farmers to adopt the system, the following approach are proffered as recommendations to intensify the promotion and widespread adoption of this proven technology that have moved Nigeria to its present position in Africa in rice production. The recommendations include:

i. Other state governments in Nigeria should borrow a leaf from Kebbi State government who worked in collaboration with the Federal Government team led by NCAM in providing an enabling environment for the spread and adoption of the technology by the State farmers.
ii. The present rice production rate in the country is increasing, however, effort should be intensified on the productivity rate which this technology is advocating and promoting.
iii. The technology is equivalent to the introduction of engineering into rice production which entails structural development, system design, field layout, bund and canal construction, development of weirs and dykes for optimum water management which improves tillering of rice seedlings suppressing weed growth within the rice field or basin invariably increasing rice production and bring about optimum water management.
iv. This good tillage practice can be adopted for other lowland crop production.
v. This system if well managed will increase productivity and reduce cost of production.
vi. The technology attracts youth to agricultural vocation and also encourage and permit mechanization practices towards achieving rice green revolution in Nigeria.
vii. There should be incentives by government and other donors to encourage farmers that adopts this technology. In addition, the technology is the way forward for agricultural revolution since it has the capability for sustenance and increased productivity.
viii. The technology is eco-friendly and should be encouraged to all lowland crop production.

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MITIGATION OF HUNGER ON THE AFRICAN CONTINENT: A REVIEW

Ogunjirin, O. A., O. L. Abiodun, J. A. Oyedokun and R. O. Jimoh
Engineering and Scientific Services Department
National Centre for Agricultural Mechanization, Ilorin, Nigeria.
e-mail: ntslola@yahoo.com

ABSTRACT
This paper takes a look at mitigation of hunger on the African continent, the types of hunger which include acute, chronic and hidden hunger. The importance of agriculture in alleviating hunger cannot be overemphasized, it has the potential to provide adequate food for the growing population, it also supply raw materials to a growing industrial sector, source of foreign exchange earner and also source of employment opportunities. The paper further looked at the causes of hunger which includes poverty, corruption, population spike and unemployment. In order to mitigate the effects of hunger on the people, there should be proactive actions on the side of African leaders with a view to protecting their people from starving to death as we are currently seeing in some African countries. To achieve this, this paper suggested these few things, among other numerous ways, to mitigating hunger on the African continents.

Keywords: Hunger, Agriculture, Food, Security, Africa.

1.0 INTRODUCTION
The three man's basic needs in order of importance are food, clothing and shelter. All over the world, food is very important because it plays a vital role for the continued existence of man. Man can live without shelter and clothing but cannot survive without food. The importance of food to mankind cannot be overemphasized and that is the reason most African countries spend billions of dollars on food production/importation to stem hunger and malnutrition amongst her teeming population.
Several African citizens face the plight of hunger on a daily basis with indication showing that the situation is worsening over time. In Africa, the threat to food security is becoming alarming and this is as a result of factors which are either natural or artificial depending on the African countries involved. A country that is food secured is one that the people have access to food that is safe, nourishing, and within the purchasing power of the indigent or ordinary people for their healthy living (FAO et al. 2018).
Efforts are being made by governments, non-governmental organizations (NGOs), and international institutions to address hunger in Africa. These efforts include initiatives to improve agricultural practices, enhance infrastructure, promote sustainable farming methods, support small-scale farmers, and strengthen social safety nets. International collaborations, such as the United Nations' Sustainable Development Goals (SDGs), aim to eradicate hunger and achieve food security in Africa by promoting sustainable agriculture, improving rural infrastructure, and enhancing the resilience of vulnerable populations.

Progress made so far still leave much work to be done to eliminate hunger and achieve food security across the African continent.

1.1 Hunger on the African continent
According to Food and Agriculture Organization of the United Nations (FAO), Hunger is defined as "an uncomfortable or painful physical sensation caused by insufficient consumption of dietary energy. It becomes chronic when the person does not consume a sufficient number of calories (dietary energy) on a regular basis to lead a normal, active and healthy life" (FAO et al. 2019).

The main causes of hunger are poverty and malnutrition. The situation of hunger in the countries of African can be classified into acute, chronic and hidden hunger.

1.2 Types of hunger on the African continent

Food and Agricultural Organization (FAO) of the United Nations classified hunger into three: -

1.2.1 Acute hunger

This type of hunger is as result of crises such as drought, wars and disasters. This is depicted with severe hunger and malnutrition which leads to a situation that lives are endangered (e.g., famine) Five African countries facing acute hunger include DRC, Ethiopia, Nigeria (northern region), South Sudan and Sudan. (Behera et al. 2019; FSIN GRFC 2020).

1.2.1.1 Chronic hunger

This type of hunger is when a person lacks daily energy intake for a lengthy period of time that is less than average of 1800 calories per day needed for a healthy and active life. It is measured as height for age in children and calorie intake in adult compared to standard. In Africa, more than 300 million people suffer from chronic hunger while about 235 million are from Sub-Saharan Africa (Tumushabe 2018).

1.2.1.2 Hidden hunger

This is a form of acute or chronic hunger caused by lack of major vitamins and minerals (Gödecke et al. 2018; Otekunrin et al. 2019a; Behera et al. 2019). According to the World Health Organization (WHO), this type of hunger affects a massive number of people with an estimate of about 2 million (WHO 2013; Ekholuenetale et al. 2020).

1.3 Importance of agriculture in alleviating hunger in Africa

The importance of agriculture in alleviating hunger in Africa lies in the benefits of agriculture to the African continent's economy as discussed under the following subsections.

1.3.1 Major source of food supply

In Africa, agriculture provides the basic source of food for both human and animal. No matter the level of development of any country, all countries in the world still need food to feed her growing population and also to survive.

1.3.2 Contribution to national income and economic growth

Most income generated by African countries from agricultural produce are through exportation to foreign countries. This contributes and boost the national income of the countries (export revenue earnings). Foreign exchange generated from exported agricultural produce gives the country's economic stability and help in her development. The agricultural sector also eliminates poverty by providing employment opportunities for the teeming rural and urban population.

1.3.3 Source of raw material for industrial development

In Africa, the agricultural sector helps in growing her economy. Apart from providing food, it also provides the necessary raw material for industries. Most agro allied industries are beneficiaries of raw materials needed for production.

1.3.4 Source of foreign exchange for the country

Most African countries that are not endowed with natural resources relied on export of agricultural cash crops to generate enough foreign exchange for economic development. Nigeria, for example, prior to discovery of oil, agriculture serves as a major foreign exchange earner for the development of the nation. Her former three geopolitical regions were developed through foreign exchange earnings from agriculture produce.

1.3.5 Provision of employment opportunities for rural people

Before the discovery of oil in some African countries, agriculture was the mainstay of most of the African nations' economy which provides employment opportunities for the rural populace thereby stemming rural–urban migration. In the sixties, about 70% of Nigerian populace were gainfully engaged in agricultural businesses both at subsistence and commercial levels.

1.3.6 A means of improving rural welfare

Rural participation in agricultural production in African countries aside from providing means of sustenance, most rural farmers engaged in cash crop production through agricultural board which by so doing generated more income, improve the lives of the rural farmers and therefore reducing poverty among them. The participation of rural dwellers in agriculture provides an avenue for government to provide basic, social, health and economic infrastructure due to their contribution to the economy. Infrastructure such as good roads, electricity, primary and secondary health centers and agricultural extension services were provided.

1.4 Causes of hunger in Africa

The causes for the widespread hunger and food shortages are complex. Countries in Africa face similar challenges but only differ in magnitude. The African continent has the capability to feed itself. However, several factors prevent self-sufficiency and success in the fight against hunger in Africa:-

1.4.1 Widespread poverty

Poverty is one of the critical causes of hunger which means deficiency of resources for the physical wellbeing of a person. It is a situation when one’s income does not cover the provision of necessities. Majority of the populace in Africa are within the poverty line.

1.4.2 High incidence of pre- and post-harvest losses caused by pests and disease

The high impact of pest and diseases on crops and animals has negative effects on harvested crops and livestock produced. These pests and diseases oftentimes lead to increase in food prices and also the death of livestock. The incidence of pests and diseases are felt in various region of Africa such as the cassava which is one of the staple foods in several African countries was affected with cassava mosaic and brown streak virus diseases taking enormous impact on the cassava tuber, in the Great Lakes region of East and South Africa. The effect of armyworm on maize and sorghum in South Sudan affected grains output (FAO 2018). Avian Influenza (Bird flu) resulted in huge economic losses for poultry businesses in several African countries in 2006 to 2008 and year 2015 to 2017 outbreaks (Otekunrin 2007; Ntsefong et al. 2017; Fasanmi et al. 2018; Otekunrin et al. 2018).

1.4.3 Population spikes

African countries are faced with rapid growing population, but increase in food production is not keeping up mostly due lack of planning and policy implementation.

1.4.4 Unemployment

Most African countries are marked with severe high unemployment rate. Graduates are not gainfully employed as a result; lack the means to take proper care of themselves and their immediate families.

1.4.5 Social exclusion

Extreme discrimination as a result of ethnic and religious affiliation often lead to exclusion in the provision of basic need of citizens in some African countries

1.4.6 Corruption

High level corruption both within leadership across African counties has led to exacerbation of hunger in the continent. Often, money meant for agricultural development are diverted into private pockets leaving little resources for development thereby affecting food production for the teeming population.

1.4.7 Conflicts, wars and insurgencies

Most African countries are faced with large part of trouble spots, internal wars and conflicts bringing with it refugee misery and hunger. For example, the evil activities of killer herdsmen in almost every part of Nigeria have adversely affected farming activities thereby giving room for less productivity in agriculture. Farmers are afraid to go to farms as herdsmen invade farmland and destroy farm produce such as cassava and grain crops which falls under the important staple food of most Nigerians. This situation has led to the sudden increase in the prices of food stuff and at present cause undue hardship melted upon the populace. The North East in Nigeria which provides the staple foods like grains, wheat and large percentage of dairy products and animal protein in form of meat is currently under the brutality of insurgency. This has not only affected food security of the area but almost entire part of the country thus leading to upward rise in the prices of food commodities in Nigeria. Internally and externally displaced persons are in excess of one million and more than ten thousand deaths recorded. The unaffected people in the affected areas are unable to continue their farming activities which has halted agricultural distribution activities leading to hunger. The problems started in 2009 and got escalated in the year 2014 (Otekunrin et al. 2019b; Behera et al. 2019; Otekunrin et al. 2020a; Otekunrin et al. 2020b).

1.4.8 Urbanization

In most African countries, there is rural-urban migration leaving a huge gap of personnel engaged in farming activities. Most rural dwellers in Africa are migrating to urban cities in search of non-existing white-collar jobs, these has negatively affected food production from the rural parts. The Food and Agricultural Organization, (FAO), pointed out that by year 2050, 70 percent of the world population would be residing in the cities. With this forecasted development there is tendency that there will be reduction of food production from rural areas thereby leading to food shortage which will eventually in the long run culminated into hunger.

1.4.9 Poor agricultural sector development

This is one of the major threats to Africa food security. Several African countries lack sustainable agricultural policy that will enhance adequate food production for her teaming population because of unstable leadership**.** The frequent changes in leadership tend to affect the implementation of agricultural polices with new government jettisoning or canceling out rightly their predecessor’s policy even when the policy is prosperous and sustainable leading to policy summersault. These inconsistences in policy often derail agricultural development thereby affecting food supply chain. The continuous interference with the market by the government and her agents through export restrictions, trading bans, etc., put farmers in a disadvantaged position in determining prices of food produce.

1.4.10 Adverse effects of weather, global warming and ecological problems
The negative and resultant effects of climate change and ecological problem have increased hunger in Africa. Gas flaring and chemical emission into the atmosphere is causing global warming and other ecological damage. Recently, most African countries experienced more rains and flooding which have made farmers to incur loses of agricultural products. Example, Nigeria experienced major flooding in some states of the federation causing damage to farm land sand preventing meager harvested crops from being transported which led to the huge increase in the prices of farm produce. Furthermore, there has been persistence drought in the northern part of the country resulting in shortage of food production. Multinational companies drilling fossil fuel with gas emission are causing global warming and change in pattern of the climate through the depletion of the ozone layer.

1.4.11 Indebtedness and mismanagement of natural resources in Africa
Poor governance and corruption in Africa culminate in indebtedness retarding economic development with the resultant mass poverty and hunger.

1.5 Research objectives
The research objectives aim to review ways to increase crop yields and enhance food production to meet the nutritional needs of the African populace and: -

1.Enhance climate resilience
2.Strengthen food systems and value chains
3.Promote sustainable and diversified agriculture
4.Reduce poverty and enhance livelihoods
5.Strengthen governance and policy frameworks

By pursuing these objectives, the African continent can make significant progress in mitigating hunger, achieving food security, and improve the overall well-being of her teeming population.

1.6 Statement of problem
The African continent faces a significant challenge in mitigating hunger and ensuring food security for its population. Despite progress made in time past, a large proportion of the population still suffers from chronic hunger, undernourishment and food insecurity. This problem is multifaceted and can be attributed to several causes.

2.0 METHODOLOGY
The method used in carryout this research work is a table desk literature review search of thirteen (13) years from the year 2007 to the year 2020. This includes reviewing various agricultural policies implemented by African leaders, international organizations, governmental and non governmental organisations with a view to assessing them and further proffered plausible action plans that would address the objectives of the study.

3.0 DISCUSSION OF RESEARCH RESULTS
Findings according to the literature showed that hunger has been a major problem in the African continent, although most African countries have carried out various policies and programs to alleviate hunger in Africa. More can still be done. African countries are besets with many problems which have affected her ability to feed herself and be self-sufficient and sustainable in food production. For Africa to end hunger, it must first tackle poverty both at the rural and urban level. African countries must tackle and resolve arms conflict and embrace democracy for peace and tranquility in the African continent. Nobody can embark on agricultural ventures in the face of insecurity and war. Social amenities and infrastructural facilities must be provided

in the rural areas to stem rural urban drifts so that farmers in the rural enclaves can contine to stay in their localities to provide food for the growing population. African government should direct banks to grant farmers low interest loans and also monitor painstakingly loans granted to farmers to ensure that such loans meant for agriculture are not diverted to non agricultural ventures. Government should make available affordable tractor services available through the ministries of agriculture and rural developments to enable farmers' embrace mechanized farming. Adequate and consistent agricultural extension services should be provided to farmers to keep them abreast with latest farming techniques and and processing. Impediments to accessing land for agriculture must be also removed. Above all, African countries must have stable and consistent agricultural policies that will aid the growth of agriculture in their respective countries.

Concerted efforts must be made by African leaders to adhere to the Malabo agreement for adequate funding of agriculture in order to eradicate hunger on the African continent. Furthermore, to eradicate hunger, adequate funding of agricultural development research projects should be prioritized.

Government should formulate and implement policies that would ensure that some percentages of the profit generated by organizations, such as commercial banks, telecommunication companies, oil companies, etc., are ploughed into agricultural development programmes. Such programmes include but not limited to farm inputs such as seeds, fertilizers, agricultural land development, mechanization inputs, agro chemicals, etc,.

4.0 WAY FORWARD TO HUNGER IN AFRICA

The repositioning of the agricultural sector in Africa is the only way to mitigate hunger for her teeming and growing population. Over the past several decades, many African countries have made great strides in reducing hunger in Africa. Although, the current situation on hunger looks grim. However, there is still hope that the problems associated with hunger can be tackled.
In order to mitigate the effects of hunger on the people there should be proactive actions on the part of African leaders with a view to protecting their people from starving to death as we are currently seeing in some African countries. To achieve this among other things, this paper will like to suggest these few things among other numerous ways of mitigating hunger in African countries.

4.1 Stop climate change

African leaders should make concerted effort to bring an end to the adverse effect of climate change and other ecological effects on agricultural production. This can be done by embracing the development and use of renewable energy solutions, reducing the use of fossil fuel and gas emission.

4.2 Consistent policy framework

For African leaders to eradicate hunger, there must be consistent and duly implementation of agricultural policies. Successive government should ensure that policies associated with agricultural development by predecessors are not jettisoned but followed to the latter to ensure implementation. Government should implement a policy whereby some percentage (may be 10%) of profits generated by commercial banks, telecommunication companies and oil companies should be declared for the development of agricultural lands. Implementation strategies and management of the resources should be put in place so that funds can be domiciled in agencies like National Centre for Agricultural Mechanization (NCAM) and National Agricultural Land Development Authority (NALDA). Local government areas should be encouraged to release some portions of land for agricultural land development purposes whereby annual rent fee can be paid by farmers to have access to lands that are already developed thus increasing the internally generated revenue (IGR). In so doing the use of hoes and cutlasses can be gradually eliminated.

4.3 Providing of social amenities and infrastructural facilities in rural parts of Africa

The provision of infrastructural facilities in the rural areas, such as access roads, portable water and electricity, are necessary to stem the rural-urban migration, thus, ensuring that there are able bodied men or adequate labour in the areas engaging in agricultural activities to boost food production in the rural areas and provide employment opportunities among the rural dwellers thereby reducing hunger on the African continent.

4.4 Population control

There is need to control population growth in order to match food production level. Hunger always set in when food production does not keep up with the growing population.

4.5 Provision of storage facilities

Most farm produce are perishable in nature which needs adequate storage facilities in preserving them. Government should provide modern silos and warehouses that can prevent and withstand adverse weather, pests, diseases and spoilage of farm produce. With these, there will be provision of food all year round.

4.6 Elimination of trade barriers

African leaders must promote free trade across borders to ease the flow of agricultural produce. Although, there are existing trade agreement among governments, enforcement of such agreement has been weak. The trade agreement should be fully operational and enforced to encourage free flow of agricultural produce across borders of African countries.

4.7 Improvement in the availability of irrigation water for farming

For better and high yielding farm produce, there is need for adequate provision of irrigation water to prevent drought. Dams and reservoirs can be constructed for irrigation purpose.

4.8 Initiation of workable food projects and policies

Local food project exists in most African countries, but few measure up to standard. The African Improved Food initiative (AIF) that started in Rwanda was a successful initiative which other African countries can emulate. This was a combination of both private and public initiative to stem malnutrition and hunger in Rwanda. Under this laudable project, AIF buys maize grown locally from farmers at a set price and process this maize in factory in Kigali and produce a super nutritious cereal from it for mothers and their children in that same region and by so doing empower them financially. Through this initiative, AIF was able to generate a lot of money to the tune of $756 million for the people of Rwanda thereby achieving food security and wiping hunger in the country.

4.9 Funding of research for national development

Research institutes should be properly funded to develop and improve innovations to boost agricultural practices in order to come up with produce and products that would address the needs of farmers on the farm.

4.10 Promotion of mechanized farming

Mechanization is crucial for self-sufficiency in food production in African continent. Modernization through farming machines and techniques inputs should be made readily affordable, available and accessible.

4.11 Growing of crops consumed on commercial scale

In order to alleviate hunger in Africa, the time is ripe for African countries to start growing the crops she consumes locally on commercial scale and export excess to European countries and to the rest of the world. African countries should discontinue the importation of staple food when they have about 60 percent of able-bodied men to till their land to produce food for her growing population.

4.12 Provision of capital for agricultural development

African government should provide farmers with enough capital mainly for agricultural purposes. Credit facilities should be made available through agricultural banks set up for the promotion of the agricultural sector. There is need to closely monitor these lending banks in order to ensure that the credit facilities extended to farmers are not diverted but carefully used for the purpose it was intended for. Loans issued at minimal interest rate should be given to farmers. Government should give directive to all deposit money banks (DMB) otherwise known as commercial banks to put aside certain percentage of their capital for lending to farmers at a single digit interest rate.

4.13 Governments' compliance of the Malabo Agreement of the African union to end hunger by 2025

Determined effort should be made by the African government to adhere with the Malabo Agreement declaration and commitments which stipulate that 10% of national annual budget of African countries should be assigned for agriculture to alleviate hunger. Also, African leaders, should massively invest in agriculture to boost domestic consumption, rural infrastructural development and engaging in export promotion of agricultural products to earn foreign exchange.

5.0 CONCLUSION

In summary, Africa, as a continent, is in the belt of high potentials of huge agricultural resources with availability of arable lands, water and agricultural friendly weather that support the production of abundant foods and fibres. If the potential is fully utilized, it will improve the economy, reduce the rate of unemployment, improve the standard of living, strengthen the security, provide food security and food sustainability of the African continent.

6.0 RECOMMENDATIONS

Mitigating hunger in the African continent requires a comprehensive approach that addresses the root causes of food insecurity and promotes sustainable solutions. The following are some recommendations that will help in solving the problem of hunger in Africa:-

i. Enhancing agricultural productivity and support small-scale farmers through investments in improved seeds, irrigation systems, mechanization, and access to credit. Promote sustainable farming practices and provide training on modern techniques to increase yields.

ii. Supporting climate-smart agriculture by promoting resilient crops, agroforestry, and sustainable land management practices. Invest in early warning systems for weather-related disasters and provide farmers with insurance schemes to help them recover from climate-related shocks.

iii. Improving rural infrastructure, including roads, storage facilities, and irrigation systems. This will facilitate the transportation of goods, reduce post-harvest losses, and increase access to markets for farmers.

iv. Enhancing access to financial services for small-scale farmers and rural entrepreneurs. Microfinance initiatives, savings groups, and agricultural credit programs can help them invest in their businesses, purchase inputs, and improve productivity.
v. Promoting gender equality and women's empowerment in agriculture. Provide women farmers with access to resources, education, and training, as they play a crucial role in food production and household nutrition.
vi. Investing in agricultural research and development to improve crop varieties, pest management, and farming techniques suitable for local conditions. Collaborate with international research institutions to share knowledge and best practices.
vii. Fostering partnerships between governments, private sector entities, NGOs, and international organizations to promote sustainable agriculture, improve value chains, and enhance food security.

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OPTIMIZATION OF GROUNDNUT PRODUCTION UNDER EARTH-UP TIME AND IRRIGATION LEVELS IN SOUTHWESTERN NIGERIA, USING RESPONSE SURFACE METHODOLOGY

Fasanu Olugbenga
Department of Agricultural Education,
Federal College of Education (Technical), Akoka, Lagos
07030755265
fasanu2008@gmail.com

ABSTRACT

Groundnut (Arachis hypogaea L.) is one of the economic crops grown in the tropics. However, water scarcity and poor soil management practices has been identified as one the major factors limiting it full production in Nigeria. This study examined the effect of drip irrigation levels and earth up time after planting on yield, water productivity and earth up time productivity of groundnut. The experiment was conducted at Federal College of Education (Technical), Akoka, Lagos, from November 2019 to February 2020 during the dry season . A Split-plot Design was used consisting of drip irrigation system with four irrigation treatments. The treatments include I_{110} (indicates 10% Surplus), I_{90} (indicates 10% deficit irrigation), I_{70} (indicates 30% deficit irrigation) and I_{50} (indicates 50% deficit irrigation) of the crop evapo-transpiration (ET_c). While earth up time were E_0 (No earth-up was done throughout the duration of experiment), E_{20} (earth-up was done at 20th day after planting), E_{45} (earth-up was done at 45th day after planting) and E_{75} (earth-up was done at 75th day after planting) respectively Furthermore, were groundnut pod number, pod weight, water productivity and earth up time productivity respectively were measured as response variables in a full quadratic polynomial model. The results showed that increasing irrigation beyond 450 mm equivalent to I_{90} will result in yield decline. Therefore, the optimal irrigation level and earth up time recommended as the most economical for groundnut in this agro-ecological zone are 450 mm and 37 days to 55 days after planting, respectively.

Keywords: Earth up, Groundnut, Irrigation, Water, Productivity, Yield,

INTRODUCTION

According to Kassam *et al*. (1975), groundnut (*Arachis hypogaea*) is a major crop grown in the arid and semi-arid zone of Nigeria. It is either grown for its nut, oil or its vegetative residue (haulms). Uko *et al*. (2013) stated that groundnut belong to the fabaceae family which is the king of oil seeds derived from two Greek words Arachis which means legume or beans and hypogaea which means below groundnut (refers to formation of pods in the soil). It is also called a wonderful nut, earth nut, monkey nut, goobe, prinder, pamda, manila nut and poor men's cashew nut.

The worldwide groundnut production has reached about 399 million metric tons per year. China is the world's largest groundnut producer followed by India and United States. Groundnut is a very important oil seed and food crop around the globe for its nutritional and trade values (Deksissa et al., 2008). Mainly native to provide food for humans or livestock and in the absence of meat from a valuable dietary protein component (Musambasi et al., 2003).

Recently, the use of groundnut meal is becoming more recognized not only as a dietary supplement for children with protein related malnutrition. Groundnut production is influenced by several environmental factors, especially by moisture stress, soil type, soil fertility as reported by several authors (Simmonds and Williams, 1989; Ravindra et al., 1990; Ntare et al., 2001).

Statement of the problem

Groundnut is largely produced under rainfed condition in Nigeria. The yield is therefore affected by water stress whenever there is rainfall which becomes erratic. This has been recognized as one of the limiting factors militating against full production of groundnut round the year. It has also been hypothesized that heaping soil on the base of groundnut shoots help to increase yield of the pod. This study therefore seek to determine combined effect of drip irrigation levels and earth up time on the yield, earth up time productivity and water productivity of groundnut in Southwestern Nigeria.

MATERIALS AND METHODS

The experiment was conducted at the Teaching and Commercial Farm of the Department of Agricultural Education, Federal College of Education (Technical), Akoka, Lagos (FCET), longitude 6.5167° N, latitude 3.3850°E, with an altitude of 10 m above sea level on coastal area of Southwestern Nigeria. The experiment was carried out between the months of November 2019 to February 2020 during the dry season. The averages of the weather parameters over the study site during the period of the experiment is given in Table 1.

Table 1. Average Meteorological data at the experimental site during the period of the experiment

Month/Year	*Maximum Temperature* ^0C	*Minimum Temperature* ^0C	*Relative Humidity* %	*Wind Speed* *m/sec*	*Solar Radiation* $MJ/m^2.day$	ET_o *mm/day*	*Rainfall* *mm*
November 2019	31.38	26.96	82.20	2.33	18.11	4.01	12.21
December 2019	29.31	26.56	78.70	2.00	18.23	4.03	4.00
January 2020	30.65	25.81	83.34	2.29	17.99	3.80	0.00
February 2020	29.08	26.69	86.15	2.32	17.15	3.71	5.00

Land preparation

The study site has been used for planting Maize and Okra in the previous year. The major weeds cleared from the site during land preparation was Spear grass (*imperata cylindrica*) and Nuke-Noh (*Tridax procumbens*). An area of 24 m by 10 m portion of the field was cleared and appropriate land preparation was carried out to permit effective seed bed formation.

Soil samples were collected randomly from twelve points to a depth of 0.45 m and analyzed using standard soil analysis procedure prior to the starting of the experiment. The soil texture within the depth considered is sandy loam according to Soil Survey Staff (2006). Other results of the soil sample analysis are given in Table 2.

Table 2. Soil particle size analysis and other physicochemical properties of the study site

Parameters	**Values**
Sand (%)	80.4 ± 5.82
Silt (%)	12.6 ± 2.13
Clay (%)	7.1 ± 1.85
Bulk Density (g/cm^{-3})	1.32 ± 0.19

Water Holding Capacity	33.7 ± 9.45
Organic matter (%)	5.48 ± 1.76
Total N (g/kg)	8.56 ±1.10
P (mg/kg)	25.32 ± 0.55
K (cmol/kg)	0.51 ± 0.08
Ca (cmol/kg)	0.29 ± 0.06
Mg (cmol/kg)	0.29 ± 0.53
Na (cmol/kg)	0.53 ± 0.06
Fe (g/kg)	0.52 ± 0.58
Al (g/kg)	0.97 ± 0.65
Cu (mg/kg)	21.59 ± 0.11
EC (microSiemen/meter)	36.41 ± 6.72

Comment: The summation above is greater than 100%. Please check your calculation.

The experimental design adopted for this experiment is split-plot with irrigation treatments as main plots and earth-up time as random treatments within an irrigation treatment. There were sixteen treatments with four irrigation *(I)* levels and four earth-up time *(E)* levels, each treatment was replicated three times. The four irrigation level treatment consist of I_{110} (indicates 10% surplus), I_{90} (indicates 10% deficit irrigation), I_{70} (indicates 30% deficit irrigation) and I_{50} (indicates 50% deficit irrigation) of the crop evapotranspiration (ET_c) respectively. The levels of earth up time were E_0 (No earth-up was done throughout the duration of experiment), E_{20} (earth-up was done at 20th day after planting), E_{45} (earth-up was done at 45th day after planting) and E_{75} (earth-up was done at 75th day after planting) respectively.

The actual crop water evapo-traspiration was calculated using the relationship in Equation (1).

$$ET_c = ET_o \times K_c \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

ET_o is the reference crop evapotranspiration (mm/m^2/d), it was calculated from the daily weather data (relative humidity, sunshine hours, wind speed, minimum and maximum temperature) according to the FAO-Penman Monteith model (Allen *et al*., 1998). The K_c represents the groundnut crop coefficients, which were selected for the initial, developmental, mid-season and late season or maturity stages based on Igbadun (2012) previous work.

The experimental plots during field preparation were tilled manually. Thereafter, well leveled planting beds were created. The seeds were sown on 13th November, 2019 at one seed per hole at a row spacing of 30 cm by 60 cm inter-row giving a planting density of 55,555/ha. Weeding and other cultural practices were carried out manually. When the seed has germinated appropriate insecticides were applied to protect the crop. Thereafter, earth up were carried out by maintaining soil height of about 5 cm around the collar of the groundnut stem (Thilini *et al.,* 2019). This was done at different intervals of 20 days after planting for treatment E_{20}, 45 days after planting for treatment E_{45} and 75 days after planting for treatment E_{75} respectively. No earth up was done for treatment E_0.

Irrigation water source was from the Overhead Reservoir Tanks meant for the FCET Waterworks having its water supply from industrial bore holes. Drip irrigation method was adopted. The drip laterals were made of polyethylene material having 13 mm diameter. The emitters were placed at a spacing of 0.3 m with an average discharge of 0.75 L/h at operational pressure of 25 kPa. The irrigation schedule was monitored based on the interpretations from the daily weather data collected from the University of Lagos meteorological station just about 500 m from the experimental site. The soil moisture content was monitored using digital soil moisture meter (*Lutron*) calibrated from the experimental site soil data using gravimetric method. Irrigation was scheduled to be 5-day interval and the amount was based on the summations of daily ET_c during the 5 days prior to irrigation. There were occasions were the irrigation date was shifted by a day or two on the events of rainfall. The rainfall amounts were recorded by a raingauge stationed within the experimental site. The irrigation amount (I_a) which is the volume of irrigation water applied in liters (L) per irrigation event was calculated from Equation (2).

$$I_a = I \times W_a \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2)}$$

where, I is irrigation (mm) and W_a is the wetted area (m^2) by emitters.

The gross irrigation (IR_g) was determined by the relationship between the irrigation amounts (I_a) and the irrigation application efficiency (E_a) using Equation (3).

$$IR_g = \frac{I_a}{E_a} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \textit{(3)}$$

Irrigation application efficiency of 80% was used. This takes care of possible losses along the tank, supply lines and the emitters (ASAE, 1990).

The duration of the irrigation (T_a) per event in hours (h) was calculated using Equation (4)

$$T_a = \frac{IR_g}{N_p \times q} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \textit{(4)}$$

Where T_a is the duration of irrigation per event (h), N_p is number of emitter(s) per plant, IR_g (L) is the gross irrigation and q is the emitter discharge (L/h). In this study, one emitter was used per plant.

Measurements and methods

Plant height and Days to 50% flowering (Anthesis)

The plant height was determined on weekly basis using a meter rule. Measurement was taken from the base of each plant to the tip of the shoot in situ. The days to 50% flowering was noted when about half of the plants on the field begin to bloom. Plants that manifest flowers were counted, while the days after planting (DAP) was noted.

Leaf Area Index

The leaf area index was determined by measuring the maximum length and widest width of the randomly selected functional leaves. Product of the maximum length and widest width was multiplied by a factor of 0.821 (Aniefiok *et al*., 2019). Leaf area index was further calculated using Equation (5).

$$\textit{Leaf Area Index} = \frac{\textit{Total Leaf Area per plant X total number of plants}}{\textit{Plot total Area}} \ldots\ldots\ldots\ldots\ldots\ldots\text{(5)}$$

Canopy Cover

The active plant canopy cover was measured using *Canopeo* application version for android smart phone. *Canopeo* is automatic colour threshold image analysis tool developed in the *MATLAB* programming language *(Mathworks, Inc., Natick, M.A)* using colour values in the red-green-blue (RGB) system. The smart phone camera is used to capture the plant image by placing it directly above the plant at a height of 1 m during the day time. The image is automatically analyzed based on the selection of pixels according to the ratios of red/green, blue/green and excess green index (Liang *et al*., 2017; Paruelo *et al*., 2000). The results of the analysis is converted into a binary image where white pixels correspond to the pixels that satisfied the selection criteria (green canopy) and black pixels correspond to the pixels that did not meet the selection criteria (not green canopy). Fractional green canopy cover ranges from

0 which translates to no green canopy cover to 1 which translates to 100% green canopy cover (Andres and Tyson, 2015). The application automatically records geographical coordinates, date and time so that the identity of each image can be traced.

Pod yield
Harvesting was carried out as soon as majority of the groundnut plant foliage start manifesting yellowish colouration and leaf senescence sets in. Pods from each plant stand under each treatment were stripped manually. The matured and immature pods were counted and recorded. The pod yield was determined by weighing after air drying.

Pod length
Pod length was determined by using a vernier caliper to measure the gap between two opposite ends of the pod.

100-kernel weight
Weight of 100-kernel was determined after removing the kernels by opening the pods. Thereafter, 100 kernels were randomly selected from each treatment and weighed. Also the whole kernel weight was determined while the shell after left after removing the kernels were also weighed and recorded.

Above-ground biomass
Five groundnut plants under each treatment were selected after the pods have been stripped. They were weighed and placed inside the oven at a preset temperature of 75°C for 24 hours. The samples were weighed at interval of 2 hours using a digital scale until a constant weight was obtained.

Harvest Index
The harvest index was calculated as the ratio of the kernel yield to the above ground biomass as expressed in Equation (6).

$$Harvest\ index = \frac{Weight\ of\ Kernel\ yield\ (\frac{tons}{ha})}{Above\ ground\ biomass(\frac{tons}{ha})} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(6)$$

Crop water productivity
The crop water productivity expressed in (kg/mm/ha) was determined from the ratio of the yield to crop evapotranspiration. This is mathematically expressed in Equation (7).

$$Crop\ water\ productivity = \frac{Crop\ yield\ (kg/ha)}{Crop\ evapotranspiration\ (mm)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(7)$$

Crop evapotranspiration was computed using Equation (8).

$$ET_c = P_e + I - D - R - \Delta W \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(8)$$

Where, P_e = Effective rainfall (mm), I = Irrigation depth (mm), D = Drainage depth (mm), R = Surface Runoff (mm) and ΔW = Change in soil moisture from the commencement to the end of the field experiment

Earth up time productivity
The earth up time productivity expressed in (kg/day/ha) was determined from the ratio of the yield to the duration of earth up after planting. This is mathematically expressed in Equation (9).

$$Earth\ up\ time\ productivity = \frac{crop\ yield\ (kg/ha)}{Duration\ of\ earthing\ up\ after\ planting\ (days)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (9)$$

Optimization of drip irrigation and earth up

In order to optimize the combination of irrigation and earth up time on the yield of groundnut in this study, Response Surface Methodology (RSM) was employed. The RSM is a useful statistical technique for the investigation of complex processes. The input parameters or independent variables to the system and the response or dependent variables are linked by a mathematical model. The mathematical models for the desired responses as a function of selected variables were developed by applying the multiple regression analysis on the experimental data (Khor *et al*., 2016). The general quadratic equation model is stated by:

$$Y = \beta_0 + \sum_{i=1}^{k} \beta_i x_i + \sum_{i=1}^{k} \beta_{ii} x_i^2 + \sum_{i<j}^{k} \beta_{ij} x_i x_j + \varepsilon \ldots\ldots\ldots\ldots\ldots\ldots (10)$$

where, Y represents the responses (dependent variables) viz pod yield, kernel yield, 100-kernel weight, above-ground biomass, harvest index, crop water productivity, earth up time productivity and net returns. β_0 represents the constant coefficient; β_i, β_{ii}, and β_{ij} represent the coefficients for linear, quadratic and interaction effects respectively. Also x_i and x_j represent input factors (independent variables) these are irrigation and earth up time levels, while ε is the standard error. The quality of the developed models to predict the response variables i.e. groundnut yield and its components was determined by the coefficients of determination (R^2) while the analysis of variance (ANOVA) was used to evaluate the statistical significance of the model. The developed model was used to plot three-dimensional (3-d) surfaces and two-dimensional (2-d) contour to visualize individual and interactive effects of the process factors on the response variables within the predefined range using *Minitab software, version 17*. Kernel yield, crop water productivity, earth up time productivity and net returns were simultaneously maximized.

RESULTS AND DISCUSSION

Data analysis

Data processing were conducted using *Microsoft Excel 2007*, while ANOVA were conducted at the significant difference of 0.05 (α = 0.05) using *Minitab software, version 17*. Table 3 summarizes the response of the groundnut growth components to the effect of irrigation and earth up time. The interaction between irrigation and earth up time was not significant for groundnut growth components (P < 0.05, 0.001). Considering the individual effects of irrigation and earth up time, it was found that main effect of irrigation was significant for all the growth components (canopy cover, Plant height, Leaf area index and 50% Anthesis). On the other hand, the main effect of earth up time was not significant for the growth components. Therefore, this is evident among the treatments that as irrigation level increases the growth components performance were enhanced. The results are in agreement with the findings of Wien (1997) who found out that Barbara nuts plants' leaf number, leaf area and plant height had a linear correlation with the availability of soil moisture as a result of increase in irrigation regime.

Table 3. Effects of irrigation and earth-up time treatments on groundnut growth

Treatments	Canopy Cover (%)	Plant Height (cm)	Leaf Area Index	Days to 50% Flowering (Anthesis)
$I_{50}\ E_0$	72.51e	15.10d	2.51e	26.32d
$I_{50}\ E_{20}$	78.17de	15.18d	2.48e	26.45d
$I_{50}\ E_{45}$	82.81cd	15.21d	2.45e	26.35d
$I_{50}\ E_{75}$	86.02bcd	15.32d	2.47e	26.53d
$I_{70}\ E_0$	86.91bcd	16.79c	3.34d	26.64d
$I_{70}\ E_{20}$	91.07abc	16.89c	3.37cd	26.88cd
$I_{70}\ E_{45}$	93.58ab	16.82c	3.37cd	27.11bcd
$I_{70}\ E_{75}$	91.44abc	16.91c	3.48cd	26.96bcd
$I_{90}\ E_0$	93.31ab	23.06b	3.81bc	28.19abc
$I_{90}\ E_{20}$	94.58ab	22.67b	4.11ab	28.28ab
$I_{90}\ E_{45}$	96.69a	22.53b	4.11ab	28.29ab
$I_{90}\ E_{75}$	93.47ab	23.19b	3.68bcd	28.07abc
$I_{110E}\ E_0$	97.84a	25.75a	4.35a	29.06a
$I_{110}\ E_{20}$	97.87a	25.88a	4.43a	29.21a
$I_{110}\ E_{45}$	99.59a	25.80a	4.39a	28.76a
$I_{110}\ E_{75}$	97.78a	25.99a	4.35a	29.11a
I	**	**	**	**
E	NS	NS	NS	NS
I x E	NS	NS	NS	NS

I = Irrigation, E= Earth up time. Means that do not share the same letter are significantly different at (P< 0.05, P<0.001)

Table 4 shows the summary of the groundnut yield and its yield components response to the effect irrigation and earth up time. The interaction between irrigation and earth up time was significant for pod number per plant, fresh pod weight, fresh pod yield, kernel yield and harvest index ($P < 0.05, 0.001$). The main effect of irrigation was significant for all the yield components under consideration except for immature pod number. Increase in irrigation level tend to increase yield significantly, however, it was observed that as water application increased beyond certain level, the yield showed a slight decline. Al-Moshileh (2007) also demonstrated a similar reduction in yield in response to high levels of soil moisture for legumes. They found that legumes are susceptible to water logging due to the sensitivity of rhizobia within root nodules to anaerobic condition. Consideration for earth up main effects also shows significance for pod number per plant, immature pod number, fresh pod weight, fresh pod total yield, kernel yield, shell weight and harvest index, respectively.

Table 4. Effects of irrigation and earth-up time treatments on groundnut yield and its components

Treatments	Pod Number per plant	Immature Pod Number per plant	Pod Length (cm)	Fresh Pod weight (kg/plant)	Fresh Pod Yield (t/ha)	Weight of 100 Kernels (kg)	Kernels Yield (t/ha)	Shell weight (t/ha)	Above Ground Biomass (t/ha)	Harvest Index
$I_{50}\ E_0$	7.01e	0.33c	2.57c	0.02i	0.91i	0.14e	0.61g	0.02g	4.54f	0.21g
$I_{50}\ E_{20}$	13.03de	0.67c	2.59c	0.03ghi	1.78ghi	0.14de	1.17fg	0.03efg	4.56f	0.39efg
$I_{50}\ E_{45}$	13.34cde	1.00bc	2.52c	0.03hi	1.73hi	0.14e	1.17fg	0.03efg	4.37f	0.40efg
$I_{50}\ E_{75}$	9.35e	2.67ab	2.34c	0.02i	1.33i	0.14e	0.88g	0.02fg	4.35f	0.31fg
$I_{70}\ E_0$	12.04de	1.33bc	2.78bc	0.04fghi	2.45fghi	0.15cde	1.76efg	0.04efg	4.98ef	0.49def
$I_{70}\ E_{20}$	19.36bcd	1.33bc	2.80bc	0.07cdef	4.05cdef	0.16abcde	2.90cde	0.06bcde	4.86ef	0.83ab

$I_{70}\ E_{45}$	22.06b	0.10c	2.80bc	0.09bcdef	4.98bcde	0.17abcd	3.60cd	0.07bcd	4.89ef	0.73abcd
$I_{70}\ E_{75}$	13.08de	3.33a	2.63c	0.05fghi	2.60fghi	0.15bcde	1.89efg	0.04efg	4.98ef	0.52cdef
$I_{90}\ E_{0}$	14.02cde	1.00bc	3.38ab	0.06defg	3.50defg	0.18ab	2.54de	0.05cdef	5.40def	0.65bcd
$I_{90}\ E_{20}$	20.77bc	0.67c	3.64a	0.10bcd	5.17bcd	0.18abc	3.67bcd	0.08bc	6.04cde	0.87ab
$I_{90}\ E_{45}$	26.68ab	0.67c	3.52a	0.12ab	6.67ab	0.19a	4.98ab	0.09ab	7.42bc	0.90a
$I_{90}\ E_{75}$	16.06de	3.67a	3.37ab	0.06efgh	3.25efgh	0.17abc	2.40def	0.04defg	7.28bc	0.57cde
$I_{110E}\ E_{0}$	22.37b	0.33c	3.61a	0.11bc	5.33bc	0.18ab	4.19bc	0.06bcde	7.53b	0.71abcd
$I_{110}\ E_{20}$	22.39b	0.33c	3.73a	0.11bc	5.58bc	0.19a	3.98bc	0.08ab	7.57b	0.74abc
$I_{110}\ E_{45}$	31.05a	0.10c	3.73a	0.15a	8.27a	0.18abc	6.07a	0.11a	9.68a	0.85ab
$I_{110}\ E_{75}$	21.60b	3.33a	3.84a	0.10bc	5.34bc	0.17abcd	3.97bc	0.07bcd	9.71a	0.69abcd
I	**	NS	**	**	**	**	**	**	**	**
E	**	**	NS	**	**	NS	**	**	NS	**
I x E	**	NS	NS	**	**	NS	**	**	NS	**

I = Irrigation, E= Earth up time.   Means that do not share the same letter are significantly different at (P< 0.05, P<0.001)

Evaluation of optimized Irrigation water/Earth up time combination

In order to obtain the optimized inputs of irrigation water and earth up time for the groundnut, the lower limits of irrigation and earth up time were set as I_{50} and E_0 respectively, while the upper limits were extended to I_{110} and E_{75}.

Fresh Pod yield

The highest fresh pod yield (6.53 ton/ha) was obtained by application of 420 mm irrigation water and earth up time of 45th day after planting while the lowest fresh pod yield (1.53 ton/ha) was observed at the lowest levels of all combination treatments i.e. 120 mm irrigation water and 0 day also 75th day after planting. The effects of independent variables on fitted fresh pod yield curves by full quadratic polynomial equation are shown in Equation (11). The quadratic model revealed that irrigation and earth up time are significant at $p<0.05$ as shown by the model summary table. While the interactions between irrigation and earth up time are not significant. The model summary reveals that model lack of fit is not significant, while the coefficient of determination is *86.48%*. The standard deviation is 0.82 while the 3D and 2D views are shown in
Figures 1 and 2. Aminpour and Mousavi (2006) also reported that onion yield was improved by increasing of irrigation water volume.

Regression equation for Pod Yield (t/ha)

$$Y_{pod} = -5.27+0.0298I + 0.1103E - 0.000018I^2 -0.001461E^2 + 0.000011I*E \quad \ldots\ldots\ldots\ldots\ldots (11)$$

where, I = irrigation amount (mm)   and E = Earth up time (Days after planting)

Model Summary

S	*R-sq*	*R-sq(adj)*	*R-sq(pred)*	*p*	*Lack of Fit*
0.817	*86.48%*	*84.87%*	*82.62%*	*0.001*	*0.064*

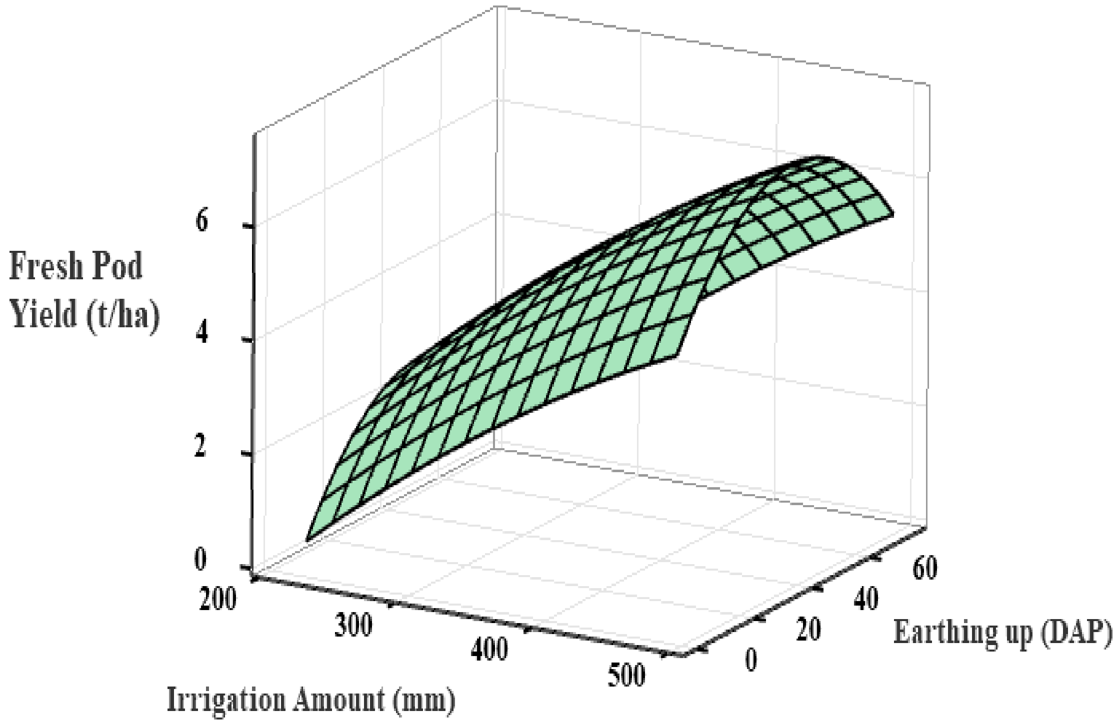

Figure 1. The 3D view of the groundnut fresh pod yield from interaction of irrigation and earth up time.

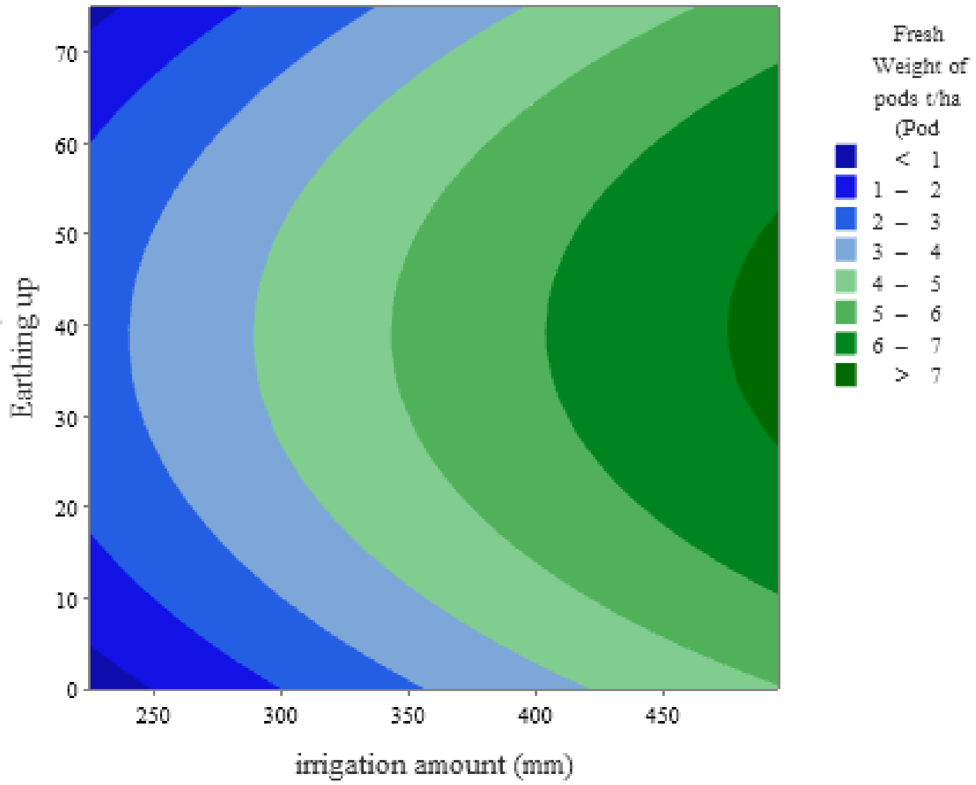

Figure 2. The 2D view of the groundnut fresh pod yield from interaction of irrigation and earth up time

Fresh Kernel yield

The highest fresh kernel yield (5.20 ton/ha) was obtained by application of 420 mm irrigation water and earth up time of 45th day after planting while the lowest fresh kernel yield (1.13ton/ha) was observed at the lowest levels of all combination treatments i.e. 120 mm irrigation water and 0 day also 75th day after planting. The effects of independent variables on fitted fresh kernel yield curves by full quadratic polynomial equation are shown in Equation (12). The quadratic model revealed that irrigation and earth up time are significant at $p<0.05$ as shown by the model summary table. The elliptical curve shown in Figures 3 and 4 are the fallout of interaction between the input factors while the interactions between irrigation and earth up time are significant. The model summary reveals that model lack of fit is not significant (0.093), while the coefficient of determination is *85.37%*. The standard deviation is 0.64.

Regression equation for Weight of Fresh Kernel (t/ha)

$$Y_{kernel\ yield} = -4.06 + 0.02229I + 0.0784E - 0.000013I^2 - 0.001020E^2 + 0.000004I*E \ldots\ldots\ldots\ldots (12)$$

where, I = irrigation amount (mm) and E = Earth up time (Days after planting)

Model Summary

S	*R-sq*	*R-sq(adj)*	*R-sq(pred)*	*p*	*Lack of fit*
0.642	*85.37%*	*83.63%*	*81.01%*	*0.001*	*0.093*

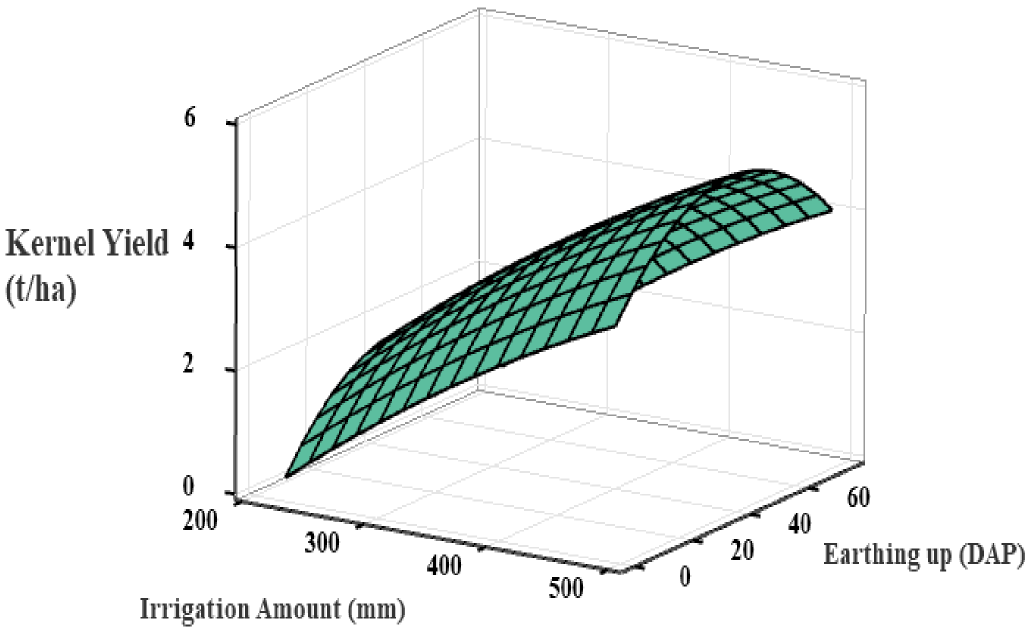

Figure 3. The 3D view of the groundnut kernel yield from interaction of irrigation and earth up time.

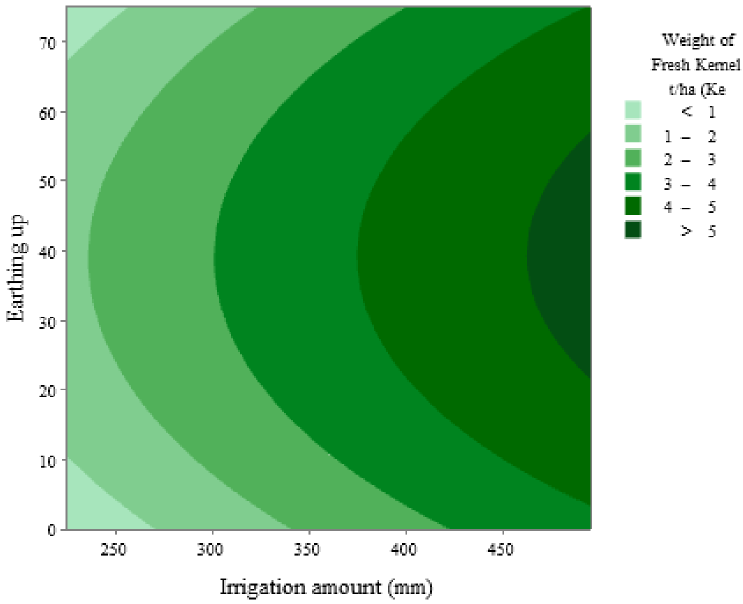

Figure 4. The 2D view of the groundnut kernel yield from the interaction of irrigation and earth up time.

Crop water productivity

The highest water productivity (10kg/ha/mm) was obtained by application of 420 mm irrigation water and earth up time of 45th day after planting while the lowest fresh kernel yield (3.2kg/ha/mm) was observed at the lowest levels of all combination treatments i.e. 120mm irrigation water and 0 day also 75th day after planting. The effects of independent variables on fitted fresh kernel yield curves by full quadratic polynomial equation are shown in Equation (13). The quadratic model revealed that irrigation and earth up time are significant at $p<0.05$ as shown by the model summary table. The elliptical curve shown in Figure 5 is the fallout of interaction between the input factors. While the interactions between irrigation and irrigation, earth up time and earth up time are not significant. The model summary reveals that model lack of fit is not significant (0.093), while the coefficient of determination is *73.63%*. The standard deviation is 1.63. The water productivity was observed to decline after applying 430 mm irrigation water. This is evident in the 3D and 2D surface plot in Figure 5 and 6. Pervin *et al.* (2014) in a similar experiment in Gazipur, Bangladesh on groundnut reported that irrigation application between 370 mm and 450 mm gave the best water productivity, further irrigation beyond 45 0mm did not lead to significantly productivity rather a decline.

Regression equation for Water Productivity (kg/mm/ha)

$Y_{water\ productivity} = -11.86 + 0.0839I + 0.2246E - 0.000092I^2 - 0.002796E^2 - 0.000015I{*}E$……………….(13)

where, I = irrigation amount (mm) and E = Earth up time (Days after planting)

Model Summary

S	*R-sq*	*R-sq(adj)*	*R-sq(pred)*	*p*	*Lack of fit*
1.626	*73.63%*	*70.49%*	*66.33%*	*0.000*	*0.089*

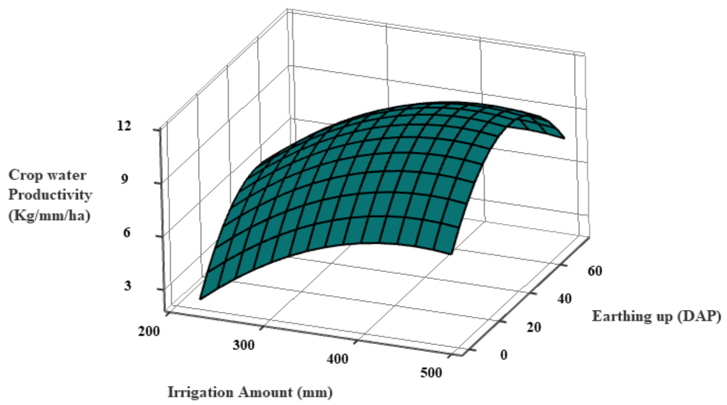

Figure 5. The 3D view of the crop water productivity from the interaction of irrigation and earth up time.

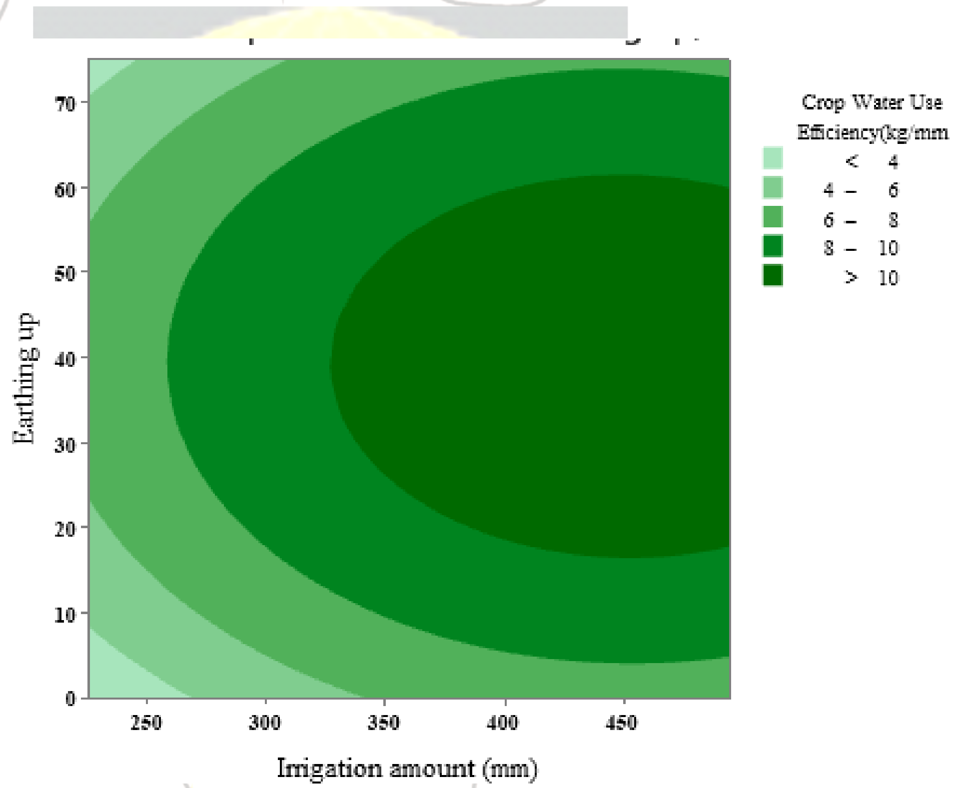

Figure 6. The 2D view of the crop water productivity from the interaction of irrigation and earth up time.

Earth up time productivity

The highest earth up time productivity (10kg/ha/day) was obtained by application of 420 mm irrigation water and earth up time of 45th day after planting while the lowest earth up time productivity (3.2kg/ha/mm) was observed at the lowest levels of all combination treatments i.e. 120mm irrigation water and 0 day also 75th day after planting. The effects of independent variables on fitted fresh kernel yield curves by full quadratic polynomial equation are shown in Equation (14). The quadratic model revealed that irrigation and earth up time are significant at $p<0.05$ as shown by the model summary table. The elliptical curve shown in Figure 7 is the fallout of interaction between the input factors while the interactions between irrigation and irrigation, earth up time and earth up time are not significant. The model summary reveals that model lack of fit is not significant (0.093), while the coefficient of determination is *73.63%*. The standard deviation is 1.63. The earth up time productivity was observed to decline after applying 430 mm irrigation water. This is evident in the 3D and 2D surface plot in Figures 7 and 8. Pervin *et al.* (2014) in a similar experiment in Gazipur, Bangladesh on groundnut reported that irrigation application between 370 mm and 450 mm gave the best water productivity, further irrigation beyond 450 mm did not lead to significantly productivity rather a decline.

Regression equation for Earth up time productivity (kg/day/ha)

$$Y_{\text{Earth up time producitivity}} = -159.4 + 0.820I + 5.040E - 0.000680I^2 - 0.06617E^2 - 0.00091I*E \ldots\ldots\ldots\ldots (14)$$

where, I = irrigation amount (mm) and E = Earth up time (Days after planting)

Model Summary

S	*R-sq*	*R-sq(adj)*	*R-sq(pred)*	*p*	*Lack of fit*
34.72	*71.83%*	*68.48%*	*64.48%*	*0.000*	*0.063*

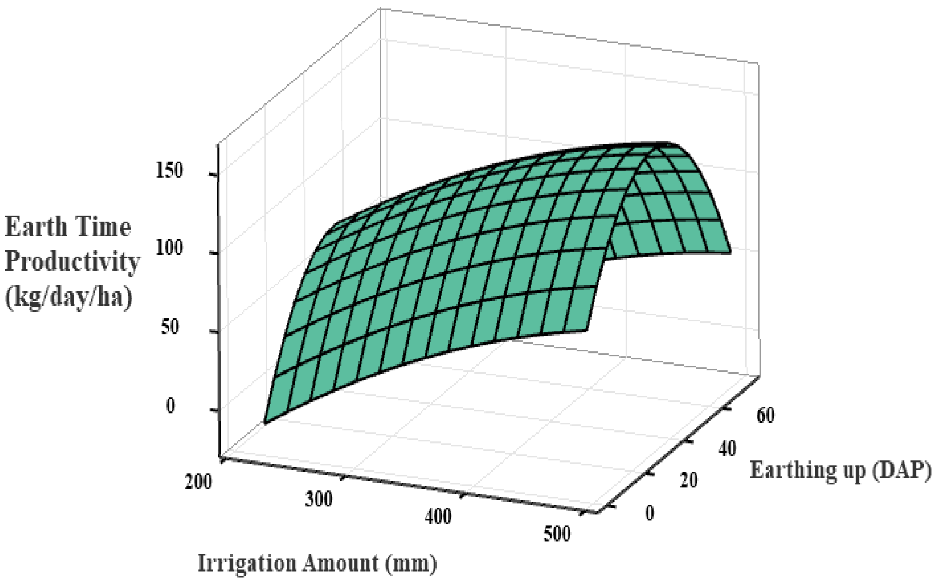

Figure 7. The 3D view of the earth time productivity from the interaction of irrigation and earth up time.

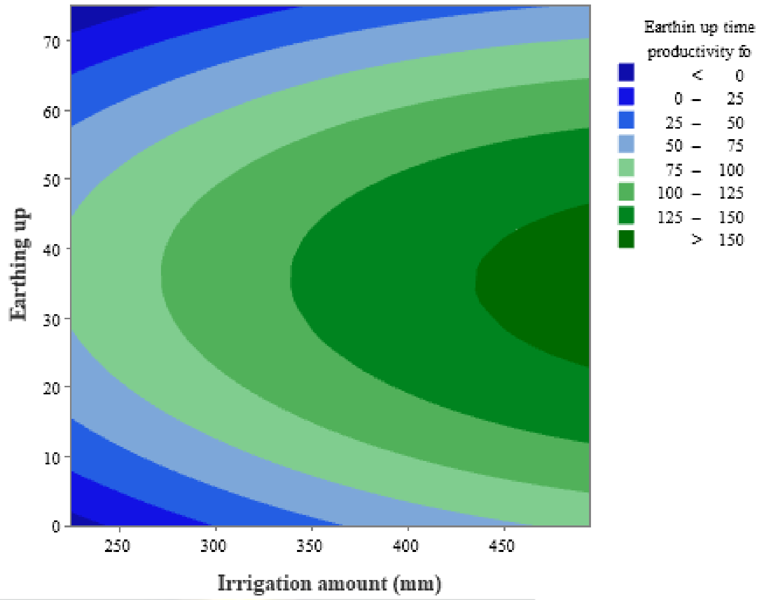

Figure 8. The 2D view of the earth time productivity from the interaction of irrigation and earth up time.

Resource optimization

Optimum levels of irrigation and earth up time for achieving the targeted rates of responses based on maximum yield, water productivity and earth time productivity. The results of economic scenario showed that 420 mm irrigation water and earth up time from 37th day after planting resulted above 9 ton /ha, above 150 kg/ha/day for earth time productivity and above 12 kg/ha/mm for water productivity as shown in Figure 9.

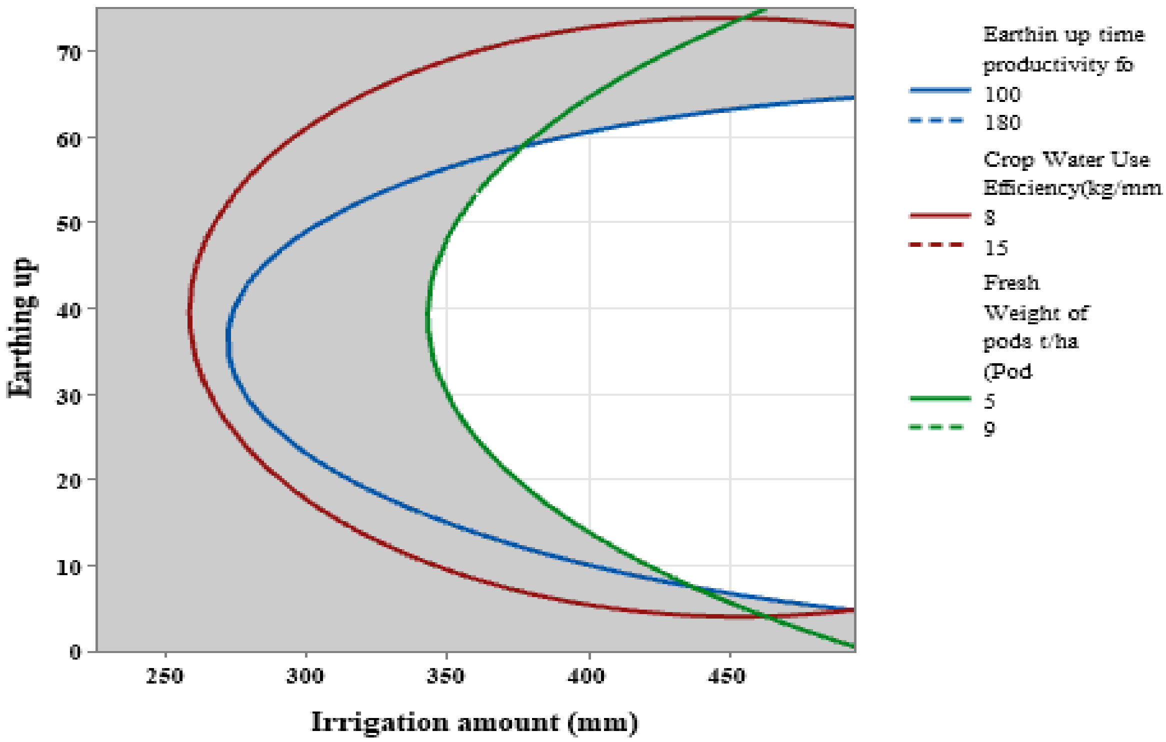

Figure 9. Comprehensive evaluation of pod yield, crop water productivity and earth up time productivity of groundnut under irrigation and earth up time.

***Note**: Unshaded area in figure means the feasible zones ≥95 % of the maximum value of pod yield, crop water productivity and earth up time productivity.*

CONCLUSIONS AND RECOMMENDATION

Increasing irrigation beyond 450mm will result in yield decline. While setting up earth up before 20 days after planting may not result into yield increase, while setting earth up beyond 70 days after planting will not result in yield increase. Therefore, the optimal irrigation level and earth up time for groundnut in this agro-ecological zone are 450 mm and 37 days after planting, respectively. Therefore, the optimal irrigation level and earth up time recommended as the most economical for groundnut production in this agro-ecological zone are 450mm and 37 days to 55 days after planting.

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IDENTIFICATION OF OPTIMUM TILLAGE TIME IN KAFANCHAN AREA OF KADUNA STATE NIGERIA USING REMOTELY SENSED DATA

[1]Danbaba G. and [2]Tanam U. I.
[1,2]Department of Environment Management, Bingham University, Karu
[1]danbaba.goma@binghamuni.edu.ng
[2]tanam.isaac@binghamuni.edu.ng

ABSTRACT
Tillage has been identified as the single most expensive operation in crop production. Major causes of this are the amount of energy expended to overcome adverse soil conditions. These conditions exist because of wrong or inappropriate timing of the operation. Farmers in Kafanchan area have been observed to spend a great deal of resources during tillage for lack of knowledge the optimum time for the operation. The purpose of this work therefore, was to identify the optimum time for tillage operation in Kafanchan. The Thornthwaite and Mather model was used to compute the monthly potential evapotranspiration (PET) for Kafanchan from data gathered remotely in order to compute the climatic water balance. Results observed revealed that the area had water deficit in the months of January (0.00mm) to mid-May (484.09mm) and October to December (0.00mm). Water surplus was observed from May and ends mid-October. From the developed graphical model, it was concluded that the optimum tillage time in Kafanchan should be from the second week of May and should stop in the first week of June.

1. INTRODUCTION

Tillage operation in various forms have been practiced from the very inception of growing plants. Primitive man used tools to disturb the soils for placing the seeds (Davies, 1983). The word tillage is derived from 'Anglo-Saxon' words *Tilian and Teolian,* meaning to plough and prepare soil for seed to sow, to cultivate and to raise crops. Tillage is the mechanical manipulation of soil with tools and implements for obtaining conditions ideal for seed germination, seedling establishment and growth of crops (Kawuyo *et al*, 2017). Tillage remains the single most expensive operation in crop production. Sheruddin *et al* (1988) described it as the single most expensive input to crop production, contributing about 20% of factors involved in the operation can be on-season and off-season tillage (Khurshid *et al*., 2006;). This is as a result of the energy intensity involved.

As a soil engagement operation, the condition of the soil is critical to the performance of tillage tools and so must be considered in every tillage system (Tanam and Babatunde, 1995). Whereas soil type is a major contributor to tillage quality, Ozgoz *et al* (2012) reported that temporal variability of soil physical properties can be greater than spatial variability. Ahaneku and Dada (2013), citing Lewandowski *et al* (1999) included timing of tillage and soil water content among factors that affect tillage quality. Similarly, Hua *et al* (2020), citing James and Kenichi (2005) and Romer and Romula (2018) included time, ambient temperature and load as external factor influencing soil behaviour. Adama *et al* (2022) referred to optimum time of field operation as the appropriate time for that operation, and added that failure to carry out the operation at the optimum time leads to reduction in both quality and quantity of yield. It must be added that not carrying out tillage operation at the optimum time leads to high energy consumption as more power may be required to overcome difficult soil conditions. Difficult soil conditions include hardness in dry condition and stickiness in wet condition. Tanam (1994) explained that moisture content greatly affects the type of failure soil undergoes during ploughing for instance, as well as the failure strength. Very high moisture content leads to low soil workability due to increased failure strength resulting from pore water pressure, or high slip level due to the molten nature of the soil. Friable stage of the soil, the moisture content between shrinkage limit and plastic limit, has been identified as the best stage of performing tillage. Farmers in and around Kafanchan have spent a great deal of resources during tillage for not knowing the optimum time for the operation. The aim of this work therefore, was to identify the optimum time for tillage operation in Kafanchan.

2. MATERIALS AND METHOD

2.1 Study Area

Kafanchan is the capital town of Jema'a Local Government Area of Kaduna state of Nigeria. Located in the southern part of the state, it lies on latitude 9°34'52.54" N and longitude 8°17'33.36" E and altitude of 742 m. The town lies within Southern Guinea Agro-Ecological *Zone* consisting of forests and savannah lands*, with a* population of about 79,522 majority of whom are predominantly farmers.

2.2 Data Collection

Three different soil textures, silty loam, sandy loam and loamy sand, were identified within the study area. The mean monthly precipitation and observed runoff for the period of 31 years, January 1990–December 2021, for Kafanchan was obtained from remotely sensed Meteorological data of Kaduna State obtained from National Aeronautics and Space Administration (NASA).

2.3 Model Evaluation

Monthly potential evapotranspiration (PET) was computed using the Thornthwaite and Mather (TM) (1957) model given in equation (1) for determination of climatic water balance.

$$PET = 16 \times C \times \left(10 \times \frac{T}{I}\right)^{a} \qquad (1)$$

where

PET = the potential evapotranspiration (mm month^{-1});

T = the mean monthly temperature (°C);

I = the annual heat index for the 31 years ($I = \Sigma i$);

i = the monthly heat index$\left(i = \left[{}^{T}/_{5}\right]^{1.514}\right)$;

a $= 6.75 \times 10^{-7} \times I^3 - 7.71 \times 10^{-5} \times I^2 + 1.792 \times 10^{-2} \times I + 0.49239$

C = a correction factor for each month ($C = [m/30] \cdot [d/12]$), where *m* is the number of days in the month and *d* is the monthly mean daily duration, that is, number of hours between sunrise and sunset and expressed as the average for the month.

The quantitative water surplus (+) or deficit (-) with P as precipitation was estimated using P - *PET*, which was determined in Table 2. The cumulative values of (*P* - *PET*) determined the accumulated potential water loss (*APWL*), for each month. Beginning with the first month after the rainy season that has a negative value, this was zero for months having positive P - PET values. The actual soil moisture storage (*STOR*) for each month was determined equation (2).

$$STOR = AWC \times e^{(APWL/AWC)} \qquad (2)$$

where *AWC* is the water holding capacity (Available Water Capacity) of the soil.

This was calculated based upon the land cover, soil texture and rooting depth as suggested by Thornthwaite & Mather (1957). Table 1 is the summary of the computation. Changes of actual storage (ΔSM) for all the months were calculated using equation (3).

$$\Delta SM_{month} = STOR_{month} - STOR_{previous\ month} \qquad (3)$$

Table 1: Computation of water holding capacity of the root zone and available water capacities (*AWC*) for different soil textures and land uses

Soil Texture	AWC (%)	Rooting	Depth of AWC (mm)
Sand	10	0.5	83
Sandy Loam	15	1.5	300
Loamy Sand	10	0.5	50
Silty Loam	20	0.62	125
Loamy Sand	10	1	100
Sand	10	0.3	20

Source: Author's Compilation, (2023)

Water infiltration and its addition to the soil moisture storage are implied by a positive value of SM, whereas a negative value of SM denotes subtraction of water from the storage that was used for evapotranspiration.
The actual evapotranspiration (*AET*) was computed for all the months, as given in equations (4) and (5).

$$AET = \Delta SM + P \quad \text{for} \quad \Delta SM < 0 \qquad (4)$$

$$AET = PET \quad \text{for} \quad \Delta SM > 0 \qquad (5)$$

Equation (6) was used to calculate the water deficit (*DEF*) for crop evapotranspiration in each month for the months having negative ($P - PET$).

$$DEF = PET - AET \qquad (6)$$

The amount of excess water that cannot be stored is denoted as moisture surplus (*SUR*). When storage reaches its capacity, *SUR* is calculated using equation (7).

$$SUR = P - PET \qquad (7)$$

When the soil storage is not at its capacity, no surplus exists. In a month in which the soil moisture storage capacity is just satisfied, *SUR* is obtained using equation (8).

$$SUR = P - (AET + \Delta SM) \qquad (8)$$

where ΔSM is the change in actual soil moisture storage.
The available annual surplus is defined by equal the actual runoff. The monthly computed surplus should be higher than the monthly runoff (RO) because of the delay between the time of precipitation and the time when water actually passes the gauging station. For large catchments, it can be expected that in any given month, about 50% of the surplus water that is available for runoff goes off (Thornthwaite and Mather, 1957). The remainder of the excess is stored in the basin's subsurface, groundwater, tiny lakes, and channels and is ready for runoff throughout the course of the following month.
Taking into account the area with various land uses and the corresponding values from the monthly water balance table, the annual amount of real evapotranspiration and runoff from the watershed was computed. Area-weighted data represent the monthly real evapotranspiration and runoff from each catchment area.

3 RESULTS AND DISCUSSION

Table 2 indicates the accumulated potential water loss (*APWL*) for Kafanchan Area from monthly precipitation and temperature as prescribed in the TM Model.

Table 2: Summary of the P, PET, AET and runoff for Kafanchan (mm).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
P	0.00	0.00	93.16	67.70	484.09	793.59	814.05	484.38	625.91	268.04	0.00	0.00	**3630.93**
PET	98.90	110.76	122.35	117.19	103.96	70.66	57.66	57.73	60.36	65.75	62.65	66.96	**994.92**
AET	-56.02	-24.95	89.15	62.28	103.96	70.66	57.66	57.73	60.36	65.75	0.00	0.00	**486.57**
Runoff	45.77	22.89	11.44	5.72	14.15	368.54	562.47	494.56	530.05	366.18	183.09	91.54	**2696.40**

Source: Author's Analysis, 2023.

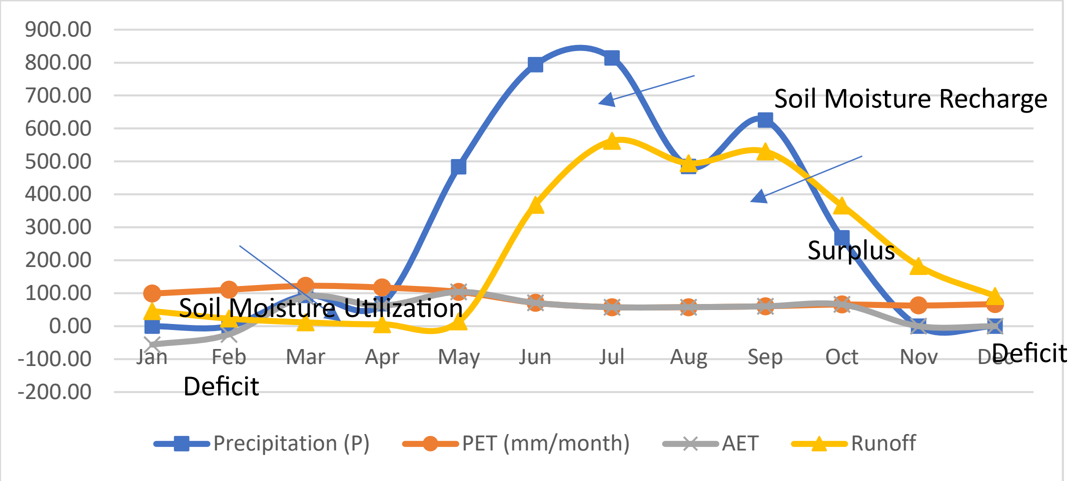

Figure 1: Water Balance Status of Kafachan Area

This graph gives a great deal of information regarding the water balance of the Kafachan area. Besides showing the seasonal pattern of precipitation, actual evapotranspiration (*AET*), potential evapotranspiration (*PET*) and runoff, it indicates the periods of moisture deficit, soil moisture recharge, soil moisture utilization and the optimum tillage time. Figure 2 is a comparison of water balance deficit and surplus in Kafanchan.

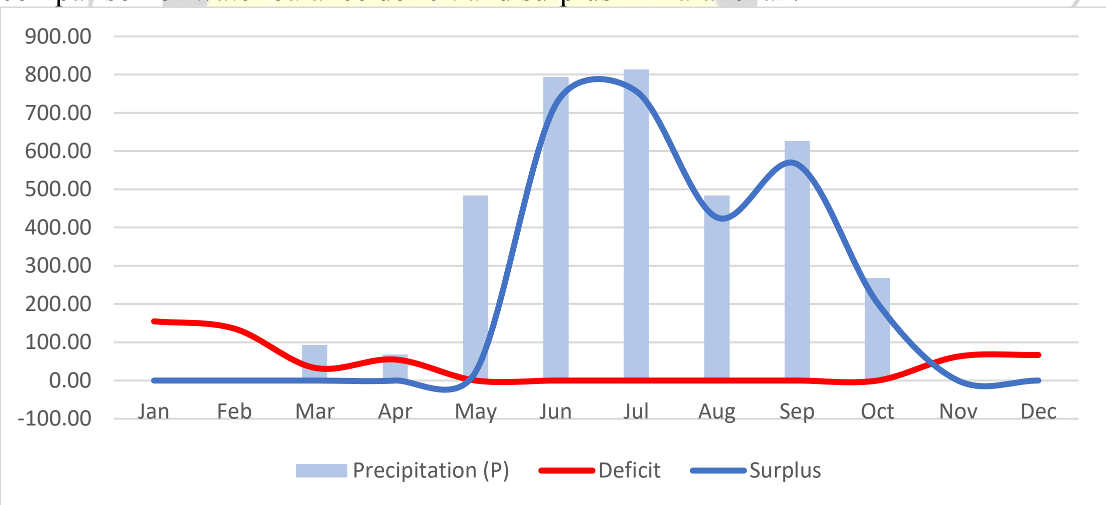

Figure 2: Water Balance Comparison between Surplus and Deficit in Kafachan Area

The moisture deficit indicates that plants will be under some stress during that period, indicating the need for irrigation. The area is relatively dry in the months of January–May. Further, it can be seen that there is a water deficit again in the months of October–December. Soil moisture recharge takes place from early May to August. From mid-May to December is the period of water surplus.

Comparatively, it be observed from Figure 2 that surplus within Kafanchan begins in May and ends mid-October. Whereas, Deficit reigns through mid-October back to May with peak deficit in the month of January (154.92 mm). Optimum tillage time therefore, should be from second week of May and should not exceed the first week of June.

4 CONCLUSIONS

A study of 31-year precipitation pattern of Kafanchan area of Kaduna State – Nigeria was conducted in order to determine the optimum tillage time for the area. The monthly potential evapotranspiration (PET) for Kafanchan was computed using Thornthwaite and Mather model using data obtained remotely from NASA to determine the climatic water balance for the area. Results obtained showed that the area was relatively dry in the months of January–May and there was a water deficit again in the months of October–December. There was a surplus from May to mid-October. The graphical model developed revealed that the optimum tillage time in Kafanchan should be from the second week of May to the first week of June.

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EFFECT OF MAGNETISED WATER ON ENVIRONMENTAL AIR POLLUTION FROM POULTRY DROPPINGS OF BROILER CHICKEN

Oniya[1] O. O; Baker[2] A. T; Jimoh[3] R. O; Ilevbaoje[4] O. O; Haruna[4] A. A
[1] Department of Agricultural Engineering, Ladoke Akintola University of Technology, Ogbomoso
[2]Department of Land and Water Management Engineering, National Centre for Agricultural Mechanization, Ilorin, Nigeria.
[3]Department of Engineering and Scientific Services, National Centre for Agricultural Mechanization, Ilorin, Nigeria.
[4]Department of Land and Water Management Engineering, National Centre for Agricultural Mechanization, Ilorin, Nigeria.
Corresponding author: bakeradebayour@gmail.com

Abstract
This study was conducted to assess the effect of magnetised water (MW) on the environmental air pollution by the poultry droppings from the broiler chicken (BC). Poultry farming is an essential contributor to Nigeria's economy and a source of protein for human consumption. Despite its significance, many poultry farms in Nigeria experience offensive odour around the area where poultry farm is sited. Affordable solutions are necessary to overcome these challenges. Forty numbers of broiler chickens were housed at National Integrated Farm Project (NIFAP), Ilorin, Nigeria. The magnetised water treatment unit had a transparent container surrounded with 12 pieces of 10 x 25 x 50 mm neodymium magnet rated 1.5 Tesla, connected to a 50 L bucket with 25.4 mm pipe for regulating the flow of water. The experiment had four treatment houses denoted as T_0, T_1, T_2 and T_3 with ten birds in each of the treatment houses. T_0 was a non-magnetised water group served as a control group, T_1 was water magnetised for 55 s, T_2 for 110 s and T_3, for 165 s. Ammonia concentration in each of the treatment houses were determined using UV spectrophotometer from 3rd -7th week and recorded. The paired t-test statistical analysis was used to analyze the result of the experiment.

Keywords: magnetised water, broiler chicken, air pollution, paired t-test, poultry droppings

1.0 INTRODUCTION

One of the issues with a chicken farm is the air pollution (offensive odour) where it is located. The two primary odor contaminants in a poultry farm are ammonia (NH_3) and hydrogen sulfide (H_2S). Nkukwana (2018) believes that broiler chicken farming is essential for a nation's economic progress and offers animal nutrition for normal growth. The chemical breakdown of uric acid in bird droppings by certain bacteria in the litter produces ammonia, a gas that is present in every poultry house and has a significant negative impact on the health and wellbeing of the birds (Sheikh et al., 2018). In homes where eliminated litter is used to raise subsequent flocks, ammonia generation is very high.

According to Ritz et al. (2009), ventilation and litter quality have the most impacts on the ammonia levels in chicken buildings. The amount of moisture, pH, and temperature in the litter have an impact on how quickly bacteria break down uric acid. Wet litter is a typical problem in chicken houses, which eventually raises the ammonia content. typical reasons include poor ventilation, sloppy droppings, and malfunctioning, overfilled, or low-positioned drinkers. According to Li et al. (2017), the ammonia level in chicken houses shouldn't be more than 25 ppm. The performance of the birds is negatively impacted over 25 ppm. High concentrations also impair the birds' immune systems, body weight increase, feed conversion, general livability, carcass condemnation rate, and susceptibility to illness. The conjunctiva, corneas of the eyes, and mucous membranes of the respiratory system are all irritated by the characteristically unpleasant odor of ammonia gas at high concentrations (Swelum et al., 2021).

The study by Allocati *et al*. (2013), birds are more susceptible to respiratory infections, particularly E. coli infections, since increased levels of ammonia induce damage to the mucous membranes of the respiratory system. Ammonia concentrations of 20 to 30 ppm usually allow humans to detect its odour. The health and wellbeing of the birds are seriously impacted by ammonia gas in poultry houses. Ventilation systems are intimately related to the ammonia content in poultry houses. By lowering the bonding angle from 1040 to 1030, decreasing the surface tension, raising its solubility, and lowering the rate of carbonate deposition in pipe, magnetized water's characteristics are altered (Babu 2010). The goal of this study was to determine the impact of magnetised water on the air pollution caused by broiler chicken droppings.

2.0 MATERIALS AND METHODS

This study was housed at the National Integrated Farm Project (NIFAP) unit of the National Centre for Agricultural Mechanization (NCAM), Ilorin, Nigeria on longitude 4.6122^0 East and Latitude 8.4161^0 North. A total number of 40 broiler chicken at a day-old were randomly distributed into 4 treatment groups of 10 birds each. The system of rearing for the first 4 weeks was a deep litter system where the treatment houses were constructed using planks and iron sheets and the floor was covered with some wood shavings as the litters, and the remaining 3 weeks, the birds were transferred to the battery cage house. (Figures 1a and 1b). In this system of housing, the birds were kept in litter floor arrangement of 1.90 m by 1.14m dimension. Feed and water were made inside the house and as a general rule of thumb, broiler chicken require 1 kg of starter crumbs of grower pellets and 1.5 kgs of finisher pellets. The total quantity of feed fed to the birds at the end of 7th week of the study was 150 kg bags of starter feed and 250 kg bags of finisher feed.

According to Alhassani and Amin (2012), chicken requires 0.91 – 1.36 litres of water for every 0.45 kg of feed consumed and estimated the daily water consumption of broilers by multiplying the age of the bird in days by 0.00591 litres of water. In this study, broiler chickens in each treatment houses were given 10 litres of water per day and at the 7th week, the total quantity of water given to the birds was estimated to be 490 litres.

Figures1a and b: Deep litter house and battery cage house respectively.

2.1 Magnetic Treatment Unit

The magnetic treatment unit was developed by using 10 x 25 x 50 mm neodymium magnet. Neodymium magnet is a permanent magnet that is produced by adding neodymium (Nd)), iron (Fe) and boron (B) together to form NdFeB magnet which is the strongest magnet available globally with magnetic flux density ranging from 1.0-1.5 T (1T = 10,000 G) or even greater. According to Alhammer *et al*. (2013), neodymium is a strong rare earth magnet which is effective at room temperature and a high temperature up to 80 ^{0}C without demagnetization.

The magnetic treatment unit in this study employed the arrangement used by Yusuf *et al*. (2022) which consisted of a pipe (a 20 by 60 mm diameter rectangular transparent pipe and 960 mm long but constructed using a plastic container) surrounded with 12 pieces of the neodymium magnet. The magnetic treatment unit was connected to a 50 L bucket with 25.4 mm pipe control for regulating the flow of water. Another 20 L bucket was connected with a non-returning valve along the main pipe for the distribution of water for treatment houses 2 and 3. Figures 2a and 2b showed pictorial views respectively of the magnetic treatment device for producing magnetised water.

Figures. 2a and b: Pictorial view of the magnetic treatment unit set – up for the production of magnetised water.

The magnetised water that was used for this study was produced using a flowing method, where water was allowed to flow through the magnetic field in the magnetic treatment chamber. The water source for the production of broiler chicken was from a running tap water in the poultry farm and allow to flow through the magnetic treatment unit once for 55 seconds which was given to the broiler chicken in the treatment house denoted as T_1, the broiler chicken in the treatment house T_2 were given magnetised water which was allowed to pass through the magnetic treatment unit for 110 seconds, and the broiler chicken in the treatment house T_3 were given magnetised water which was allowed to pass through the magnetic treatment unit for 165 seconds. Broiler chicken in the control house denoted by T_0 were given non-magnetised water.

2.2 Analysis of Concentration of Ammonia (Offensive Odour) of the Poultry Droppings

Ammonia generation in the poultry houses results from the breakdown of nitrogen containing compounds in the poultry litter. Ammonia has a distinctive, pungent smell and is known for its irritating effect on the respiratory system, eyes and mucus membrane. Samples from the poultry droppings as shown in Figure 3 were collected from the broiler chicken on the 3rd, 4th, 5th, 6th and 7th week to assess the effect of drinking magnetised water (MW) on the offensive odour by poultry droppings. The samples were put in a white polythene sack and taken to the Central Research Laboratory of Nigerian Stored Product Research Institute, NSPRI Ilorin, Nigeria for the determination of the concentrations of Ammonia (NH_3). Standard methods of UV spectrophotometer were used as given by Kamal *et al.* (2016).

Figure 3: Samples of poultry droppings collected

2.3 Paired t-test statistical analysis for ammonia concentration

The statistical analysis adopted was the paired t-test to know if the effect of MW was significant on the air pollution by the broiler chicken or not. The mean difference between the results of magnetised water and that of NMW was determined. The mean, the standard deviation, the standard error and the t-test values were calculated using Equations (1), (2), (3) and (4) respectively as given by Hedberg and Ayers (2015). The data for used for the computation of the paired t-test as an illustration was obtained from Table 2 and presented in Table 1

$$\overline{d} = \frac{\sum d}{n} \tag{1}$$

$$\delta = \sqrt{\frac{\sum d^2 - n(\bar{d})^2}{n-1}} \quad (2)$$

$$\delta_{Er} = \frac{\delta}{\sqrt{n}} \quad (3)$$

$$t_{cal} = \frac{\bar{d}}{\delta_{Er}} \quad (4)$$

where;

$\bar{d}$ = mean of the difference from x_1 and x_2,

Σd = summation of d

n = number of the observations,

δ = standard deviation

σ_{Er} = standard error

t_{cal} = calculated value of t-test.

$$\bar{d} = \frac{383.8}{7} = 54.83$$

$$\delta = \sqrt{\frac{25141.24 - 7(54.83)^2}{7-1}} = 26.131$$

$$\delta_{Er} = \frac{26.131}{\sqrt{7}} = 9.861$$

$$t_{cal} = \frac{54.83}{9.861} = 5.560$$

t_{cal} was compared with the value of t_{tab} at α = 5% significant level but 2.5 % (α = 0.05/2 = 0.025) for paired t t-test.

Table 1. Data of ammonia extracted from Table for calculating the paired t-test

Conc. NH_3 NMW	Conc. NH_3 MW_1	d= NMW -MW_1	d^2
0.01060	0.00238	0.00778	0.00006053
0.09830	0.00339	0.00644	0.00004147
0.01021	0.00574	0.00447	0.00001998

0.01139	0.00787	0.00352	0.00001239
0.01127	0.00797	0.00330	0.00001089
n = 5		$\sum d = 0.02551$	$\sum d^2 = 0.0001453$

3.0 RESULTS AND DISCUSSION

3.1 Concentration of Ammonia in poultry droppings

The result of the concentration of ammonia gas (NH_3) from the droppings of broiler chickens that were given magnetised water and non-magnetised water are presented in Table 2, the mean concentration of NH_3 for MW_1 were 2.38×10^{-3}, 3.39×10^{-3}, 5.7416×10^{-3}, $7.87 \times 10^{-}3$ and 7.97×10^{-3}mg/kg; MW_2 were 3.18×10^{-3}, 2.10×10^{-3}, 4.66×10^{-3}, 7.32×10^{-3}, and 6.91×10^{-3}mg/kg; MW_3 were 2.06×10^{-3}, 3.64×10^{-3}, 4.63×10^{-3}, 5.61×10^{-3} and 5.17×10^{-3}mg/kg; while the corresponding values of NMW were 10.16×10^{-3}, 9.83×10^{-3}, 10.21×10^{-3}, 11.39×10^{-3} and 11.37×10^{-3}mg/kg. Figure 4.6 showed the trends of the concentration of ammonia in the poultry house. The result from the broiler with non-magnetised water showed higher values throughout the study period. The higher values of ammonia, the more pronounced is the environmental odour produced by the waste. For each of the five times that samples were collected for the examination, the broiler chicks who received magnetized water had lower levels of ammonia gas.

This indicates that, as compared to broiler chicks given non-magnetized water, the feed given to them was digested more quickly and more extensively, which ultimately resulted in a lower concentration of NH3. The result was in agreement with the study of Yusuf et al. (2022) who reported that magnetised water reduced the concentration of ammonia gas and also reduced the offensive odour from the poultry droppings.

Table 2. Concentration of Ammonia (NH_3) in the poultry droppings

Wk.	To (mg/kg) [NH_3 (%) $\times 10^{-3}$]	T1 (mg/kg)	T2 (mg/kg)	T3 (mg/kg)	UEPA 2001
3	10.16	2.38	3.18	2.06	5.00
4	9.83	3.39	2.10	3.64	-
5	10.21	5.74	4.66	4.63	-
6	11.39	7.87	7.32	5.61	-
7	11.27	7.97	6.91	5.17	17.00
Total	**52.96**	**27.35**	**24.17**	**21.11**	**22.00**
Mean	**10.57**	**5.47**	**4.83**	**4.22**	

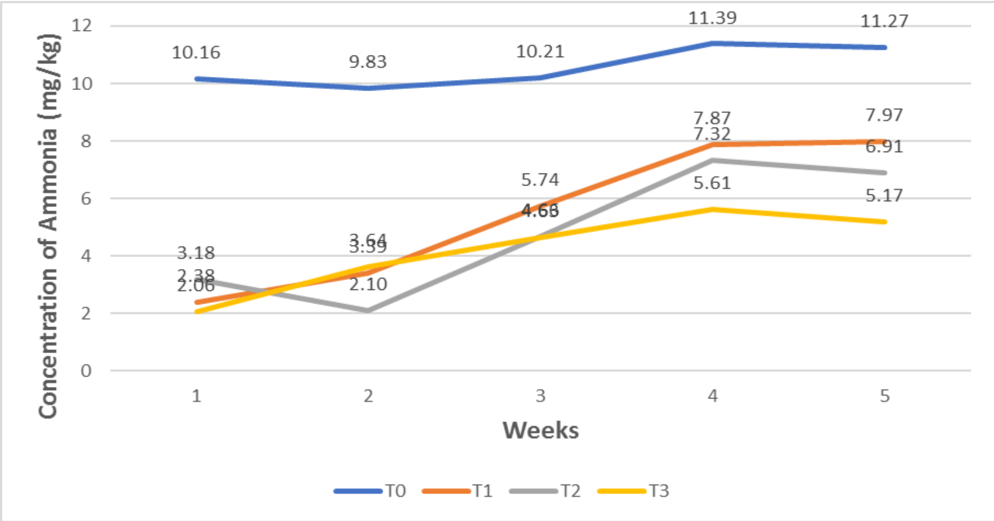

Figure 4: Concentration of Ammonia

4.0 CONCLUSION

Magnetised water should be allowed to flow through the magnetic treatment chamber unit for 165 s for effective treatment. Magnetised water reduced the concentration of ammonia gas and also reduced the offensive odour from poultry droppings. Magnetised water that was treated for 165 s and passed through the magnetic field reduced the odour of poultry droppings by 15.34% - 27.87%. The effect of magnetised water was statistically significant on the removal of offensive odour that is normally caused by ammonia at $\alpha \leq 0.025$ for magnetised water treated for 165 s but the effect of magnetised water that was allowed to flow 55 s and 110 s was significant at $\alpha \leq 0.05$. Magnetised water is therefore recommended for broiler chicken production in Nigeria to control offensive odour in poultry farms.

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CAPACITY BUILDING FOR SPECIALIZED SERVICE DELIVERY IN SAWAH ECO-TECHNOLOGY AND RICE FARMING (SERIF): A REQUIREMENT FOR EFFECTIVE SPECIALIZATION FOR LOW COST STRATEGIES IN THE RICE VALUE CHAIN

Dada-Joel, O. T.[1], Onyemize, U. C.[1], Ademiluyi Y. S.[1], Oyelade, O. A.[1]. Kasali, M. Y.[1], Olanrenwaju, J. S.[2]., Agboola, A. O.[2], Wakatsuki, T[3] and A. R. Kamal[1]

[1]National Centre for Agricultural Mechanization (NCAM), Ilorin, Nigeria,
[2]New Sawah Project, [3]Emeritus Prof. Shimane University, Japan.

ABSTRACT

This study presents the different types of capacity building trainings that has been successfully carried out in four States of Nigeria on the use of Sawah Eco-technology for rice farming (SERIF). The use of division of labour in executing the tasks involved in SERIF through specialized service delivery is the key to achieve effective turnover, green revolution and food security geared towards the rice value chain. This can be achieved through effective funding as this will bring about continuous improvement through adaptive and innovative research for sustainability on the best practice that Sawah Eco-technology represent. This paper discuss on how the training carried out on SERIF was able to impact positively on the yield of the farmers selected in five different sites. The paper also noted the training areas the farmers in the five selected sites preferred.

Keywords: specialization, division of labour, effective turnover, rice value chain, capacity building

1. INTRODUCTION

Rice has become a commodity of strategic significance and the fastest-growing food source in Africa, such that its availability and price are now a major determinant of the welfare of the poorest people who are the least food secure consumers in Africa. It is now grown and consumed in more than 40 African countries where about 20 million farmers are engaged in its production and about 100 million people depend on rice directly for their livelihood. However, self-sufficiency in African rice production is declining as demand increases. Therefore, there is an urgent need to increase and improve the continents production of rice in order to satisfy the high demand.

Striving for African self-sufficiency in rice production and processing, should not depend only on cultural practices, but putting on effective specialized agronomic, mechanized and managerial delivery into each point of service in the rice value chain for efficiency in land development, rice seedling delivery, fertilizer delivery, provision of mini harvester, mini threshers, cleaners and storage facilities. Specialized service provision to every aspect of production will encourage division of labour and effective turnover and in turn ensure the green revolution and food security.

The presidential initiative on decreasing rice importation and increasing domestic production is a decisive step which calls for proactive measures from all stakeholders in the rice development industry. One of such proactive measures is lowland mechanization for accelerated domestic paddy production through Sawah Eco-technology for sustainable, domestic rice production and achievement of food security (Buri et al., 2009; Greenland, 1997; Wakatsuki et al., 2009).

The Sawah system is the rice farmers' basic infrastructure for intensive and sustainable rice production (Oladele and Wakatsuki 2010). Sawah technology thus refers to the mechanized production of rice in lowlands through an improved method of maximum utilization of naturally occurring water (Wakatsuki et al., 1998; Kyuma 2004; Hirose and Wakatsuki, 2002; Wakatsuki and Masunaga, 2005; Wakatsuki et al., 2005).

Rice farmers in Nigeria have not acquainted themselves with the new rice farming system that has to do with the management of water through Sawah Eco-technology. This alone has led to the continuous low yield experienced by Nigerian rice farmers over the years. NCAM led Sawah Eco-technology which was first introduced to rice farmers in Kebbi State became what they used to kick start the Anchor Borrowers Programme in Kebbi State which has recorded tremendous success stories right from the inception of the programme in November 2015 to date.

In order to help Nigerian rice farmers in actualizing their dream in making Nigeria a self-sufficient country in rice production, it became necessary to train rice farmers in Nigeria on the procedures and steps involved using Sawah Eco-technology in meeting the demand of rice production in Nigeria. Therefore, this study takes a look at the training conducted on SERIF in five selected sites which is meant to build the capacity of farmers in specialized skills.

2. METHODOLOGY

2.1 Study Area

Rice farmers in five selected areas in four states of the country were used for this study. These four states were Kebbi, Kwara, Lagos and Osun. The choice of these five sites were based on the presence of lowland ecology that favoured rice farming. This study was carried out between 2011 and 2013 cropping seasons.

2.2 Selection of Farmers

The four states Ministry of Agriculture together with their agencies (ADP, FADAMA and CADP) assisted to recruit registered rice farmers that needs to be trained on rice farming, including associations like RIFAN and AFAN.

2.3 Method for Conducting the Training

The training was conducted through a combination of short theoretical classes and large practical classes on-the-job. Audio visual and slide presentations were also used to train these farmers at the five selected sites. The projection was to show them samples of what has not been seen.

2.4 Training Instruments used

The instructors of this training practically establish a rice farm with the trainees in order for them to have a better on-the-job experience of the entire stages of rice farming using SERIF. On the aspect of field work demonstration, training instruments such as power tiller, plough, leveler, bund maker, GPS terminal, total station survey equipment, measuring tape, twine ropes, hand tools, shovel, spade, digger, head pan, water pump, sandbags and hoses were used where necessary.

2.5 Resource Persons

The National Centre for Agricultural Mechanization (NCAM) led SERIF were the experts consulted to train the selected farmers in the five sites where this study took place.

3. RESULTS AND DISCUSSION

The Nigerian SERIF team has carried out capacity building for farmers, extension agents and research personnel in different locations of Nigeria as shown in Table 1. This has led to the acquisition of specialized skills in the various value chains of rice production. The data presented in Table 1 describe the various operations performed during the respective exercise that transformed successfully into providing specialized service as SERIF is being adopted and intensified in order to achieve the Green Revolution (Oladele et al., 2010).. Since the technology has attained the minimum yield target of 4 tons per ha on initial trials, improvement in yield could be attained as the skills accompanying the technology is intensified (Ofori et al., 2005). This service delivery will become competitive which will lead to high yield target attainment and will be accepted as a form of agri-business (Oladele and Wakatsuki, 2010).

Table 1. Training parameters/skills and the number of farmers involved

S/No.	Parameter	Location and Number of Farmers					Total number of farmers involved	Ranking per Training activity
		Songbe	Ajase-ipo	Jega	Patigi	Itoikin		
1.	State site is located	Osun	Kwara	Kebbi	Kwara	Lagos	N/A	N/A
2.	Number of people involved in site selection	4	4	6	5	2	21	4th
3.	Number of people involved in field and topo survey	2	1	-	2	3	8	8th
4.	Number of people involved in group formation	3	3	4	2	4	16	7th
5.	Number of people involved in bund and canal construction	7	10	8	6	6	37	3rd
6.	Number of people involved in land development	15	2	5	9	18	49	1st
7.	Number of people involved in machine operation	3	2	6	3	4	18	6th
8.	Number of people involved in nursery and seedling production	5	6	3	2	3	19	5th
9.	Number of people involved in transplanting	10	5	15	4	8	42	2nd
10.	Average Size of farm (ha)	6	3	> 50	22	6	N/A	N/A
11.	Average yield (tons/ha)	5	4.8	7.2	6.5	4.5	N/A	N/A

3.1 Number of Farmers involved in SERIF Training based on Skills Impacted

It can be deduced from Table 1 that a total of 8 different trainings were involved in SERIF. The training programme on land development which ranked 1st has the highest number of farmers involved which according to information displayed on Table 1 showed a total of 49 farmers were involved in the five selected sites. The training on rice transplanting ranked 2nd with a total of 42 farmers involved in the five selected sites. The training on bund and canal construction ranked 3rd with a total of 37 farmers involved in the five selected sites. The training on site selection ranked 4th with a total of 21 farmers involved in the five selected sites. The training on nursery and seedling production ranked 5th with a total of 19 farmers involved in the five selected sites. The training on machine operation ranked 6th with a total of 18 farmers involved in the five selected sites. The training on group formation ranked 7th with a total of 16 farmers involved in the five selected sites. Lastly, the training on field and topo survey ranked 8th with a total of 8 farmers involved in the five selected sites.

3.2 Average Size of Farm

It can be deduced from Table 1 that Jega site located in Kebbi state has the highest average farm size of 50 ha and above. This was followed by Patigi site in Kwara state which had an average farm size of 22 ha. Songbe and Itoikin sites located in Osun and Lagos, respectively, both shared same average farm size of 6 ha. It is only the Ajase Ipo site located in Kwara State that has the least average farm size of 3 ha.

3.3 Average Yield

It can be deduced from Table 1 that the highest average yield of 7.2 tons/ha was obtained in Jega site which is located in Kebbi State. Patigi site located in Kwara state recorded an average yield of 6.5 tons/ha which was the second highest obtained in this study. The farm sites of Songbe, Ajase Ipo and Itoikin located in Osun, Kwara and Lagos states recorded an average yield of 5 tons/ha, 4.8 tons/ha and 4.5 tons/ha, respectively. It is only Itoikin site in Lagos state that recorded the lowest average yield of 4.5 tons/ha.

3.4 Importance of Training offered on SERIF Activities

3.4.1 Land development

Land development was seen in Table 1 to be one of the SERIF trainings that most of the farmer drew their attention to. Land development in SERIF comprises of different operations that include land clearing and tillage operations for the purpose of preparing a suitable field for rice production. This interest shown on this particular training can be attributed to the fact the traditional system is predominantly manual which causes it to be time consuming and drudgery laden. The use of machineries such as power tiller with its associated implements has made land development activity easy and attractive in SERIF.

3.4.2 Rice transplanting

Rice transplanting was also seen as one of the SERIF trainings that called on the farmer’s attention in the five selected sites. The traditional way of transplanting rice with the use of hand is labour intensive as most farmers complain of backache due to their stooping position while planting. SERIF have come up with the use of line-guided transplanting which is a method that makes subsequent management of the rice farm sustainable for the introduction of mechanical weed control and row harvesting.

3.4.3 Bund and canal construction

Bund and canal construction was also seen as one of the trainings that farmers showed interest on in the five selected sites. Most rice farms in Nigeria are been cropped under free flowing water while in SERIF water level for rice farming is been managed using bund and canal structures for optimum growth of rice. The only problem with the traditional way of farming rice is the inability of the farmers to manage available water optimally.

3.4.4 Site selection

Site selection also showed its relevance as farmers also indicated their interest in knowing about it. Site selection in SERIF involves mastery of other soft skills that involves geo-positioning System (GPS), map making and interpretation, knowledge of topography and gradient, and land marking. All these skills seems tedious to the farmers as they are used to native intelligence which is limited in potential in achieving a large scale consideration.

3.4.5 Nursery and seedling production
Farmers also showed interest to know about nursery and seedling production. Most farmers are used to the broadcasting method of planting rice which amount to losses of yield potential. The adoption of nursery and seedling production which goes with transplanting can account for addition of a quarter of the final paddy yield which the broadcasting method is unable to achieve.

3.4.6 Machine operation
Machine operation which was meant to showcase the use of machines in overriding the manual way of farming activities showed some level of avoidance by these rice farmers in the selected five sites. This may be attributed to possible apathy when farmers do not have access to these machines for use after the training. Efforts are being intensified to ensure rice farmers in Nigeria make use of machine for their farming operation.

3.4.7 Group formation
Group formation which was meant to showcase the importance of bringing team member together to cooperate and operate in synergy during rice farming was seen lacking as farmers also showed little interest in this area during the SERIF. This may be attributed to the fact that these farmers fail to take leadership role which is important for the skills been taught.

3.4.8 Field and topo survey
Field and top survey which was meant to showcase the technical skills needed for maximizing the potentials of the lowland for nutrient and water distribution at minimal cost by taking advantage of gravity. It was shown in the data gathered that many farmers in this study showed very little interest because of requirement for background knowledge to handle survey equipment and interpret data.

4. CONCLUSION AND RECOMMENDATION
4.1 Conclusion
SERIF in the five locations were effectively and successfully delivered for sustainable technology and food security. The various services deliverable can earn an appreciable income to the participants, higher efficiency for every services for which special skills have been developed, lower operating cost and higher profit to the farm owner.

4.2 Recommendation
Rice stakeholders, women and youth should adopt the service delivery model involving site selection, field and topo survey, group formation, land development, bund and canal construction, machine operation, nursery and seedling production and transplanting to Sawah rice farming since specialization in different services when delivered to clusters or cooperatives can bring about wealth creation and food security.

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VARIABILITY OF SOIL COMPACTION IN A TROPICAL ALFISOL

Yisa, M.G.[1], Adeniran, K.A.[2] and Adebayo H.O [3].

[1]Department of Agricultural Engineering, Federal University of Technology, Minna, Niger State

E-mail :-mgyisa@gmail.com

[2]Department of Agricultural Engineering, University of Ilorin, Ilorin. Nigeria.

E-mail:- kadeniran_2003@yahoo.com

[3]Department of Agricultural and Bioresources Engineering, University of Abuja, Abuja. Nigeria.

E-mail; - adebayohawah403@gmail.com

Abstract

Soil physical properties such as moisture content, bulk density, percentage pore space, and resistance to penetration at 5cm, 10cm and 20cm depths were measured from an arable field of 100m by 100m using 5 x 5 randomized complete block design. Measurements of the soil physical properties (bulk density, moisture content, percentage pore space, and resistance to cone penetration) were made before and after traffic measurements whereby a Steyr 8075 pneumatic diesel tractor with a gross weight of 4000 kg was used with four passes (traffic) on the field. Wheel traffic led to reduction in values of moisture content and porosity. These effects were more significant on the surface (5 cm depth) than at the 10 cm and 20 cm depth). Wheel traffic increased soil properties such as bulk density, soil resistance to cone penetration and soil compaction on the sub surface than on surface. Increase in bulk density, soil resistance to cone penetration and soil compaction will affect crop emergence while reduction in soil moisture content and porosity will affect adversely crop growth. Results obtained were analyzed using the Analysis of Variance (ANOVA) technique. The results show that for moisture content before at 1% and 5% levels of significance, there was significant differences occurred for the plots after wheel traffic for soil moisture content, bulk density, porosity, soil resistance to cone penetration and soil compaction. Variability of soil compaction caused by increase in wheel traffic thus adversely affects food production.

Keywords: - Variability, soil compaction, bulk density, porosity and soil resistance to cone penetration.

1. INTRODUCTION

Soil compaction is the squeezing together of soil particles, reducing the space available for air and water, thereby increasing the density of the soil which hampers infiltration of water, soil-air movement, seed emergence, root growth and ultimate reduction of crop yield (Voorhees, 1996). Raper (2005) reported that soil compaction is one of the most devastating effects of vehicle traffic. When a vehicle passes over the soil surface and soil compaction occurs, there is reduced volume available for air and water as the mineral components are pressed closer together. Voorhees *et al.,* (1979) reported that soil compaction effects can last for years and may not be reduced by tillage, freezing or thawing. Craul (1994) observed that factors like poorly graded soil, soil loosened by tillage, increased vehicle load, wheel traffic and repeated loadings increases soil compaction.

Barik *et al.,* (2014) worked extensively on the effect of field traffic operation on the changes in spatial variability of soil aggregate stability and soil physical properties. They concluded that repeated field traffic operations spatially and significantly influenced the aggregate stability and increased bulk density, penetration resistance, volumetric moisture content as it decreases total porosity as indicators for soil compaction. However, Abich *et al*., (2022) took a holistic approach in investigating the effect of soil compaction on physico-mechanical properties of silt loam soils of Njoro, Kenya. They found out that penetration resistance, cohesion, and angle of internal friction were pertinent to wheel traffic induced compaction. Also, they established that Increasing traffic passes from 0 to 5-wheel passes, resulted in increased bulk density, soil cohesion, penetration resistance, and angle of internal friction. Nawaz *et.al.,* (2023) concluded that the magnitude of adverse effects of traffic induced compaction on dry sandy loam soil in their study, was lesser than those involving heavier field traffic in wet field conditions. Umaru *et. al*., (2021) compared the temporal variation of soil bulk density, and soil moisture content with varying soil compaction and its subsequent influence on physiological performance of sweet potato. They found out that soil compaction significantly decreased plant chlorophyl 11 content, leaf area index and gas exchange parameters.

Raper (2005) reported that the two measures of soil compaction that are commonly used are soil bulk density and cone index. As soil compaction occurs, the bulk density increases due to constant mass and reduced volume. Soil compaction naturally varies with soil type; sandy soils have naturally higher bulk densities than clay soils due to the many small pores associated with clays. The unit is composed of a 30^o cone connected to a rod. A handle on the upper end is used to force the cone into the soil. Some methods of measuring insertion force are included with the unit. Cone index is defined by the insertion force divided by the cross-sectional area of the base of the cone. Cone index has two main advantages over bulk density measurements. First, they are easier to obtain requiring significantly reduced time to quantify the entire soil profile. The process can be automated and the entire zone surrounding a row can be quickly sampled for excessive soil compaction. Second, cone index measurements can be compared across soil types much easier than bulk density measurements. One significant disadvantage is that cone index measurements are greatly affected by soil moisture. Soil bulk density and cone index have been conclusively proven to increase as the magnitude and intensity of vehicle traffic increased. These increases in soil compaction have been found to reduce rooting and crop yield, but occasionally weather conditions or prevalent soil conditions prevent significant cause–effect relationships from being found. Raghavan *et al.,* (1990) reported that two types of soil compaction exist; these include shallow and deep compaction. Shallow compaction occurs within the normal tillage zone (5-26cm) while deep compaction occurs below the normal tillage zone (26-50cm). Soil variability plays a significant role in crop performance especially in dry conditions where spatial variability of soil texture can show across a large field. Apart from soil compaction, other soil variables include soil moisture content, organic matter, soil pH, soil structure, porosity and infiltration rate. This variability depends on the size of the field, soil condition, topography, location and the climatic condition of the area. The objective of this study was to determine the extent of the variability of soil compaction in an arable land.

2. MATERIALS AND METHODS

2.1. Description of the Study Site

The study was conducted on a site located at Gidan Kwano, along Minna-Bida Road in Niger State. The site is located in the Southern Guinea Savannah Ecological Zone of Nigeria approximately on latitude 09^{0}35’26’N and longitude 06^{0}28’45’E’. The climate is tropical with dry and wet seasons. The wet season is between May and September while dry season starts in October and ends in April. The mean annual rainfall is about 553 mm. The soil is sandy-loam classified as alfisol. The common crops grown in the area are yam, guinea corn, maize, rice and cassava.

2.2 Layout and Instrumentation

The study was carried out on a site having a total land area of 1 ha (100 m^2 by 100 m^2). The field was divided into 25 plots of 10 by 10 m^2 using a 5 by 5 randomized complete block design. A Steyr 8075 tractor with pneumatic tyres was used as the agent of compaction. Four passes were made across the field taking measurements after each pass. The tractor has a maximum gross weight of 4000 kg, maximum gross axle weight of 1500 kg, front tyre size of 12.5 cm to 20 cm with 20 bar inflation pressure and a rear tyre size of 16.9 cm to 30 cm with 0.9 bar inflation pressure. Height of the tractor is 2.36 m, length is 3.62 m, height of the front tyres is 0.7 m, height of the rear tyre is 1.4 m, width of the front tyre is 0.2 m and the width of the rear tyre is 0.4 m.

2.3 Soil Physical Properties

2.3.1 Determination of soil moisture content

Soil moisture content before and after wheel traffic was determined using the gravimetric method. Soil samples were collected on each of the plots at 5, 10 and 15 cm-depths respectively using a soil auger. These moist samples were weighed and oven-dried at a temperature of 105^0C for 24 hours and later allowed to cool in desiccator for 2 hours. After which they were weighed again. Soil moisture content was calculated as:

Soil moisture content (%) = {(Mass of wet soil sample (g) - mass of dry soil sample (g))/Mass of dry soil sample (g)} x 100% (1)

2.3.2 Soil bulk density

Soil bulk density was determined using the relationship shown below:

Bulk density = Mass of dry soil (g)/Volume of oven dry soil (2)

2.3.3 Soil porosity

Soil porosity was determined from the relationship:

Pore space (%) = {1 – (bulk density/particle density)} x 100% (3)

2.3.4 Soil resistance to penetration

The soil resistance to penetration was determined using a cone penetrometer. This was done at 5, 10 and 15cm-depths before and after wheel traffic.

3. RESULTS AND DISCUSSION

3.1 Effects of wheel traffic on moisture content

Table 1 shows the results obtained for mean moisture content before and after wheel traffic at 5, 10 and 15cm depths. The values of the moisture content before wheel traffic were between the range 8.3% to 18.0%. After wheel traffic it was between the range 7. 24 to 16.03%. A reduction in soil moisture content occurred after the wheel traffic on the plots was observed from the table. The effects of wheel traffic on moisture content of soil samples obtained on the treated plots followed the order 5cm > 10cm > 15cm soil depths. From the table, shows the results of the analysis of variance of the mean moisture content before and after wheel traffic. From the table, at 1% and 5% levels of significance, significant differences occurred when the moisture contents before wheel traffic were compared to those after wheel traffic. The result shows that the consequence of increase in wheel traffic is that it will reduce soil moisture available for crop use.

3.2 Effects of wheel traffic on bulk density

Table 3 shows the effects of wheel traffic on bulk density before and after wheel traffic. As shown in the table, sustained wheel traffic led to an increase in bulk density. Bulk density increased as the soil depth increased, before traffic the range of 1.20 to 1.80 g/cm^3 was obtained, while after traffic the range of 1.80 to 2.36 g/cm^3 was obtained. Unlike moisture content, the effect of the increase in traffic on bulk density followed the order 15cm > 10cm > 5m for the different soil depths.

Table 4 shows the results of the analysis of variance for porosity before and after traffic. It was revealed that at 1% and 5% level of significance, significant differences occurred when the mean porosity before traffic were compared to those after wheel traffic. Increase in wheel traffic increases bulk density this can lead to hardening of the top soil thereby affecting crop emergence.

3.3 Effects of wheel traffic on porosity

Table 5 shows the effects wheel traffic on porosity. The impact of the wheel traffic resulted in the decrease in soil porosity. Porosity before traffic was between the range 32.10% to 54.72%, while after traffic the range of 10.94% to 32.08% was obtained. Unlike moisture content, decrease in porosity did not follow any order. The results of the analysis of variance for porosity before and after wheel traffic revealed that at 1% and 5% levels of significance, significant differences occurred when the mean porosity before wheel traffic were compared to those after traffic. Increase in wheel traffic thereby reduces porosity. The consequence of this effect is that it will lead to a reduction in crop aeration.

3.4 Variability of soil resistance to cone penetration

Table 7 shows the effects wheel traffic on soil resistance to penetration. Before traffic the range of 8.0 to 19.5 Pa was obtained while after traffic it increased to 16 to 26 Pa. Like bulk density, mean resistance to cone penetration increased as the soil depth increased. Table 8 shows the results of the analysis of variance for resistance of soil to cone penetration before and after wheel traffic. At 1% and 5% level of significance, significant differences occurred when the mean resistance to cone penetration before wheel traffic was compared to those after wheel traffic. Increase in wheel traffic thus hardens the soil surface thereby reducing crop emergence.

3.5 Variability of soil to compaction

Figs 1 and 2 show the variations obtained on the treated plots before and after wheel traffic respectively. These variations range between 9.50 Pa to 18.83 Pa for plots before wheel traffic and between 16.22 Pa to 25.20 Pa after wheel traffic. These show that soil compaction increased after wheel traffic.

4. CONCLUSION

The results show that wheel traffic affected soil moisture content, bulk density, porosity, soil resistance to cone penetration and soil compaction. Wheel traffic led to reduction in values of moisture content and porosity. These effects were more serious on the surface (5cm depth) than the subsoil. Wheel traffic increased bulk density, soil resistance to cone penetration and soil compaction. The effects of wheel traffic increased soil properties such as bulk density, soil resistance to cone penetration and soil compaction on the subsoil than on surface. Increase in bulk density, soil resistance to cone penetration and soil compaction will affect cop emergence while reduction in soil moisture content and porosity will affect adversely crop growth. Variability of soil compaction caused by increase in wheel traffic thus adversely affects food production.

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Table 1. Mean moisture content before and after wheel traffic

Plots	Soil moisture content before tillage (%)			Soil moisture content after tillage (%)		
	5cm depth	10cm depth	15cm depth	5cm depth	10cm depth	15cm depth
A	9.10	9.85	9.42	7.97	8.98	8.39
B	10.31	12.80	10.22	9.27	10.35	9.12
C	10.16	12.01	10.16	9.23	9.88	9.14
D	11.88	13.26	11.87	10.36	11.66	10.18
E	14.36	16.40	13.08	11.17	14.03	10.82

Table 2. Analysis for Variance for mean moisture content

Analysis of Variance (ANOVA)				
Source of variation	SS	DF	MS	F_o
Treatment	24.62	8	61.6	15.4
Block	3.97	4	1.99	
Error	0.6	16	0.55	
SST	21.05	28		

Table 3. Mean bulk density before and after wheel traffic

Plots	Bulk density before wheel traffic (g/cm^3)			Bulk density after wheel traffic (g/cm^3)		
	5cm depth	10cm depth	15cm depth	5cm depth	10cm depth	15cm depth
A	1.78	1.57	1.69	2.33	2.15	2.30
B	1.51	1.31	1.47	2.03	1.88	1.97
C	1.61	1.48	1.56	2.18	2.07	2.11
D	1.42	1.44	1.49	1.99	2.03	1.94
E	1.32	1.21	1.41	1.92	1.81	2.01

Table 4. Analysis for Variance for mean bulk density

Analysis of Variance (ANOVA)				
Source of variation	SS	DF	MS	F_o
Treatment	0.24	8	0.06	2
Block	0.05	4	0.03	
Error	0.03	16	0.004	
SST	0.22	28		

Table 5. Mean porosity before and after wheel traffic

Plots	Porosity before wheel traffic (%)			Porosity after wheel traffic (%)		
	5cm depth	10cm depth	15cm depth	5cm depth	10cm depth	15cm depth
A	33.59	40.60	36.38	11.92	21.51	13.13
B	43.17	50.57	44.60	23.32	22.04	25.51
C	39.40	44.00	40.98	17.66	22.05	20.38
D	46.42	45.66	47.12	24.90	23.47	26.72

E	50.11	54.42	46.64	27.69	32.08	29.97

Table 6. Analysis for Variance for mean porosity

Analysis of Variance (ANOVA)				
Source of variation	SS	DF	MS	F_o
Treatment	278.20	8	139.10	1.05
Block	25.98	4	12.99	
Error	132.73	16	16.59	
SST	384.95	28		

Table 7. Mean soil resistance to cone penetration before and after wheel traffic

Plots	Soil resistance to cone penetration before wheel traffic (Pa)			Soil resistance to cone penetration after wheel traffic (Pa)		
	5cm depth	10cm depth	15cm depth	5cm depth	10cm depth	15cm depth
A	11.10	11.80	12.50	19.41	20.78	21.99
B	13.02	13.90	14.40	20.61	21.64	24.89
C	9.70	10.30	11.00	17.03	18.37	19.19
D	15.00	15.84	16.40	20.69	21.65	22.54
E	16.00	16.90	17.20	21.79	22.75	23.74

Table 8. Analysis for Variance for soil resistance to cone penetration

Analysis of Variance (ANOVA)				
Source of variation	SS	DF	MS	F_o
Treatment	39.70	8	9.93	0.28
Block	16.51	4	8.26	
Error	35.81	16	4.48	
SST	59	28		

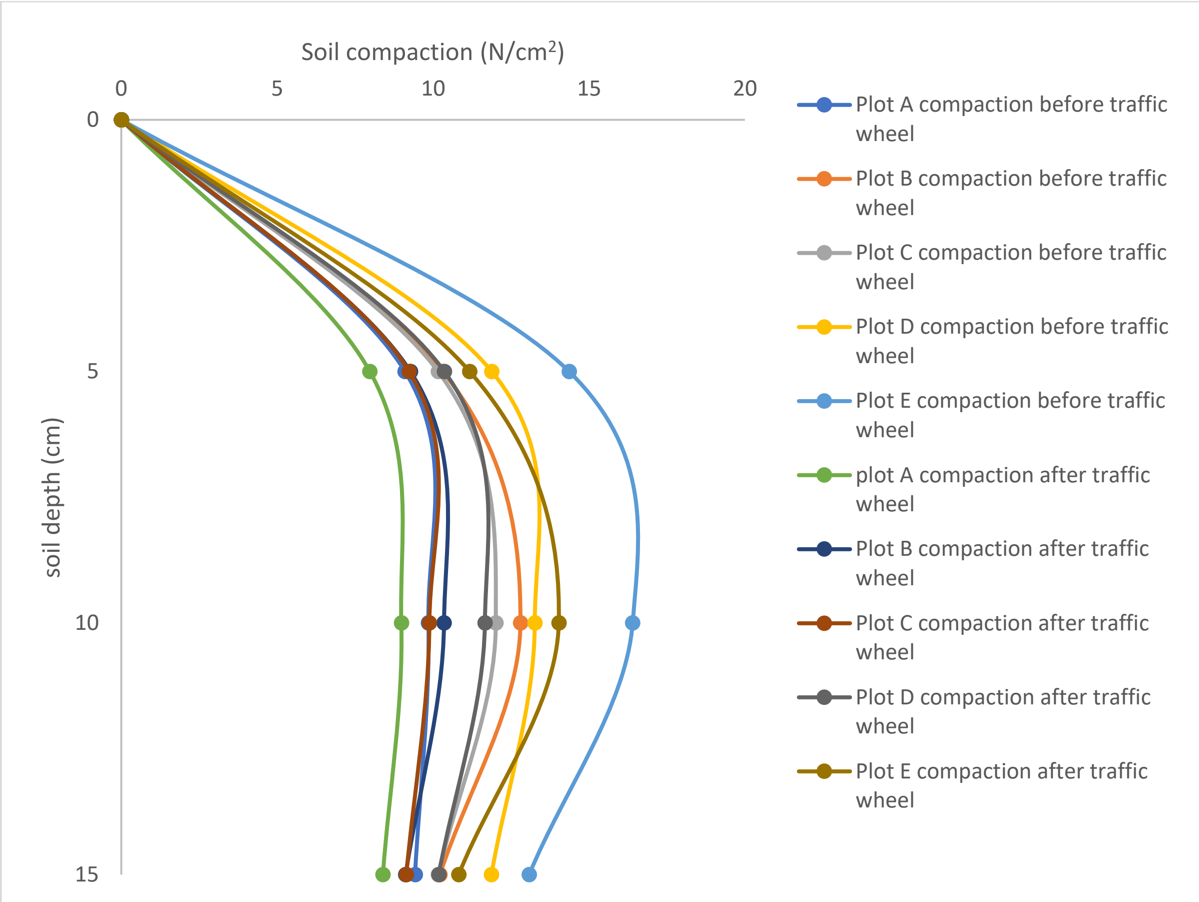

Fig. 1 Variability of soil compaction before and after wheel traffic

X-RAYING THE IMPACT OF TILLAGE PRACTICES ON PROPERTIES OF SOILS IN NIGERIA

Amool, Shagbaor Hycent[1], Agidzi Donald[2]
[1-2]Department of Agricultural and Environmental Engineering, University of Agriculture, Makurdi, Benue State. Nigeria

ABSTRACT
An appropriate tillage method is necessary to create a suitable seed bed condition for optimum crop growth and yield. A review study was conducted to investigate the effect of different tillage methods on the physical properties of soils in different locations in Nigeria. The Tillage treatments were disc ploughing plus disc harrowing (DP+DH), double disc ploughing (DDP), double disc harrowing (DDH), disc ploughing (DP) and disc harrowing (DH) as minimum tillage (MT), reduced tillage, mulching and zero tillage (ZT). Using secondary data from document analysis, themes were developed that captured the wide range of tillage methods used in Nigeria with evaluation of their effects on soil physical properties and crop yield as reported by some authors. Tillage treatment had a sizable impact on all of the soil parameters taken into account, including bulk density, penetration resistance, moisture content, and temperature. As the amount of time following tillage grew, the surface soil temperature reduced as a result of the growth of plant foliage that shaded the ground. The choice of appropriate tillage system for growing crops in Nigeria is very important for continuous management of soil for sustainable productivity.

1.0 INTRODUCTION

According to Nta *et al*. (2017), the main goals of tillage are to prepare an ideal seed bed for plant growth, eliminate competitive weed, and improve the physical condition of the soil. Tillage is the mechanical manipulation of soil to keep it loose for plant growth and free of weed during the growth of plants.

Tillage practices affect soil respiration, temperature, water content, pH, oxidation-reduction potential, and, soil microorganisms (Kladivko, 2001). In most farming communities, poor tillage directly affects soil aggregate, temperature, water infiltration and retention. These effects go beyond crop productivity and sustainability (Lori *et al*., 2017), emissions of greenhouse gas (Stavi and Lal, 2013), soil structure and carbon (C) sequestration (Guo and Gifford, 2002; Gattinger *et al.,* 2012). Intensive tillage over a long period of time causes soil degradation, compaction, and loss of soil and soil organic matter (SOM) in many agroecological areas around the world. Good soil management practices such as soil fertility preservation, managing water resources and irrigation systems, restoration of degraded land, implementation of integrated pest management, fertility utilization, and practicing conservation agriculture (Montagne *et al.*, 2007). By encouraging sustainable production of crops, good soil management practices specifically aim to improve the supply of healthy and high-quality food while also promoting market access and farmer livelihoods (Poole and Lynch, 2007).

Soil physical quality is the capacity of a given soil to meet plant and environmental demands for water and aeration (McKenzie *et al*., 2011). Continuous land use and high economic growth threatens resources sustainability and agricultural land in Nigeria and other developing countries. The majority of agricultural lands are used for non-agricultural and recreational purposes, which has a negative impact on overall agricultural output.
There are three interdependent aspects of soil that affect crop productivity which are biological; chemical and physical health. Soil physical properties are less researched or studied compared to soil chemical and biological conditions. For instance, many commercial farmers use heavy

farm machineries for land preparation without prior knowledge of the adverse effects of such practice on soil quality (Babalola, 2000). This practice consequently has led to the removal of the productive topsoil and exposes sub-soils to further degradation (Kachallah *et al.,* 2021). The suitability of soil for sustaining plant growth and biological activity is a function of its physical properties (Are *et al.,* 2011). Various reports on soil degradation (Babalola *et al.,* 2000; Salako *et al*., 2006). Indicated that plough and harrow are among the heaviest machines used for farming operations. Tillage has no significant impact on growth and yields of certain crops like cowpea (Mupangwa *et al.*, 2012).

Nigeria is an agrarian community where tropical crops are being cultivated. In order to facilitate farming, many heavy agricultural equipment is used. However, the effect of these equipment on selected soil properties, soil strength and crop water use on crops in Nigeria have not been scientifically quantified. Information on response of a good number of crops to different tillage practices in African countries particularly Nigeria is limited.

1.1 Objectives of the Study

Therefore, the aim of the study was to review on the effects of tillage practices on soil properties in terms of soil bulk density, penetrative resistance, moisture content and temperature in Nigeria.

1.2 Relevant Soil Properties Parameters

1.2.1 Soil Bulk Density

Bulk density is routinely assessed to characterize the state of soil compactness in response to land use and soil management practices (Mupangwa *et al.*, 2012). The bulk density of soil reflects the mass or weight of a certain volume of soil. Soil bulk density determines the infiltration, available water capacity, soil porosity, rooting depth/restrictions, soil microorganism activity, root proliferation, and nutrient availability. An increasing bulk density implies a decrease of macropores and an increase in meso- and micropores and the resultant changes impacted on hydraulic conductivity (Mupangwa *et al.*, 2012). Thus the bulk density affects the pore diameter and its distribution and resultantly effects the soil hydraulic properties (Himangshu *et al*., 2016). Lin *et al.* (2005) reported that the increasing bulk density not only induces changes in the pore-size distribution but also affects the ability of soil to shrink and to conduct water in the soil.

1.2.2 Soil Penetration Resistance

The penetration resistance (PR) is an appropriate index to evaluate soil compaction problems, limiting plant root development. PR is a physical property of soil, which represents the behavior and effects of different soil properties such as bulk density, moisture content, porosity and permeability, which, result from the particles size distribution, the structure, and the mineral and organic content of soil (Soane *et al*., 1981). The PR is an index that can be evaluated through a simple, fast and punctual determination, made directly on the field, by penetrometer or recording penetrometer that are effective and fast (Bowen, 1981). The PR determined in this way is an indirect measure of the force exerted by the roots to penetrate the pores of the channels, or to deform the soil structure.

1.2.3 Soil Moisture Content

The soil moisture content correspondingly referred to as water content and is an indicator of the quantity of water existing in soil. By means, moisture content in soils is the relation of water quantity in a portion to the quantity of solids in the soil sample, expressed as a proportion for example (percentage) (Lin *et al*., 2005).
Soils normally contain a finite amount of water, which can be expressed as the “soil moisture content.” This moisture exists within the pore spaces in between soil aggregates (inter-

aggregate pore space) and within soil aggregates (intra-aggregate pore space). Normally this pore space is occupied by air and/or water. If all the pores are occupied by air, the soil is completely dry. If all the pores are filled with water, the soil is said to be saturated.

1.2.4 Soil Temperature

Soil temperature is simply the measurement of the warmth in the soil. Soil temperature is one of the most important factors affecting plant growth. The optimum range of soil temperature for plant growth is between 20 and 30°C (Frey et al., 2013). The rate of plant growth declines drastically when temperature is less than 20°C (suboptimal) and above 35°C (supraoptimal). Further, all soil processes are temperature dependent. Consequently, the thermal regime of soil strongly influences the edaphic environment (Jacobs et al., 2007). The release of soil nutrients for root uptake is also dependent upon soil temperature regime. It is a physical parameter that plays a major role in ensuring crop productivity and sustainability (Adak *et al*., 2012). It controls biological and biochemical processes in the soil which invariably affects soil organic matter formation, fertilizer efficiency, seed germination, plant development, ability of plant to survive during dry season, nutrient uptake and decomposition, and disease and insect occurrence (Jacobs *et al*., 2007; Leifeld and Fuhrer, 2005). It is also affects the rate of water flow in the soil by controlling water viscosity, surface tension, and relative hydraulic conductivity (Schmidt *et al*., 2004). It controls the rate of decomposition of soil organic matter which is the critical factor in maintaining global carbon and nitrogen balance (Himangshu *et al*., 2016). Inadequate soil temperature delays crops germination, leads to retarded maturity and undergoes spatiotemporal changes during crop growing season (Mucaj, 2005).

2.0 METHODOLOGY

2.1 Approach to Data Collection

This study, consistent with Braun and Clarke (2006), used thematic analysis in an open-ended way, to investigate the general impact of tillage practices on the properties of soils in Nigeria. The researchers employed a purposive sampling strategy of secondary sources of information and document analysis whereby the results of various studies in the field carried out in Nigeria and discussed relative to others within and without the country was used.

2.2 Ethical Protocol

All studies reported in this study were properly acknowledged and referenced.

2.3 Data Analysis

This study used thematic analysis (Braun and Clarke, 2006). This required the transcription of journal paper review and followed coding stages. Initially, the authors read and re-read transcripts of journals in order to identify potential themes, which they then forwarded to the lead author. The second level of analysis involved both the first and last authors reviewing these initial codes. They considered particularly how to retain the diversity of the initial codes, while producing overarching elements, higher level sub-themes. The research objectives, the impact of tillage practices on properties of soils in Nigeria, informed this process. At the third stage, analysis conducted by the first and last authors identified quotes that were congruent with the overarching themes. Next, the authors reviewed themes prior to defining and naming them. Finally, once themes were finalized, by the first and last authors, the write-up of the report began.

3.0 RESULTS

The analysis produced four themes.

3.1 Soil Bulk Density

In Oyo State of Nigeria, Lasisi *et al.* (2014) study of effect of tillage methods on the soil and crop observed the values of soil bulk density for a period of 12 weeks and recorded that the highest set of values of bulk density was obtained on no tillage (NT) treatment whilst the least set of values was recorded on disc ploughing and harrowing (DPH) throughout the planting period for both 0-5 and 5-10 depths. They also observed from the result that bulk density values increased with time in all tillage treatments. They attributed the general increase in soil bulk density with time in all the tillage treatments to the combined effect of rainfall impact and cycles of wetting and drying of the soil. They concluded that soil bulk density was significantly ($P < 0.05$) affected by tillage method, bulk density decreasing with increasing degree of tillage (NT>DH.>DP.>DPH.) Osunbitan *et al.* (2005) and Aluko and Lasisi (2009) reported similar results for a loamy sand and sandy loam soils, respectively, in other South-Western parts of Nigeria.

The percentage of dry bulk density produced by tractorization of a land (after second ploughing) was higher than that of a site not ploughed at all. Nta *et al*. (2017) reported that this phenomenon is expected as the level of compaction itself is an indication of the pressure on microorganisms in the soil causing their death. Soil compaction causes three problems, viz, killing of microorganisms, moisture removal and difficult root penetration; these are factors which affect plant growth and yield, this is line with the findings of Ojeniyi and Agboola (1995) which reported that repetitive tillage degraded soil qualities and caused rapid collapse of soil structure. In the sub-humid and humid regions of the tropics, the high intensity rainstorms tend to increase the loosening effects of tillage. Intensive soil cultivation which may increase soil bulk density is intimately connected with reduced porosity and the alteration of pore size distribution (Nta *et al*., 2017).

In North-Eastern Nigeria, the result on the effect of different tillages used as treatments had significantly affected soil bulk density during 2 years (2020-2021) of study, reported by Kachallah *et al.* (2021). The highest soil bulk density of was found in plots with disc plough/disc harrow (DP/DH) treatments and lowest soil bulk density of was found in plots with zero tillage (ZT). This was in line with Osunbitan *et al*. (2005); Rashidi and Kashavarzpour (2007) as reported by Kachallah *et al.* (2021).

High bulk density levels can result from poor structural stability (i.e. collapse of soil structure after wetting) or from compaction by animals or farm machinery. Soil friability decreases, in general, with increasing bulk density. Soil tensile strength increases with bulk density as shown by numerous authors (e.g. Shittu *et al*., 2023). The strength increases due to an increase in cohesive forces of capillary bound water and the increased effectiveness of cementing materials (e.g. drying and hardening of formerly dispersed clay). Further, increased density is usually associated with the decrease in mainly structural porosity (Shittu *et al*., 2023), which plays a vital role in brittle failure. Soil fragmentation may be even more sensitive to soil compaction than tensile strength. Shittu *et al.* (2023) showed that compaction of a sandy loam in wet conditions increased tensile strength by 20 and 60% for 8–16 mm aggregates soil cores (Ø = 4.45 cm), respectively, whereas the geometric mean diameter in a drop-shatter test increased by 172%. High bulk density can be a result of direct impact from heavy traffic or a consequence of poor structural stability caused by e.g. low SOM content.

3.2 Soil Penetration Resistance

The result of soil penetration resistance (Cone index) at a soil depth range of 0-10cm over a period of twelve weeks was observed by Lasisi *et al.* (2014) in Oyo State of South West Nigeria. Penetration resistance across the three soil depths considered was consistently highest on no tillage (NT) treatment and lowest on disc ploughing and harrowing (DPH) treatment. The lower penetration resistance obtained on disc ploughing and harrowing enhanced better plant root development and nutrient absorption within the soil, which in turn, enhanced better plant growth when compared to untilled plots (Lasisi, 2008). It was observed from the result that penetration resistance increased with increase in soil depth for all the tillage treatments. Penetration resistance was significantly ($P<0.05$) affected by tillage treatment with penetration resistance decreasing with increasing degree of tillage (NT>DH>DPH).

Shittu *et al.* (2023) reported that tillage practices had a significant impact on soil penetration resistance measurements to a depth of 50 cm for Zero Tillage (ZT), Conventional Tillage (CT), CT + ML (Mulching) and Reduced Tillage (RT) under cowpea plant in 2018 and 2019. The results had shown a decreased soil penetration resistance (SPR) at 10 and 30 cm soil depth. However, there was higher penetration resistance at 50 cm soil depth across all the treatments. There was significantly high difference in SPR between RT and other treatments (CT, CT + ML, ZT) between 15 and 30 cm soil depth. SPR in RT treatment exceeded the critical level of 2 MPa (Hamza and Anderson, 2005) between this depth (15-30 cm) which would indicate potential soil compaction at this depth. Penetration resistance between 15–30 cm soil depth in RT plots reached 2.26 MPa and then decreased. The Lower SPR under CT and CT + ML were likely associated with deep plowing, thereby forming more soil macropores in CT and CT + ML than in RT. The soil PR in this study agreed with those reported in South Africa for pasture (Raper *et al.*, 2000), maize in Libya (Lampurlanes and Cantero-Martinez 2003), and India for wheat (Gathala *et al*., 2011) who stated that reduced tillage practices increased soil penetration resistance and bulk density when compared to other traditional tillage methods such as conventional and zero tillage practices.
Compared with other tillage practices, RT had a higher soil strength in the two seasons. As a result, mechanical resistance to root development and proliferation may exist in RT compared to other tillage practices (Shittu *et al.,* 2017). This could explain why there was a negative relationship between cowpea yield and soil penetration resistance. The lower SPR in the CT and CT + ML plots could be attributed to soil loosening to a depth of 30 cm due to tillage and crop residue assimilation in the top layer. Blanco-Canqui and Ruis (2018) and, Idowu *et al.* (2019) reported similar findings.
A significant effect of different tillage treatments on soil penetration resistance was also found during two years of study by Kachallah *et al.* (2021). The highest soil penetration resistances of were obtained for the zero tillage (ZT) treatment and lowest for the disc plough + disc harrow treatment. The difference in penetration resistance observed and reported were attributed to the amount of moisture retention. These results are in agreement with those of Bababola (2001) who concluded that (DP/DH) conventional tillage (CT) has lower penetration resistance than that of the zero tillage (ZT) treatment. Greater soil penetration resistance of reduced tillage (RT), manual tillage (MT) and no-till (NT) treatments may also be due to lower soil moisture contents. This is in line with the results reported by Ghuman and Lal (1984) that penetration resistance decreased with increase in soil moisture content and vice versa. The kind of results reported in their study was expected because after load application from tractor traffics, ploughing which is primary tillage operation will break the soil that will result in larger clods since the soil had been compacted. It is expected that the depression of the penetrometer probe into the soil will be affected by over-burden pressure from the soil which will lead to high penetration values. Harrowing as secondary tillage is expected to produce better tilth than ploughing and hence the reduction in penetration resistance compared to ploughing leading to lower penetration resistance.

3.3 Soil Moisture Content

The values of moisture content at two different soil depths of 5 and 10cm were studied by Lasisi *et al*. (2014) in Oyo State. At both depths, the no tillage method had the highest moisture content whilst the disc ploughing and harrowing method had the lowest moisture content. The lower values obtained on conventionally tilled could be attributed to deep percolation on these plots. On the other hand, the higher values of the moisture content obtained on no tillage method could be attributed to the fact that vegetation residues left on the soil provided a mulching effect which enhanced moisture conservation on these plots. Moisture content increased with the soil depth for all the treatments while the time after tillage operations had no significant effect on the moisture content of the plots. Moisture content was significantly

(P< 0.05) affected by tillage method, moisture content decreasing with increasing degree of tillage (NT> DH> DP.>DPH).

Nta *et al.* (2017) carried out another study in Oyo State and reported that the no-tillage method in their experiment recorded higher percentage of soil moisture content than that of the ploughing method. This was in line with the result of the studies conducted on an Afisol, in another South-Western part of Nigeria by Ndaeyo *et al*. (1995) which indicated that zero tillage had higher soil moisture content in the profile than ploughed plots attributed to the soil moisture reserve through rainstorm amelioration.
Nta *et al.* (2017) in the same study noted that the zero-tillage recorded higher percentage of total porosity than that of the ploughed method, which produced the lower percentage of total porosity. This is in accordance with the observation of Ahn and Hintze (1990) in their work that tillage practices lowered porosity due to decline in organic matter and weakening of soil structure.

3.4 Soil Temperature

The values of surface (0-5cm) soil temperature obtained from the tillage treatments in Oyo State was reported by Lasisi *et al.* (2014). The observations were made immediately after tillage operations, soil temperature values were reported to be highest on disc ploughing and harrowing treatment and lowest on no tillage treatment. These temperatures progressively declined as the time after tillage operations increased. At the 12th week after tillage, the soil temperature on plots treated with disc ploughing and harrowing (DPH) and no tillage (NT) had declined progressively. Statistical analysis of these results showed that soil temperature was significantly ($P < 0.05$) affected by tillage treatments. This progressive decline in soil temperature was be attributed to the gradual development of plant foliage, which increasingly shaded the ground. The soil temperature was relatively higher on disc ploughing and harrowing plots compared to no tillage plots. The higher values obtained on disc ploughing and harrowing was attributed to the breakup of the soil structure caused by tillage operations, which loosened the soil, making it porous. The lower values obtained under no tillage treatment was attributed to the influence of residues on the soil surface, which intercepted incoming radiation and thus reduced soil temperature. Nangju (1979) reported that higher soil temperatures enhance better seedling emergence and early growth on a tropical soil. This suggests that better seedling emergence and early growth can be expected on conventionally tilled plots (DH, DP, and DPH) considering the relatively higher soil temperatures obtained on these plots compared to the temperatures obtained on the untilled plots (NT).

4.0 CONCLUSION

According to the studies we analysed, soil bulk density, penetration resistance, and moisture content all generally reduced as the degree of soil loosening by ploughing increased (NT > DH > DP > DPH). With increasing time following tillage operations, bulk density and penetration resistance rose. Tillage treatment had a sizable impact on all of the soil parameters taken into account, including bulk density, penetration resistance, moisture content, and temperature. As the amount of time following tillage grew, the surface soil temperature reduced as a result of the growth of plant foliage that shaded the ground.

5.0 RECOMMENDATIONS

The following recommendations are made with due considerations to the above findings:

1. Adoption of Conservation Tillage: Conservation tillage practices, such as minimum tillage or no-till, should be encouraged. These practices minimize soil disturbance, reduce erosion, and help improve soil structure and moisture retention.

2. Crop Rotation: Implementing a crop rotation system can help break pest cycles, improve soil fertility, and reduce the risk of soil erosion. Rotating crops with different nutrient requirements can also help maintain a balanced nutrient profile in the soil.
3. Organic Matter Management: Enhancing organic matter content in the soil is crucial for sustaining soil health. Farmers should be encouraged to add organic amendments such as crop residues, animal manure, compost, and cover crops to improve soil structure, nutrient availability, and water-holding capacity.
4. Nutrient Management: Proper nutrient management is essential for maintaining soil fertility. Soil testing should be promoted to determine the nutrient status of the soil and guide the application of fertilizers. Balanced fertilization practices should be followed to avoid nutrient imbalances and minimize environmental pollution.
5. Water Management: Efficient water management practices, such as irrigation scheduling and conservation techniques, should be adopted to minimize water loss through evaporation and runoff. This will help maintain soil moisture levels and prevent soil degradation.
6. Soil Erosion Control: Implementing erosion control measures, such as contour plowing, terracing, and the use of vegetative cover, can help reduce soil erosion caused by tillage practices. These measures will help protect the soil from degradation and preserve its fertility.
7. Training and Education: Farmers and agricultural extension workers should be provided with training and educational programs to raise awareness about the impact of tillage practices on soil properties. This will facilitate the adoption of sustainable tillage practices and ensure their proper implementation.
8. Research and Development: Continued research and development efforts should be undertaken to better understand the impact of different tillage practices on soil properties in Nigeria. This will help develop region-specific recommendations and technologies that can further enhance soil health and productivity.

By implementing these recommendations, farmers and policymakers can promote sustainable tillage practices and ensure the long-term health and productivity of soils in Nigeria

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COMPARATIVE STUDY OF THE EFFECT OF LAND LEVELLING AND TILLAGE OPERATION ON SOME PHYSICAL PROPERTIES OF LOAMY SAND IN 2018 AND 2019 CROPPING SEASON

Gbadamosi Lateef[1], Olaoye, J.O[2] And Ariyo, O.E[3]
[1]Kwara State Polytechnic, Ilorin, Nigeria.
[2]University of Ilorin, Ilorin, Nigeria
[3]Kwara State Ministry of Agriculture, Ilorin, Nigeria

ABSTRACT

Unlike levelled land, undulation land has negative effects on agricultural production in the guinea savannah region of Northern Nigeria to an increasing measure in subsequent cropping seasons. A comparative study of the effect of land levelling and tillage operations on some physical properties of loamy sand was conducted in an attempt to solve the problem of undulation topography of land surface in the guinea savannah of Nigeria. Some physical properties investigated were soil moisture content (M_C), Soil bulk density, (b_d), soil particle density and soil porosity (p) of loamy sand. The study was conducted in the experimental field of department of Agricultural and Biosystems Engineering, University of Ilorin in 2018 and 2019 cropping season. The measured plot of land of 125 x 62 m was divided into two plots, each of 120 x 25 m. One plot was levelled (L_1) and the other plot was unlevelled (L_2). The levelled and unlevelled plots were further divided into six sub plots, each of 20 x 25m. The tillage treatments were: plough, harrow, ridge (PHR) tagged (T_1), only harrow, (H) tagged (T_2) and only ridging (R) tagged (T_3). The experimental design was completely randomized design (CRD). The tillage methods imposed on L_1 were T_1L_1 (ploughing, harrowing and ridging), T_2L_1 (harrowing alone) and T_3L_1 (ridging alone), and the treatment were replicated twice. The same treatments were imposed on L_2, and tagged T_1L_2, T_2L_2, and T_3L_2. Statistical analysis was carried out on the field results using analysis of variance (ANOVA). Results showed that whereas in 2018 cropping season, moisture content and bulk density, were statistically different at $p \leq 0.05$, porosity was not statistically different. In 2019 cropping season, moisture content was not statistically different at $p \leq 0.05$, but bulk density and porosity were statically different. The results of this study shows that plough, harrow and ridge provided better tillage intervention for the levelled and unlevelled plots. In like manner, levelling operation increased bulk density and decreased porosity of the soil in 2018 season but increased bulk density on the levelled plot in 2019 season.

KEYWORDS

Comparative Study, Land Levelling, Tillage Operation, Physical Properties, Loamy Sand.

1. INTRODUCTION

The undulating nature of land surface in the guinea savannah of Nigeria poses setback to agricultural production in the region. The undulation is on medium to steep slopes and is very prone to water erosion, Gintaras (2016). Studies have shown that undulating topography moves faster moisture and nutrient from high spot to low spot on the field, Gonzalez and Moret-Fernandez, (2011). Maize (*zea mays*) is most productive in the guinea savannah of Nigeria due to favourable climatic conditions of adequate sunshine, temperature (21^0C – 32^0C) and moderate rainfall, (900 – 120mm), Amusa and Iken, (2014). Due to undulating topography grain yield obtained in the savannah ectone region of Nigeria is lower, this is in the range of 0.5 – 2.2 tons/ha as against 3 - 5 ton/ha FAOSTAT (2015).

However, to develop the land in a manner which will allow sustainable crop production requires application of extensive soil conservation measures. Land levelling is a conservation solution to create a slight and uniform slope to integrate, facilitate more uniform distribution of water in undulating lands, Farmanullah *et al* (2007). Land levelling provides suitable surface to control the flow of water, to check soil erosion and provide better surface drainage. It is an important process in the preparation of land as it enables efficient utilization of scarce water resources through elimination of unnecessary depression and elevated contours, Gupta, (2011).

Despite the positive effects of land levelling, it destroys the physical properties of the soil majorly from the compression of the subsoil from the constant use of farm machinery that limits the development of the rooting system resulting to the difficulty of absorption of nutrients that affects the yield of plants, Naresh *at al.* (2014).

The influence of tillage on crop residue cover, soil properties and yield components of Cowpea in derived Savannah Ectones of Nigeria were undertaken by Olaoye (2002). The study affirmed that tillage methods greatly affect the yield components of crops. The issue of land levelling and tillage methods remains strong determining factors affecting crop performance. The effect of soil compaction and different tillage systems on the bulk density and moisture content of soil and the yields of winter oilseed rape and cereals were undertaken by Orzech *et al.* (2021). The tillage treatment imposed on the soil greatly affect the performance of subsequent operations on the field such as planting, weeding and plant protection operations (Yusuf and Olaoye, 2016). Therefore, the objective of this study is to compare the effect of land levelling and tillage operation on some physical properties of soil on the field and the cultivation conducted on two consecutive cropping seasons.

2. MATERIAL AND METHOD

2.1 Experimental Site

The studies were conducted in 2018 and 2019 cropping season at the research farm of the department of Agricultural and Biosystems Engineering, faculty of Engineering and Technology, University of Ilorin. The sloppy (2% - 5%) land was on latitude 8^{o} 28’ 54.55”N and longitude 4^{o}, 40’ 56.4”E.

2.2 Experimental Methods and Design

The experimental field with dimensions 125 m x 62 m, was divided into two plots each of dimension 120 x25 m. One plot (L_1) was levelled and the other (L_2) was unlevelled, remaining at its natural topography. The two plots were further divided into six subplots each of 20 m x 20 m. The tillage treatments were laid out in a completely randomized block design (CRBD). The tillage operations performed were ploughing, harrowing, ridging (PHR) tagged (T_1), harrowing alone (H) tagged (T_2) and ridging alone (R) tagged (T_3). These were randomly imposed on L_1 and L_2 and replicated Twice.

The levelling operation performed on the levelled plot was achieved by initial ploughing and harrowing of the plot. Thereafter, land leveler coupled to tractor cut soil from high spots and moved to fill the low spots. The high spots and low spots were pegged out based on the topography survey map of the field. The three tillage treatments were randomly performed on the six sub plots on unlevelled plot. The tillage implements used were a 3-bottom Disc Plough, an offset disc harrow with 18 blades on a gang and a disc ridger with 2-discs, all powered through a Mahindra, 4 WD, 80 hp tractor.

2.3 Soil Samples Collection from the Tillage Treatment Imposed on the Levelled and Unlevelled plots

Soil samples were collected from the plots based on the treatments imposed on the both L_1 and L_2. Core sampler of diameter 11cm and height, 11cm was used to collect soil samples at a depth of 15 cm. Three samples were collected in the Subplots.

The physical properties determined were soil moisture content (Mc), Soil bulk density, (ρ) and soil porosity (n).

The soil moisture content was determined using the standard oven method which involves placing the samples in an oven for 24hrs at a temperature of 105°C. Moisture content was determined by the formula given by Orzech *et al.* (2021).

$$Mc = \frac{Ww - W_d}{Ww} \times 100\% \qquad 1$$

where

Mc = Moisture Content (%) (wet basis)

w_w = Wet Weight of soil (g)

w_d = Dry weight of soil (g)

Bulk density was determined using a core sampler that was pushed into the soil by hammering. The soil sample was emptied into a moisture can of known mass and weighed using a digital weighing balance.

The bulk density (ρ) was calculated using the equation by Naghdi and Solgi, (2014):

$$\rho = \frac{Wd}{Vc} \qquad 2$$

where;

ρ = Bulk Density (g/cm^3),

w_d = Weight of the dry soil (g)

v_c = Volume of the core sampler (cm^3)

The porosity of the soil was derived from the expression

$$Porosity\ (n) = \left(1 - \frac{\rho}{\gamma}\right) \qquad 3$$

Where γ = soil specific gravity (assumed $2.65gcm^{-3}$) Gandunaetal (2017).)

2.4 RESULT AND DISCUSSION

Tables 1 and 2 show the Analysis of variance (ANOVA) on the effect of levelling and tillage systems on soil physical properties in 2018 and 2019 cropping seasons.

Table 1: Effect of Tillage Systems and Levelling on Soil Physical Properties 2018 Season

Measured soil physical properties	Source	Df	MS	F	Sig
Mc (%)	T	2	4.61	8.534	0.017
	L	1	0.013	3.776	0.906^{ns}
	T*L	6	0.264	0.301	0.615^{ns}
ρ_d (g/cm^3)	T	2	0.003	4.478	0.0645^{ns}
	L	1	0.031	46.26	0.0005^{*}
	T*L	6	8.33 x 10^6	0.004	0.996^{ns}
Porosity	T	2	9.6225	3.241	0.111^{ns}
	L	1	19.568	6.590	0.0387^{*}
	T*L	6	0.008	0.002	0.998^{ns}

P* Significant at $P \leq 0.05$ ns = not significant at $P \leq 0.05$.

Table 2: Effects of Tillage System and Levelling on Soil physical properties at 2019 Season

Measured soil physical properties	Source	Df	MS	F	Sig
Mc (%)	T	2	2.676	0.334	0.729^{ns}
	L	1	0.441	0.055	0.822^{ns}
	T*L	6	2.616	0.3260	0.734^{ns}
ρ_d (g/cm^3)	T	2	0.002	9.696	0.013^{*}
	L	1	0.002	9.783	0.20^{*}
	T*L	6	0.004	22.826	0.002*
Porosity	T	2	2.823	10.393	0.111^{*}
	L	1	2.803	10.319	0.018^{*}
	T*L	6	6.413	23.607	0.001^{*}

Tables 3 and 4, show the mean values of levelling and Tillage system on soil physical properties in 2018 and 2019 cropping seasons.

Table 3: Means values of Tillage Treatment and Levelling

Experimental Treatments	Moisture content Mc (%)	Bulk Density (g/cm^3)	porosity (%)
Tillage systems			
T_1 (ploughs + Harrowing + Riding)	7.50^b	1.395	47.300
T2 (Harrowing)	10.650^a	1.470	44.450
T3 (Riding)	8.600^b	1.473	44.375
Land levelling			
L_1 (levelled)	8.063^*	1.827^a	47.50^a
L_2 (unlevelled)	8.063*	1.070^b	44.50^b
SE	0.87	0.002	3.303

Means not followed by the same letter are statistically different at 0.05 as determine by DMRT

Table 4: Means values of Tillage Treatment and Levelling using Duncan Multiple Range Test at 2019 Season

Experimental Treatments	Moisture content (%)	Bulk Density (g/cm^3)	Porosity (%)
Tillage systems			
T_1 (ploughs + Harrowing + Riding)	7.055	1.5300^a	42.200^b
T_2 (Harrowing)	8.710	1.5150^a	42.750^b
T_3 (Riding)	8.650	1.4875^b	43.850^a
L and levelling			
L_1 (levelled)	8.121	1.90^a	46.75^a
L_2 (unlevelled)	8.101	1.06^b	43.78^b
SE	0.861	0.003	0.272

Means not followed by the same letter are statistically different at 0.05 as determine by DMRT

2.4.1 Effects of Tillage Methods on Soil Moisture Content (M_C)

It was seen from Table 1 that in 2018 cropping season, tillage methods significantly affected the moisture contents whereas, in 2019 cropping season, Table 2 showed that levelling and tillage methods did not significantly affect moisture content. While Table 3 showed that in 2018 season, moisture content was statistically different at $P \leq 0.05$ on tillage treatment (T2), only harrowing. The highest moisture content of average value, 10.65%, indicated the presence of large soil clods with little pore opening, also, Table 4 showed that in 2019 cropping season, moisture content was not statistically different at $P \leq 0.05$ on the levelled plot, unlevelled plots and tillage treatment.

2.4.2 Effects of Tillage Treatments on Soil Bulk Density (ρ_d)

It was observed in Table 1 that in 2018 cropping season, only leveling was significant on soil bulk density, whereas, Table 2 showed that in 2019 cropping season, levelling, tillage methods and their interaction were significant on bulk density. Table 3 showed that in 2018 cropping season, bulk density was statistically different on levelled plot at $P \leq 0.05$. The high average value of 1.82 g/cm^3 observed on levelled plot indicated higher soil compaction due to pressing of the soil particles together. Table 4 showed that in 2019 cropping season, the levelling and tillage methods were statistically different at $P \leq 0.05$. The higher average value of bulk density of 1.90g/cm^3 indicate pronounced soil compaction on a previously levelled soil in 2018 season as against average value of 1.827g/cm^3 in 2018 cropping season. Similarly, the tillage methods showed higher bulk density in 2019 as against lower value shown in 2018 season. The increased value observed in 2019 season may be due to effect of constant machinery movement on already levelled plots in 2018 season.

2.4.3 Effects of Tillage Treatments on Soil Porosity

Table 1 revealed that the effect of levelling was significant on porosity and the effect of tillage methods were not significant on levelling, tillage methods and their interaction during 2018 planting season whereas, Table 2 showed that the effect of levelling, tillage methods and interaction have significant effect on porosity in 2019 cropping season. Table 3 in 2018 cropping season showed that the tillage methods were not statistically different at $P \leq 0.05$. The higher mean value of porosity of 47.5% indicated improvement on soil by the tillage methods. Similarly, Table 4 showed that in 2019 cropping season, levelling, tillage methods and their interaction were statistically different at $P \leq 0.05$. The higher mean value of porosity of 46.7%

obtained for levelled plot could be due to the effect of the tillage treatment (T3) only ridging, as this has tendency of exposing more the soil pores.

3. CONCLUSIONS

Results obtained from the comparative study of the effects of tillage methods on levelled and unlevelled land in two consecutive years (2018 and 2019) showed that a combination of ploughing, harrowing, and ridging, provided better tillage intervention for the levelled and unlevelled plots as evidenced in the minimum moisture content, bulk density and high porosity observed in 2018 and 2019 season. Whereas levelling operation increased the bulk density and decreased the porosity of soil in 2018 season, it increased bulk density alone on already levelled plot in 2019 season. Tillage methods were observed to improve soil porosity in 2019 cropping season.

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QUALITY ENHANCEMENT OF STIFF DOUGH (*TUWO*): A REVIEW

Danjuma, E.N and Adejumo, B. A.
Department of Agricultural and Bioresources Engineering, Federal University of Technology
Minna, Niger State, Nigeria
Email: nuyelned@gmail.com

ABSTRACT
Cereal grains, mostly corn and sorghum flour are highly consumed in Nigeria-west Africa in the form of stiff dough popularly known as "tuwo" in Hausa, Northern part of Nigeria. Tuwo is semi-solid dough produced by cooking cereals flour in slurry form to form tuwo dough. The dough is formed by molding the semi-solid substance wrapped in polythene bags or containers to assume the shapes and sizes allowed to solidify. Tuwo is consumed with assorted kinds of soup, garden egg, locus beans etc. Cereals have low protein content with high carbohydrate content, the production and consumption of tuwo are paramount to be supplemented with needed nutrients to attain a balanced diet. The quality of tuwo can be enhanced by improving the nutritional and functional quality of the corn/sorghum grains in the production of quality flours through the selected pretreatment method. Pretreatment methods such as blanching, soaking and malting will improve the nutritional and functional quality and eliminate anti-nutritional contents in cereal grains. Stiff dough "tuwo" from pre-treatment of cereals grains improved cereals flour to a balanced meal, general acceptability and an optimized tuwo production can be achieved.

Keywords: Cereal, quality, nutritional, functional, anti-nutritional, stiff dough tuwo.

1.0 INTRODUCTION

Cereals are the grains of cultivated grasses which are cheap and easy to grow in all climate, and it belongs to the family of grasses, *Poaceae* (formerly *Graminae*) (Abebaw, 2018). Cereal grains are grown in large quantities and provide more food energy worldwide than any other type of crops (Muhammad *et al*., 2013) and used worldwide as staple foods globally (Fardet, 2010). Cereal grains, mostly corn and sorghum flour are highly consumed in Nigeria-west Africa in the form of stiff dough popularly known as "tuwo" in Hausa, Northern part of Nigeria. Tuwo is semi-solid dough produced by cooking cereals flour in slurry form to form tuwo dough. The dough is formed by moulding the semi-solid substance wrapped in polythene bags or containers to assume the shapes and sizes allowed to solidify. Tuwo is consumed with assorted kinds of soup, garden egg, locus beans etc. Cereals have low protein content with high carbohydrate content, the production and consumption of tuwo are paramount to be supplemented with needed nutrients to attain a balanced diet. The quality of tuwo can be enhanced by improving the nutritional and functional quality of the corn/sorghum grains in the production of quality flours through the selected pre-treatment method. Pre-treatment methods such as blanching, soaking and malting will improve the nutritional and functional quality and eliminate anti-nutritional contents in cereal grains. Stiff dough "*tuwo*" from pre-treatment of cereals grains improved cereals flour to a balanced meal, general acceptability and an optimized "*tuwo*" production can be achieved.

1.1 Stiff dough (*tuwo*)

Stiff dough (*tuwo*) is semi-solid or solid substance produced from cereals flour molded in water and heat energy to produce a meal popularly known as (*tuwo*) in Hausa, Nigeria-west Africa. Cereal stiff dough could be in the form of (corn stiff dough, sorghum stiff dough, rice stiff dough etc.). Stiff dough (*tuwo*) assumed shapes and sizes of the container allowed to solidify and also, their physical characteristics and colour depends on the grains or variety used (Bolade *et al.,* 2009). Stiff dough (*Tuwo)* is consumed with assorted kinds of soup, garden egg, locus beans etc. Considering the low protein content and other required nutrients in cereals the high carbohydrate content can be either enhanced through adequate pretreatment or complimented with needed nutrients to attain appropriate balanced diets.

2.0 Production of stiff dough (*tuwo*) from cereal flour

Stiff dough is prepared from flour of cereal flour of corn, sorghum, millet or rice, the process is as described by Bolade *et al.* (2002). The overall ratio of flour to water used for stiff dough preparation is 1:3.5 (w/v) (Figure 1). A cold slurry of the flour is first prepared by mixing 20% of the desired quantity of flour (1 kg) with 25% of the desired quantity of water (3.5L). This will be followed by bringing 60% of the water to boiling and the cold slurry initially prepared will be added to this boiling water coupled with vigorous stirring, using a wooden flat spoon, to form a pap-like consistency. The remaining quantity of the flour (80% of the desired total) will then be added gradually to the boiling pap-like paste with continuous stirring to facilitate the non-formation of lumps and to ensure a homogenous gel formation. The remaining quantity of water (15% of the desired total) will finally be added to the formed gel, covered properly without stirring and allowed to cook for about 5-7 minutes after which it was stirred vigorously to ensure smoothness of the gel. The final product that is obtained is called *tuwo* (stiff dough).

Cereals flour

↓

Making 20% cold slurry from cereals flour
at a ratio of flour to water 1:3.5(w/v)
(1kg of flour with 3.5 L of water)

↓

Pouring the cold slurry into 60% boiling water
& stirred continuously in a clockwise or anticlockwise direction.

↓

Adding 80% of the cereals flour is then poured into the boiling
Slurry gradually and stir continuously clockwise or anticlockwise
direction until a homogeneous gel is formed.

↓

15% of water is finally added and covered
& allow cooking for 5-7 minutes

↓

Finally, it is stirred vigorously
to ensure smoother gel.

↓

Finished product
cereals stiff dough

Figure 1: Flow chart diagram of the preparation of stiff dough (tuwo).
Source: Bolade *et al.* (2002).

3. Common cereal crops used in stiff dough (tuwo) production

Cereals are the grains of cultivated grasses which are cheap and easy to grow in all climate, and it belongs to the family of grasses, *Poaceae* (formerly *Graminae*) (Abebaw, 2018). Cereal grains are grown in large quantities and provide more food energy worldwide than any other type of crop (Muhammad *et al*., 2013) and are used worldwide as staple foods globally (Fardet 2010). The major crops among the *Poaceae* family that are commonly cultivated in Nigeria and are used for the stiff dough are rice (*Oryza sativa L.*), corn (*Zea Mays L.*), wheat (*Triticum aestivum L*), oats (*Avena Savita L.)* and sorghum (*Sorghum bicolor (L.) Moench*) (Abebaw, 2018).

Research revealed that cereals' nutritive contents consist of 72% carbohydrate, 12% protein, 12% water, 2% fat, 1% mineral (Ca & Fe) and 1% vitamins (B & E) (Kulp and Ponte 2000). Over 70% of dietary food in developing countries is supplied by cereals which are relatively poor sources of protein (Anigo *et al.,* 2010). Ant-nutrient such as phytic acid reduces the bioavailability of minerals such as Ca, Mg, Zn and Fe (Lesteinne *et al.,* 2005; Gupta *et al.* 2015 and Sandberg, 2000). The acceptability of stiff dough (tuwo) from cereals flour is often limited due to poor textural quality which is evident in poor mouldability, high rate of retro-gradation and instability of gels after cooling (Bolade *et al* 2009).

3.1 Corn

Corn, also known as maize (*Zea mays L.*), is a cereal grain and monocotyledonous plant belonging to the family of *Poaceae*. Corn is a staple food in many parts of the world and is the third leading crop in the world after rice and wheat (Sandhu, *et al.,* 2007). Corn is more widely cultivated throughout the world than any other grain (Ünay, *et al*.2004) and reports show that corn is an important staple food crop in Africa (Olakojo *et al*., 2005 and Mboya *et al.,* 2011).

Corn is planted in all six ecological zones of Nigeria (namely North-central, Northeast, Northwest, Southeast, South-south, and Southwest) and serves as an important source of income for farm households. Corn has equally become a commercial crop on which many agro-based industries depend for raw materials (Oluwatayo, *et al.,* 2008 and Babatunde *et al.,* 2008).

3.2 Sorghum

Sorghum (*Sorghum bicolor L. Moench*) has been consumed as a major food staple in Asia and Africa for centuries. Sorghum is classified under the family of *Poaceae,* tribe *Andopogoneae*, subtribe *Sorghinae*, genus Sorghum. All cultivated sorghum belongs to Sorghum bicolor subsp. bicolor. The morphological characteristics of sorghum differ, based on the variety and environment in which it is grown. Sorghum has been used mainly for livestock feed with only a small percentage used for food and industrial purposes (Rooney and Waniska, 2000).

Sorghum is Africa's contribution to the small number of elite grains that supply about 85% of the world's food energy (Henley, *et al.,* 2010). Sorghum also has the potential for increased human consumption due to its high level of phytochemical components (Awika and Rooney, 2004 and Taylor and Belton, 2002). Among these staples, however, sorghum occupies a unique position due to its hardiness as a crop (Henley *et al.*, 2010), and grows in various soil conditions (Dillon *et al*., 2007). Sorghum grains are rich in energy and non-energy nutrients. Sorghum is consumed as pasta, boiled and traditional beverages (Kayodé, 2006). Sorghum starch plays an important role in the production of many sorghum-based food products, including bread (Schober *et al.,* 2005).

4. Effect of Pre-Treatment Methods on the Qualities of Cereal Flour

Bolade (2010) worked on the evaluation of the suitability of commercially available corn grains for 'stiff dough' production in Nigeria. The study shows that corn varieties used during the evaluation, exhibited different physical characteristics in their kernels, varying physicochemical properties in their flours, different rheological properties (that is, cohesiveness and softness indexes) of corn stiff dough prepared from the flours as well as different assessment levels in their organoleptic properties.

Bolade and Adeyemi (2012), worked on the quality dynamics of corn 'stiff dough' (non-fermented corn-based dumplings) as influenced by steaming of corn grits at different resident times. It was found out that pre-gelatinization of starch in corn flour meant for stiff dough (*tuwo*) production, via maize grit steaming, could lead to the enhancement of textural and sensory quality attributes of the food product. A 30-minute steaming duration was found to be an optimum level for the corn grits as corn stiff dough obtained from this steaming regime was rated the highest in most of the sensory attributes. The practical application of its findings is that the information would be relevant in the production of corn flour meant for the stiff dough to enhance quality attributes both at household and commercial levels. It would also be relevant in the promotion of industrial production of corn flour meant purposely for stiff dough preparation.

Olajide and Nsakpuma (2019), worked on the functional properties of corn flour (*Zea mays*) and the stability of its paste (stiff dough) as influenced by processing methods and baobab (*Adansonia digitata*) pulp inclusion. In their study, it was discovered that Grit Soaking Operation improved the functional and sensory properties of corn flour meant for stiff dough production. In addition, the inclusion of baobab pulp enhanced the stated properties of corn flour produced by both grit-soaking and grit-non-soaking methods. The inclusion of 5% baobab pulp gave the best stability of stiff dough produced by the grit soaking method while 10% baobab pulp inclusion gave the best stability of stiff dough produced by the grit non-soaking method. Stiff dough (*tuwo*) stored under refrigerated conditions showed better paste stability compared to those stored at ambient conditions. This study showed improvement in the quality of corn flour and stability of stiff dough (*tuwo*) as a result of baobab pulp inclusion.

Mella (2011), worked on the effects of malting and fermentation on the composition and functionality of sorghum flour. It was reported that there is clear evidence that both malting and fermentation process technologies can improve the nutritional quality of sorghum flour. Changes in the composition and functionality of sorghum kernel components during malting and fermentation imply that the two methods have beneficial effects on sorghum foods. These methods may therefore help to improve the nutritional quality and increase the consumption of sorghum food products. Increased consumption will translate into increased production thus an improvement in household income and reduction of poverty and malnutrition. An investigation was made on the effects of malting and fermentation on the composition and functionality of sorghum flour samples is warranted. Such a study would determine the amounts of reducing sugars, proteins and amino acids in flour samples. Functional property analysis (e.g., hardness, springiness, colour and oil uptake during frying) of products produced from pre-treated sorghum flours is also warranted. The study also demonstrated that both malting and fermentation do have positive effects on the composition and functionality of sorghum flour and buns. The malting process caused an increase in the amounts of reducing sugars in sorghum flour samples. Fermentation caused an increase in the amounts of soluble proteins and free amino acids. Malting and fermentation pre-treatments can improve the composition and functionality of sorghum flour. Treated and untreated sorghum flours can be used to reduce the amount of oil in buns or other deep-fried food products made from sorghum: wheat composite flour. There is no difference in the composition and functionality between food grade (Macia) and the red tannin (T159781) sorghum flours.

Shabir and Sowriappan (2013), worked on the effect of soaking temperature on the physical and functional properties of parboiled rice cultivars grown in temperate regions of India. It was reported that the higher soaking water temperatures increase the hardness value which will help to increase the milling yield of rice. The pasting property of rice samples substantially decreased by parboiling with a severe decrease in temperature at 80˚C.

Opeyemi *et al.* (2016), worked on the effect of malted sorghum on the quality characteristics of wheat-sorghum-soybean flour for potential use in confectionaries and revealed that malting of sorghum can improve the nutritional quality of flours used in the production of value-added products (confectionaries).

Kaur (2011), who worked on the functional properties and anti-nutritional factors in cereal bran disclosed that bran is an excellent source of dietary fibre which improves its nutritional and nutraceutical benefits of whole grain. Cereal brans are excellent functional properties such as bulk density, water absorption and fat absorption. Also, cereals bran is more effective in increasing the shelf life of products and also aids in calorie reduction. However, the anti-nutritional factors present in cereal brans limit their potential as a low-quality feed ingredient such as phytic acid, polyphenols, tannins, oxalates, saponins and trypsin inhibitors.

Fulufhelo *et al.* (2018), worked on the effect of the germination period on the physicochemical, functional and sensory properties of finger millet flour and porridge. It was demonstrated that germination showed positive effects on some physicochemical, functional and sensory properties of finger millet flour and porridge. Germination caused a decrease in pH as well as viscosity. There was a significant increase in the oil and water absorption capacity including the solubility of the germinated finger millet flour samples. However, the germination period significantly reduced the swelling power and bulk density of the finger millet flour samples. The reduction in both two functional properties demonstrates the possibility of germinated finger millet flours being used as ingredients in different foods such as baby food, sauces and cakes. Moreover, the decrease in bulk density is advantageous since it results in small amounts of germinated finger millet flour samples packaged in a constant volume. Porridge samples prepared from germinated finger millet flour were well accepted.

Chandra *et al.* (2013) worked on the assessment of the functional properties of different flours. It was found that a trend to use novel sources of protein, fat, vitamins, and minerals for bakery products is to decrease the proportion of wheat flour by using locally available, cheap and nutritional sources. Green gram flour and potato flour have good functional properties which enhance the nutritional quality of the value-added products which was processed by the addition of green gram and potato flour.

Sharma *et al* (2018) worked on the development of functional flour using malted cereals and legumes. In the study, evidence shows that malting improves the nutritional and physio-chemical characteristics of formulated sorghum-based composite flour mix. The food products developed using sorghum-based composite flour mix have proven to possess immense functional properties in terms of protein, crude fiber, and phytonutrients particularly phenolic compounds like total phenolic and total flavonoids and minerals with potent antioxidant capacity. Sorghum is considered a poor man’s food and does not find a place in the food purchase lists of the elite. Emphasis must be laid on the popularization of consumption of sorghum through the commercialization of value-added products which is the need of time to suit the ever-changing lifestyle of people.

Kulamarva *et al.* (2019), worked on the nutritional and rheological properties of sorghum. According to his study comparing the value of sorghum to other cereals despite the absence of gluten which makes sorghum highly favourable in the diet of gluten-intolerant populations, it also leads to poor rheological properties. Composite flours comprising sorghum and flours from other cereals and legumes are an efficient way of improving the nutritive and rheological properties of sorghum. Processing can also be an important tool in terms of value addition for the cereal. Research on the effects of processing on the nutritional and viscoelastic properties of sorghum could help popularize the use of sorghum in human diets.

S/No.	Author	Research	Research Outcome
1.	Bolade (2010)	Evaluation of the suitability of commercially available corn grains for 'stiff dough' production in Nigeria.	The study shows that corn varieties used during the evaluation, exhibited different physical characteristics in their kernels, varying physicochemical properties in their flours, different rheological properties.
2.	Bolade and Adeyemi (2012)	Quality dynamics of corn 'stiff dough' (non-fermented corn-based dumplings) as influenced by steaming of corn grits at different resident times.	It was found out that pre-gelatinization of starch in corn flour meant for stiff dough (*tuwo*) production, via maize grit steaming, could lead to the enhancement of textural and sensory quality attributes of the food product
3.	Olajide and Nsakpuma (2019)	Functional properties of corn flour and the stability of its paste (stiff dough) as influenced by processing methods and baobab pulp inclusion	It was discovered that Grit Soaking operation improved the functional and sensory properties of corn flour meant for stiff dough production.
4.	Mella (2011)	Effects of malting and fermentation on the composition and functionality of sorghum flour.	It was reported that there is clear evidence that both malting and fermentation process technologies can improve the nutritional quality of sorghum flour
5.	Shabir and Sowriappan (2013)	Effect of soaking temperature on the physical and functional properties of parboiled rice cultivars grown in temperate regions of India	It was reported that the higher soaking water temperatures increase the hardness value which will help to increase the milling yield of rice.
6.	Opeyemi *et al.* (2016).	Effect of malted sorghum on the quality characteristics of wheat-sorghum-soybean flour	Revealed that malting of sorghum can improve the nutritional quality of flours used in the production of value-added products (confectionaries).

7.	Kaur (2011),	Functional properties and anti-nutritional factors in cereal bran	is an excellent source of dietary fibre which improves its nutritional and nutraceutical benefits of whole grain.
8.	Fulufhelo *et al.* (2018),	Effect of the germination period on the physicochemical, functional and sensory properties of finger millet flour and porridge	It was demonstrated that germination showed positive effects on some physicochemical, functional and sensory properties of finger millet flour and porridge
9.	Chandra *et al.* (2013)	Assessment of the functional properties of different flours	It was found that a trend to use novel sources of protein, fat, vitamins, and minerals for bakery products is to decrease the proportion of wheat flour by using locally available, cheap and nutritional sources
10.	Sharma *et al* (2018)	Development of functional flour using malted cereals and legumes.	Malting improves the nutritional and physio-chemical characteristics of formulated sorghum-based composite flour mix.
11.	Kulamarva *et al.* (2019),	Nnutritional and rheological properties of sorghum.	Research on the effects of processing on the nutritional and viscoelastic properties of sorghum could help popularize the use of sorghum in human diets.

5.0 Possible Methods of Enhancing the Quality of Stiff Dough (tuwo)

Germinated grains exert beneficial nutrients to humans and anti-nutritional factors are also reduced during the germination process (Tian *et al*., 2010; Hemalatha *et al*., 2007; Dicko *et al*., 2005 and Noda *et al.*, 2004). Sprouting provides a rich source of various phytochemicals, various minerals and vitamins, enzymes and essential amino acids which exert heath-promising effect (Gan *et al.,* 2017).

Cereal flour is mostly influenced by pretreatment processes which could slightly change its appearance, texture and nutritional contents. Improving nutritional quality and organoleptic properties (taste, sight, smell and touch) of cereal-based foods could be achieved through genetic improvement, amino acid fortification and supplementation or complementation (Kaukovirta-Norja *et al.,* 2004). Protein-rich sources and processing technologies are employed on cereals via (milling, malting, fermentation and sprouting). When the germination rate increases, it increases the content of soluble sugars for fermentation (Kouakou *et al.,* 2008). Traditional methods of food preparations such as fermentation, cooking, and malting increase the nutritive quality of food through the reduction of certain anti-nutrients such as phytic acid, polyphenols and oxalic acid.

Germinated cereals seeds are good sources of ascorbic acid, riboflavin, choline, thiamine, tocopherols and pantothenic acid (Sangronis and Machado, 2007). Germinated and coarse ground grains increase the protein content and thus protein digestibility greatly improves. It also reduces the concentration of anti-nutritional factors like phytates in malted grains hence improving their nutritional quality (Traore *et al.,* 2004). Malting reduces the viscosity of the foods and hence it can be consumed frequently (Ikujenlola and Fashakin, 2005).

6.0 Conclusion

Despite the series of work that was carried out on the processing of cereal grains to better cereal flour for quality stiff dough *tuwo* production. The nutritional and functional quality can be improved by adequately varying the blanching, soaking and malting duration/temperature. The presence of anti-nutrients in corn and sorghum which depletes most of the vital nutrients can be reduced or removed by proper pretreatment methods. Optimized cereals flour can be produced and its composite flour for better quality stiff dough (*tuwo*) production**.**

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AN AUTOMATED DRIP IRRIGATION FOR PUMPKIN (*CUCURBITA PEPO*) BASED ON CLIMATIC AND HYDRO-PHYSICAL PARAMETER MEASUREMENT AND CONTROL

[1]Oke, A. M., [2]Ofoegbu, E. O., [1]Aremu, T.E., [3]Ayobamidele, S. J., [4]Julius, M. O., [1]Akingade, T.O. and [1]Buhari, F. A.
[1]Department of Agricultural Engineering, Adeleke University, Ede, Osun State.
[2]Department of Electrical and Electronics Engineering, Adeleke University, Ede, Osun State.
[3]Department of Agricultural Education, University of Ilesa, Ilesa, Osun State.
[4]Department of Mechanical Engineering, Adeleke University, Ede, Osun State.

Corresponding Author: oke.matthew@adelekeuniversity.edu.ng

ABSTRACT

In Nigeria, agriculture serves as a mainstay of the country's economy and as a means of development to solve the problems of food scarcity and unemployment. There are methods of irrigating agricultural fields to permanently solve problems of water scarcity and to have good results that will in turn gives optimal yield. In this research, an automated drip irrigation system was developed which provided a cost-effective solution to the traditional irrigation method. The project was designed for a low-cost automatic irrigation system that allows for a more efficient way to nurture plants on the farm by implementing low-voltage sensor technology to minimize the wastage of water. This was achieved by putting together a sensing and control unit that comprises moisture sensors, turbidity sensors and atmospheric pressure sensors. The information was sent to the microcontroller from the sensors which processes the data collected and then opens or closes the valve based on the information received by the microcontroller. The data is read by the sensors and thereafter sent to the user through a GSM module, which was displayed on the Liquid Crystal Display (LCD) and was also stored on an SD card every twenty-five minutes. However, it was discovered that when this automatic irrigation system is applied in a real-life application, it will provide high efficiency in nurturing plants in the farm or the greenhouse system and thus, will result in optimum yield around the year for the farmers to harvest. Therefore, the results were then collected for some time, and there were variations for different days which was due to climatic conditions. The designed system worked optimally and is fully recommended for both small-scale and large-scale farmlands without climatic and human interruptions.

Keywords: Climate, Irrigation, Sensors, Hydro-physical parameters, pumpkin

1. INTRODUCTION

This investigation focused on using Pumpkin (*Cucurbita pepo* L.) as a case study. It is commonly called "Elegede" in Southwest Nigeria, its belongs to the *Cucurbitaceae* Family. The family is one of the largest families in the plant kingdom consisting of the largest number of edible plant species. Pumpkin young leaf locally called "Gboro" is used as an indigenous leafy vegetable. In this form, processing or pre-treatment is not required or done before cooking unlike many leafy vegetables consumed in Nigeria (Oloyede, 2012).

In recent years, there has been a rapid improvement in the agricultural system of the country. Research has it that agriculture has great importance worldwide (Dell, 2018). In Nigeria for example, a large percentage of the people depend upon the vital sector of agriculture. In the past, irrigation systems used to be dependent on the mills to irrigate the farm by conventional methods, without knowing the appropriate quantity of water needed which contributed to wastage in large quantities and thereby, destroyed the crops. However, technological advancements have helped immensely in the irrigation process, without the farmer interfering with it.

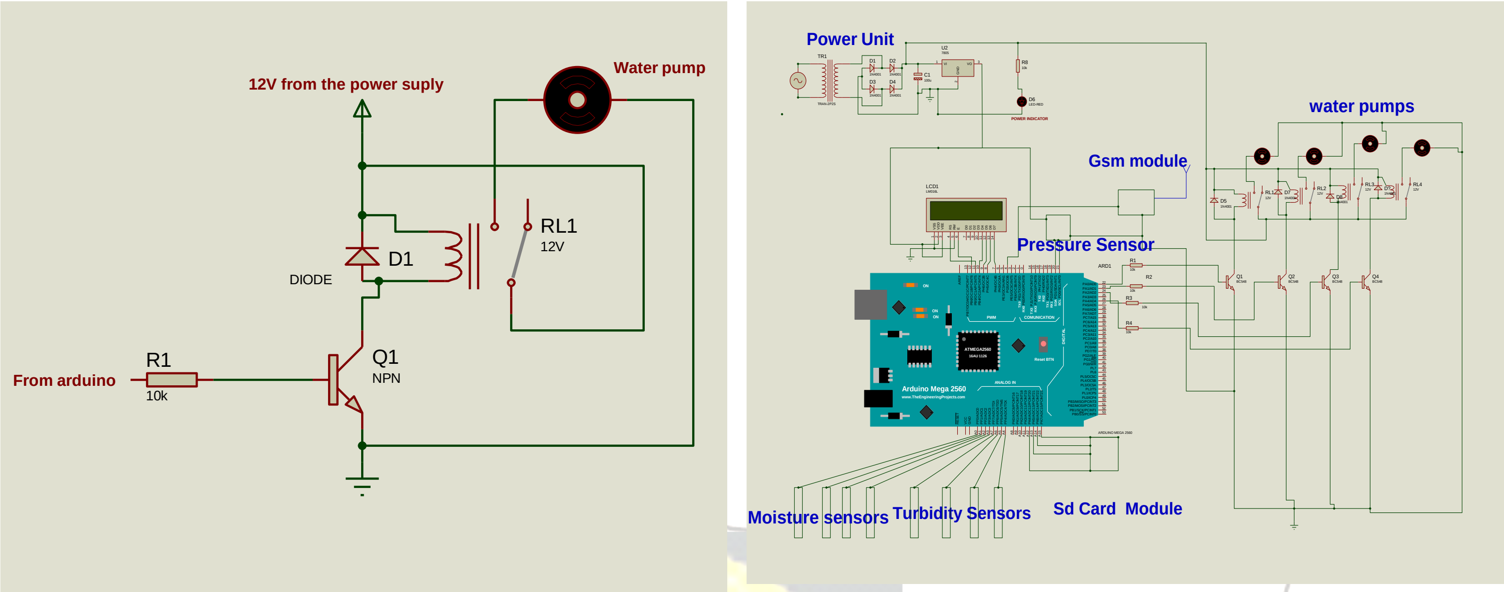
Irrigation of plants is usually a very time-consuming activity done with a required amount of time. It requires a large number of human resources. However, some farm systems use technology to reduce the number of workers, and the time required to irrigate the plants. With such systems, control is very limited and many resources are still wasted (Leroux, 2005). The production of crops also depends largely on the thermal precipitation conditions during the growing season with the challenge of water and manpower every day and, only technological advancements can solve the problems that are faced daily. This research ensured the following advantages: rapid decrease in the input of manpower at every instant in time which reduced the cost of labour since a monitoring control system was installed; high crop yield as the system works effectively and efficiently; increased water management as water was controlled maximally.

Therefore, an Automated Drip Irrigation System which is also known as micro irrigation is a system which supplies water either directly to the root zone or soil surface, through pressurized pipes, valves or drippers to make water drip slowly (Barkunan, 2019).

METHODOLOGY

A system for the measurement of climate and soil hydro physical parameters for an automated drip irrigation system with the use of a moisture sensor to sense the soil moisture level, a turbidity sensor that measured the water turbidity and a module called GY-BMP280-3.3 which measured the atmospheric pressure. This investigation shows that the design can continuously sense the moisture level of the soil, alongside measuring the turbidity level of the soil and also the atmospheric pressure. The measured values decoded by the microcontroller which has been programmed to act accordingly. If the soil moisture level falls below a certain value (pre-set value) which is 50%, the microcontroller sends a signal to trigger the relay; therefore, the DC water pump turns ON. Also, if the soil moisture level increases to a certain value (pre-set value) after the water pump has been ON, the microcontroller again sends a signal to de-activate the relay, therefore, the DC water pump turns OFF. The Liquid Crystal Display (LCD) always display the values and the DC water pump status.

The circuit as shown in Figure 1(a) is used to drive the DC water pump. This control unit contains mainly transistors and relays. The output signal from Arduino was given to the base of the transistor, and the transistor switches the relay. This in turn activates the DC water pump. However, during the process of switching off the relay, an electromagnetic field is stored in the relay coil. This action produces a high voltage spike across the relay coil that can damage the switching transistor. So, to prevent damage to the transistor, a flywheel diode is connected across the relay coil. In this project, the relay is the main control switch for the DC water pump. Figure 1 also shows the circuit diagram of the complete project.

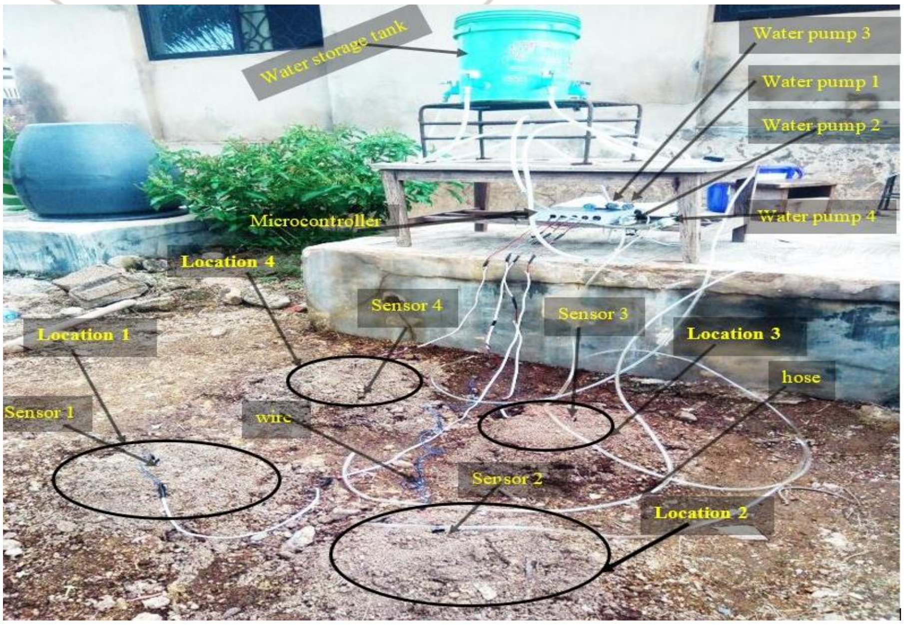


(a) (b)

Figure 4: The circuit diagram of (a) the control unit and the DC water pump (b) the whole system

RESULTS AND DISCUSSION

Figure 2 (a) shows the setup for the automated irrigation system in this investigation. The turbidity sensor was placed in the tank to sensed the clarity of the water and the four moisture content sensors were partly placed in the soil to sensed the level of moisture. The moisture content sensors were placed in various locations as shown in Figure 2(a) and, connected to the microcontroller that displayed the reading of the moisture content in the soil and the turbidity level of the water in the tank. The atmospheric pressure was not excluded, on the LCD screen.



(a)

(b)

Figure 2: (a) Design implementation, (b) pumpkin growth at two weeks

The microcontroller was programmed to a maximum of 100% and a minimum threshold of 50% that controlled and regulated the release of fluid from the tank to the soil through a water pump and connected drip lines. When the mean moisture content in the soil of any of the four locations was less the 50%, the microcontroller activated the relay to turn on the water pump to that location as shown in Plate 1 (a). Once the moisture content in the soil reached 100% at the location at designated interval, the microcontroller deactivated the relay and the pump of that same location turned off. Table 1 to Table 3 shows the data obtained before and after the activation of the relay to the water pump for irrigation. Table 1 shows the data obtained via the four sensors from the various locations at an interval of 00:25 from 00:00 am to 7:05 am before the microcontroller activation of the water pump relay. At 7:05 am, the mean value of each location was greater than the minimum threshold value meaning 12V was not sent to any of the control relays for activation. Also, from the data on the table, it was observed that the moisture content varies after every 00:25 minutes. That variation in the reading sequence saved in the microcontroller was caused by the movement of water in the soil. Though values were meant to reduce until it reaches the minimum threshold value, however, water is not always stationary in the soil but moves through the permeable areas till it reaches the area where the soil moisture sensor cannot sense it. It was also observed from Table 1 that there are variations in the sequence of the turbidity level of the water. One of the factors that causes this distortion in the sequence is the vibration impact from the environment on the tank. These variations are also observed in Tables 2 and 3. In Table 2, the mean moisture content at location 1 is 49%, less than the minimum threshold value set. Therefore, the microcontroller sent 12V to the water pump relay for the location to activate the water pump. This process then goes in a cycle. If any of the moisture content sensed in those locations goes below the threshold then the relay of that location would be triggered. Table 3 shows the date after irrigation, the mean value of the moisture content is at the threshold of 100%. At this stage, 12V was not sent to the relay, and the water pump was turned off. The whole process continues in that cycle.

Table 1: The data for 19-06-2020 (Day 1) [before irrigation]

Time (a.m.)	Location 1			Location 2			Location 3			Location 4		
	M (%)	T (%)	P (hPa)	M (%)	T (%)	P (hPa)	M (%)	T (%)	P (hPa)	M (%)	T (%)	P (hPa)
0:25	70	67	979.29	70	67	979.29	69	67	979.29	68	67	979.29
0.50	71	68	976.80	69	68	976.80	70	68	976.80	70	68	976.80
1:15	70	68	976.60	70	68	976.60	70	68	976.60	71	68	976.60
1:40	69	68	976.79	68	68	976.79	71	68	976.79	69	68	976.79
2:05	70	68	976.79	70	68	976.79	70	68	976.79	70	68	976.79
2:30	68	68	976.88	71	68	976.88	69	68	976.88	71	68	976.88
2:55	70	68	977.07	69	68	977.07	70	68	977.07	68	68	977.07
3:20	71	68	977.30	70	68	977.30	68	68	977.30	70	68	977.30
3:45	69	68	977.49	70	68	977.49	70	68	977.49	70	68	977.49
4:10	70	68	977.52	71	68	977.52	71	68	977.52	68	68	977.52
4:35	71	68	977.52	70	68	977.52	69	68	977.52	67	68	977.52
5:00	68	68	977.53	69	68	977.53	69	68	977.53	68	68	977.53
5:25	70	68	978.31	70	68	978.31	70	68	978.31	70	68	978.31
5:50	70	68	978.17	68	68	978.17	70	68	978.17	71	68	978.17
6:15	68	68	978.30	70	68	978.30	71	68	978.30	69	68	978.30
6:40	67	68	977.95	71	68	977.95	70	68	977.95	70	68	977.95
7:05	69	68	977.98	69	68	977.98	69	68	977.98	71	68	977.98
Mean	69			70			70			69		

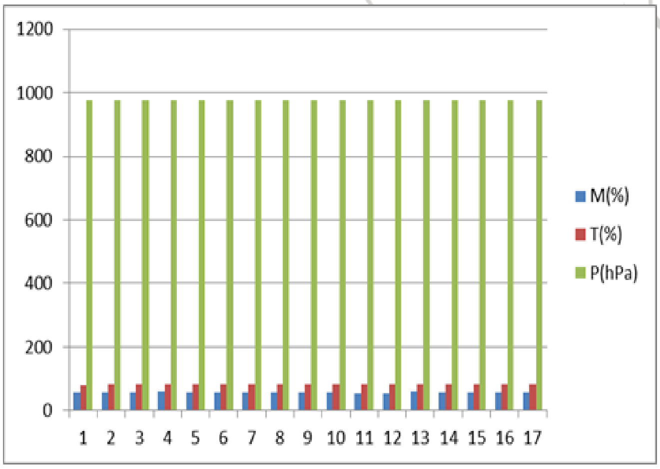
Table 2: The data for 20-06-2020 (Day 2) [before irrigation]

Time (a.m.)	Location 1			Location 2			Location 3			Location 4		
	M (%)	T (%)	P (hPa)	M (%)	T (%)	P (hPa)	M (%)	T (%)	P (hPa)	M (%)	T (%)	P (hPa)
0:25	50	40	979.79	51	40	979.79	48	40	979.79	51	40	979.79
0.50	52	49	979.80	52	49	979.80	49	49	979.80	49	49	979.80
1:15	51	50	976.10	50	50	976.10	51	50	976.10	48	50	976.10
1:40	49	53	976.29	52	53	976.29	52	53	976.29	49	53	976.29
2:05	48	57	976.29	51	57	976.29	50	57	976.29	49	57	976.29
2:30	49	57	976.38	49	57	976.38	52	57	976.38	48	57	976.38
2:55	49	57	976.57	48	57	976.57	51	57	976.57	51	57	976.57
3:20	48	57	976.80	49	57	976.80	49	57	976.80	52	57	976.80
3:45	50	57	976.90	49	57	976.90	48	57	976.90	50	57	976.90
4:10	48	57	977.02	48	57	977.02	49	57	977.02	51	57	977.02
4:35	48	57	977.02	50	57	977.02	49	57	977.02	49	57	977.02
5:00	49	57	977.03	52	57	977.03	48	57	977.03	48	57	977.03
5:25	49	57	977.81	51	57	977.81	51	57	977.81	49	57	977.81
5:50	48	57	977.67	49	57	977.67	52	57	977.67	49	57	977.67
6:15	50	57	977.80	48	57	977.80	50	57	977.80	48	57	977.80
6:40	50	57	977.45	49	57	977.45	52	57	977.45	51	57	977.45
7:05	50	57	977.48	49	57	977.48	51	57	977.48	52	57	977.48
Mean	49			50			50			50		

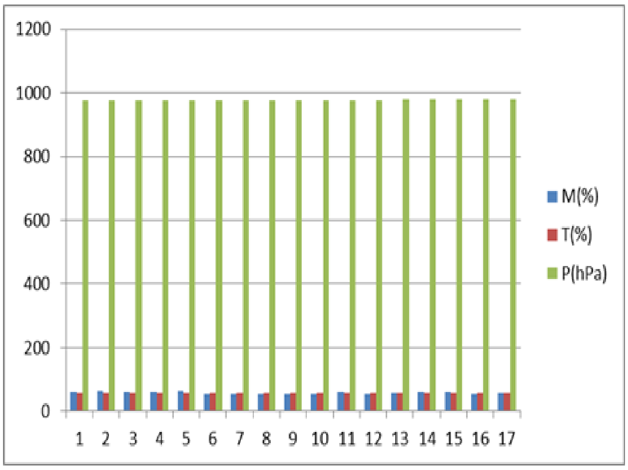
Table 3: The data for 18-06-2020 (Day 3) [after irrigation]

Time (a.m.)	Location 1			Location 2			Location 3			Location 4		
	M (%)	T (%)	P (hPa)	M (%)	T (%)	P (hPa)	M (%)	T (%)	P (hPa)	M (%)	T (%)	P (hPa)
0:25	99	79	975.29	99	79	975.29	99	79	975.29	100	79	975.29
0.50	99	82	974.8	100	82	974.8	100	82	974.8	100	82	974.8
1:15	100	82	974.60	100	82	974.60	100	82	974.60	100	82	974.60
1:40	100	82	974.79	100	82	974.79	100	82	974.79	99	82	974.79
2:05	100	82	974.79	99	82	974.79	99	82	974.79	98	82	974.79
2:30	99	82	974.88	98	82	974.88	98	82	974.88	100	82	974.88
2:55	98	82	975.07	100	82	975.07	100	82	975.07	100	82	975.07
3:20	100	82	975.3	100	82	975.3	99	82	975.3	100	82	975.3
3:45	99	82	975.49	100	82	975.49	100	82	975.49	99	82	975.49
4:10	100	82	975.52	100	82	975.52	100	82	975.52	98	82	975.52
4:35	100	82	975.52	99	82	975.52	100	82	975.52	100	82	975.52
5:00	100	82	975.53	98	82	975.53	99	82	975.53	100	82	975.53
5:25	99	82	976.31	99	82	976.31	98	82	976.31	100	82	976.31
5:50	98	82	976.17	99	82	976.17	100	82	976.17	99	82	976.17
6:15	99	82	976.30	100	82	976.30	99	82	976.30	98	82	976.30
6:40	100	82	975.95	100	82	975.95	100	82	975.95	100	82	975.95
7:05	100	82	975.98	100	82	975.98	100	82	975.98	100	82	975.98
Mean	100			98			97			97		

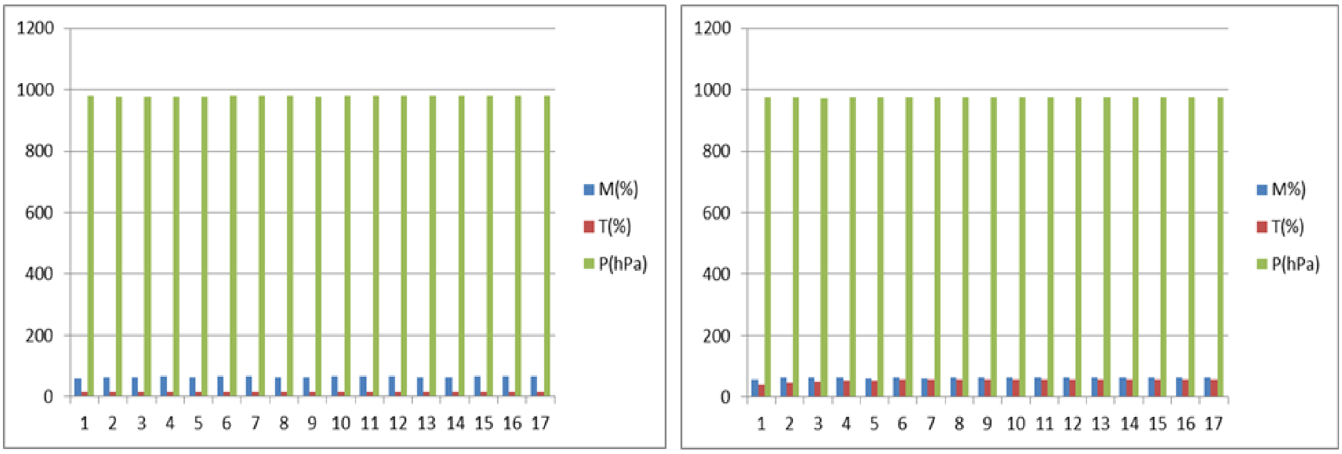
Figure 3[a-d] shows the graphical representation of moisture content, turbidity, and atmospheric pressure for the four locations every two days before irrigation took place. The blue bar is the moisture content in percentage, the red bar is the turbidity in percentage and the green bar is the atmospheric pressure in hPa. From the figure, it was observed that the atmospheric pressures were relatively constant while the moisture contents vary across all recorded days. The cause of variation in the moisture content could be a result of temperature and humidity. Figure 3c shows that location 3 has the lowest moisture content, follow by locations 2 and 4. Location 3 has the highest moisture content. This infers that location 1 reduced below the minimum threshold more often than the rest of the locations. So, most of the irrigation was done by water pump 1. It was also observed that the Pumpkin sprouted earlier at location 3 as a result of the moisture content not falling below the minimum threshold as shown in Figure 2b. Other factors could have contributed to the early growth such as temperature, light, soil nutrients, and genetics.



(a)



(b)



(c) (d)

Figure 3: The moisture content, turbidity and atmospheric pressure of (a) location 1 (b) location 2 (c) location 3 (d) location 4.

CONCLUSION

Since water is one of the factors that aid in plant growth, this investigation provided an efficient means of irrigating farmland by the implementation of a self-controlled system that constitute the microcontroller, relays, sensors, water pump, and tank. The irrigation system can supply indefinitely and make irrigation efficient, provided there is a constant supply of electrical power and water supply to the water storage tank. The implementation of this automated system not only aids the growth of the plant but also maintained the moisture content in the soil above the pre-set value making sufficient water available for the growth of the plant. The implementation of this research on a large scale would reduce the numbers of manpower on farmland, foster a greener environment all around the year and improve energy efficiency.

Also, this system helps in minimizing power and managing water utilization in the development of plants based on the control of water pumps via relays by the microcontroller once the soil means moisture content is below the threshold. Therefore, the detecting and control circuits were DC controlled. The control unit is actuated only when information is gotten from the microcontroller.

CONTRIBUTIONS TO KNOWLEDGE

The following has been achieved upon the completion of the project:

i. Successful design and implementation of a microcontroller-based automatic irrigation system.
ii. Energy efficiency reduced manpower and water management.

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A GSM BASED DATA ACQUISITION SYSTEM FOR CLIMATIC AND SOIL HYDRO-PHYSICAL MEASUREMENT

[1]Oke, A.M., [2]Ofoegbu, E. O., [1]Aremu, T.E., [3]Ayobamidele, S.J., [1]Buhari, F.A., [4]Julius, M.O. and [1]Akingbade, T.O.

[1]Department of Agricultural Engineering, Adeleke University, Ede, Osun State.
[2]Department of Electrical and Electronics Engineering, Adeleke University, Ede, Osun State.
[3]Department of Agricultural Education, University of Ilesa, Ilesa, Osun State.
[4]Department of Mechanical Engineering, Adeleke University, Ede, Osun State.

Corresponding Author: aremu.tolulope@adelekeuniversity.edu.ng

ABSTRACT

The development of a data acquisition system were designed and installed to controls an automated farmland. The information received by the sensors used in this project are being sent to the microcontroller from the sensors which processes the data collected and then opens or closes the valve based on the information received by the microcontroller. The data that is being read by the sensors is being sent to the user through a GSM module, displayed on the LCD and is also stored on an SD card every twenty-five minutes. The project was seen to produce high efficiency on the field where it was implemented. The result was then collected for the period of two (2) weeks and there were variations for different days which were due to climatic conditions. The designed system worked optimally and is fully recommended for both small-scale and large-scale implementations.

Keywords: Data acquisition, sensors, control system, climate, measurement

1. INTRODUCTION

In the instance of irrigation, resources have been wasted because irrigation was not done based on data received by a microcontroller. The hydro physical properties that is to be measured in this project determines the quantity of resources to be delivered to the farm and also the time at which it should be delivered. This project will also ensure the following advantages: rapid decrease in the input of manpower at every instant in time which will definitely reduce cost of labor since a monitoring control system will be installed; high crop yield as the system works effectively and efficiently.

The objectives of this project includes design of an arduino based data acquisition system; Test and validation of the developed system at Adeleke University farm to determine its ability to measure data, display data on a Liquid Crystal Display (LCD) and also send data to the user through a GSM module.

Data acquisition systems have been in existence since the 1960s, when creators at IBM developed the first computer-hardware machines (Ayav, 2019). They put out their first official data acquisition machine in 1963. They called it the IBM 7700 Data Acquisition System. Just one year later, they released the 1800 Data Acquisition and Control System. Unlike the International Business Machines (IBM) 7700, this system featured a component for disk storage (Abhishek Kumar, 2017).

Data acquisition (DAQ) is the process of measuring an electrical or physical phenomenon such as soil moisture, soil temperature, pressure, soil humidity, voltage, current, etc. A DAQ system consists of sensors, DAQ measurement hardware and a computer with programmable software.

Compared to traditional measurement systems, PC-based DAQ systems exploit the processing power, productivity, display and connectivity capabilities of industry – standard computers providing a more powerful, flexible and cost – effective measurement solution. A complete data acquisition system consists of DAQ hardware, sensors and actuators, signal conditioning hardware, and a computer running DAQ software

2. METHODOLOGY

A data acquisition system for the measurement of climatic and soil hydro physical parameters for an automated drip irrigation system uses moisture sensor to sense the soil moisture level, turbidity sensor to measure the water turbidity an a module called GY-BMP280-3.3 to measure the atmospheric pressure. This project requires that the design is able to continuously sense the moisture level of the soil, alongside measuring the turbidity level of the soil and also the atmospheric pressure. The measured values will be decoded by the microcontroller that will be programmed to act accordingly. If the soil moisture level fails below a certain value (pre-set value), the microcontroller will send a signal to trigger the relay, therefore the DC water pump will be ON. And also, if the soil moisture level increases to a certain value (pre-set value) after the water pump have been ON, microcontroller will again send a signal to de-activate the relay, therefore the DC water pump will be OFF. The measured values will also be logged on the memory card and, then sent to mobile Phone through the GSM module as an SMS to a phone number added in the code. There will also be a Liquid Crystal Display (LCD) that will always be displaying the values and the DC water pump status. The microcontroller used is the Arduino Mega (ATmega2560) and it is preferred because the design requires multiple input points.

The sensing unit contains the sensors that are used in this project. However, the moisture sensor and the turbidity sensor are analog sensors. Analog sensor senses the external parameters and gives analog voltage as an output. The output voltage may be in range of 0 to 5V. An Arduino has a feature called ADC. An Analog to Digital Converter (ADC) is a very useful feature that converts an analog voltage on a pin to a digital number.

On the Arduino board shown in the Figure 1 below, these pins have an 'A' in front of their label (A0 through A5). ADCs can vary greatly between microcontrollers. The ADC on the Arduino is a 10-bit ADC meaning it has the ability to detect 1,024 (210) discrete analog levels. Some microcontrollers have 8-bit ADCs (28 = 256 discrete levels) and some have 16-bit ADCs (216 = 65,536 discrete levels).

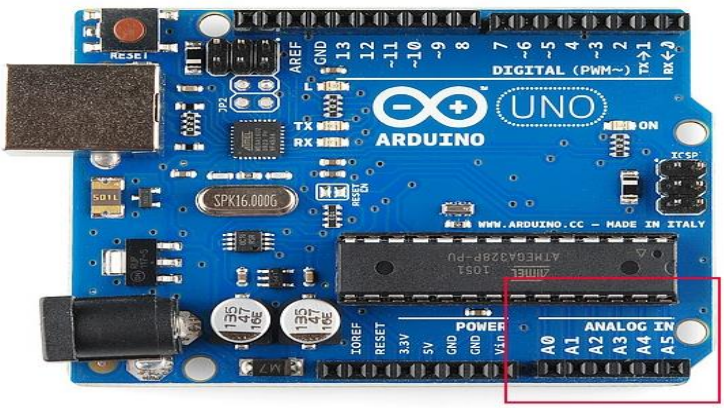

Figure 1: Arduino board

The ADC assumes 5V for 1023 and anything less than 5V will be a ratio between 5V and 1023 according to the following equation:

$$\frac{Resolution\ of\ the\ ADC}{System\ voltage} = \frac{ADC\ Reading}{Analog\ voltage\ measured} \quad (1)$$

$$\frac{1023}{5} = \frac{ADC\ Reading}{Analog\ voltage\ measured}$$

The design flowchart of the entire system is represented in Figure 2 below

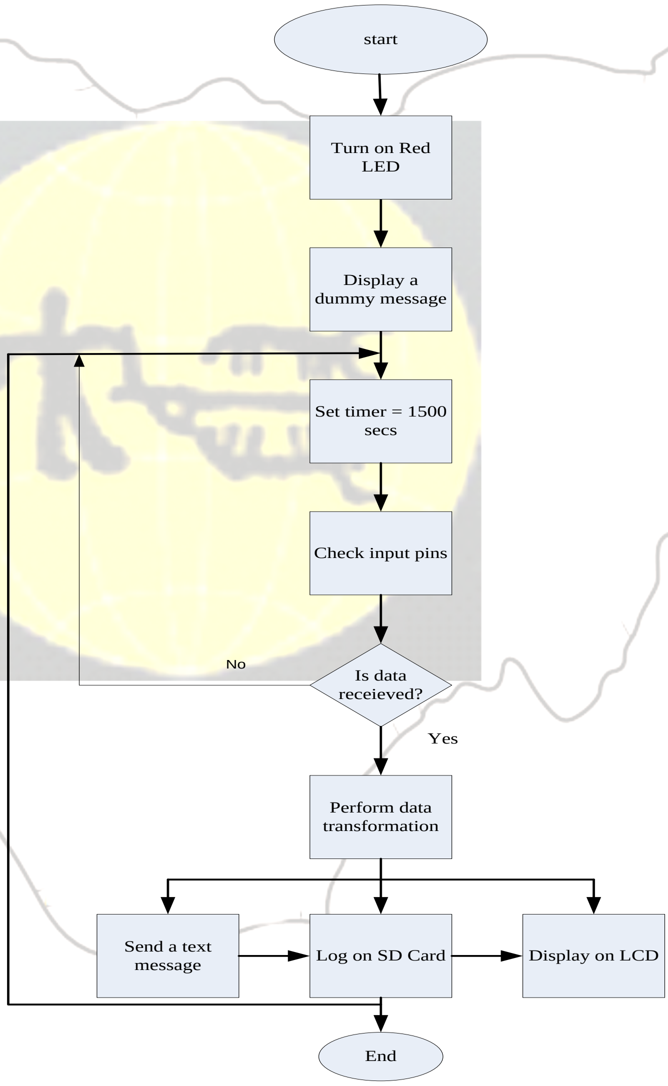

Figure: 2 Design Flowchart of the System

3. RESULTS AND DISCUSSION

The soil moisture sensor was tested at different points to ensure discharge of water at required points. The turbidity sensor and the atmospheric pressure sensor also worked as expected. The data that was displayed on the LCD of the design was used to determine the upper and lower thresholds at which the control circuit would trigger the opening and closing of the water pump.

The framework test was completed for the intended task by implementing the design on a farmland to get the required data. The tables demonstrate the data gotten from each location at a specific period of time.

<u>LEGENDS:</u>

LOC – Location.

M – Soil Moisture.

T – Turbidity.

P – Atmospheric pressure.

VAR – Variance

S.DEV – Standard deviation

Table 3.1: The data for 18-06-2020

	LOC1			LOC2			LOC3			LOC4		
TIME(am)	M(%)	T(%)	P(hPa)	M(%)	T(%)	P(hPa)	M(%)	T(%)	P(hPa)	M%)	T(%)	P(hPa)
0:25	56	79	976.79	61	58	977.29	61	14	978.29	57	40	975.29
0:50	57	82	976.8	62	58	976.8	65	14	977.8	64	49	974.8
1:15	56	82	976.1	60	58	976.6	65	14	977.6	64	50	974.6
1:40	59	82	976.29	61	58	976.79	66	14	977.79	64	53	974.79
2:05	56	82	976.29	63	58	976.79	64	14	977.79	61	55	974.79
2:30	57	82	976.38	55	58	976.88	66	14	977.88	63	57	974.88
2:55	56	82	976.57	53	58	977.07	66	14	978.07	61	57	975.07
3:20	56	82	976.8	54	58	977.3	65	14	978.3	62	57	975.3
3:45	56	82	976.9	53	58	977.49	65	14	975.49	63	57	975.49
4:10	56	82	977.02	53	58	977.52	66	14	978.52	63	57	975.52
4:35	55	82	977.02	59	58	977.52	66	14	978.52	63	57	975.52
5:00	55	82	977.03	54	58	977.53	66	14	978.53	62	57	975.53
5:25	59	82	977.81	57	58	978.31	65	14	979.31	64	57	976.31
5:50	57	82	977.67	61	58	978.17	65	14	979.17	64	57	976.17
6:15	57	82	977.8	61	58	978.3	66	14	979.3	64	57	976.3
6:40	56	82	977.45	55	58	977.95	67	14	978.95	64	57	975.95
7:05	56	82	977.48	56	58	977.98	66	14	978.98	63	57	975.98
VAR	1.19	0.498	0.2743	12.249	0	0.297	1.619	0	0.774	3.03114	19.827	0.297
S.DEV	1.091	0.706	0.5237	3.4998	0	0.545	1.273	0	0.879	1.74102	4.45275	0.545
MEAN	56.47	81.82	976.95	57.529	58	977.43	65.29	14	978.252	62.7059	54.7647	975.429

The table 3.1 above was extracted from the data gotten on 18-06-2020. From the table, there was a sort of distortion in the sequence of the moisture content which is because of the water movement in the soil. In the real sense, the values are meant to be reducing till it gets to the threshold value which is 50%. However, water is not always stationary in the soil, but moves through the permeable areas till it reaches the area where the soil moisture sensor cannot sense it. For instance, between time 04:10 and 04:35 for location 1, there was drop from 56% to 55% which is reasonable enough for a space of 25 minutes. However, between time 00:25 and 00:50 for location 3, there was a rise in the moisture content from 61% to 65% - which was because there was a flow of water around the sensor as at the time.

As observed in the table also, there was also a distortion in the sequence of the turbidity level of the water. The major cause of the distortion was the vibration and clarity of the water. The atmospheric pressure flow was dependent on the wind of the farmland at different point in time. The mean, standard deviation and variance was calculated using Microsoft Excel.

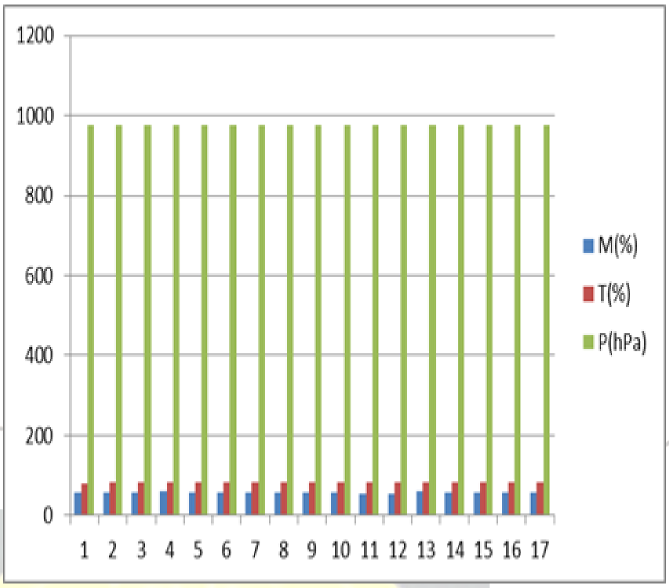

Figure 5.1: 2D Graphical representations for LOC1 of Table 3.1

The green bar in fig 3.1 represents the atmospheric pressure; the blue bar represents the moisture level; the red bar represents the turbidity level. The graph displayed as expected.

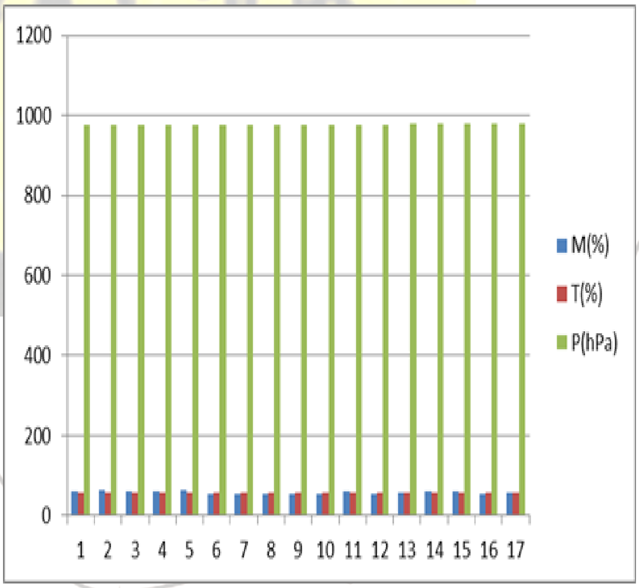

Figure 3.2: 2D Graphical representation for LOC2 of Table 3.1

In fig 3.2 above, the bar level for moisture and turbidity are very close because the data gotten for both parameters are close. The green bar represents the atmospheric pressure; the blue bar represents the moisture level; the red bar represents the turbidity level.

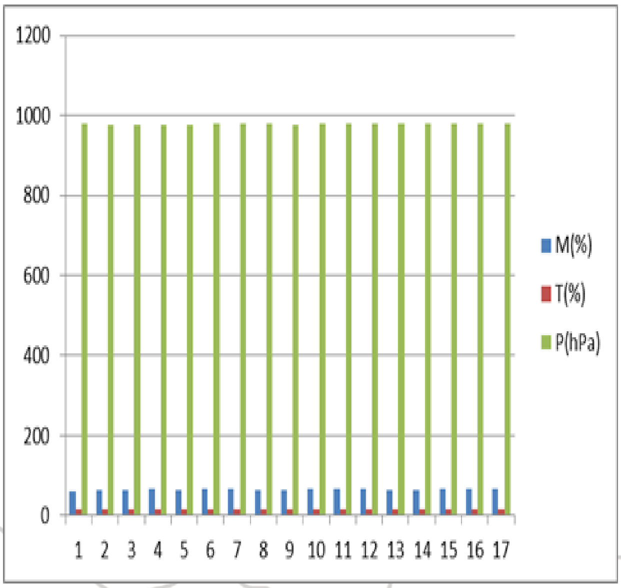

Figure 3.3: 2D Graphical representation for LOC3 of Table 3.1

In the graph in fig 3.3, the values for turbidity are very low which caused the bar not to be very obvious amidst others. However, the green bar represents the atmospheric pressure; the blue bar represents the moisture level; the red bar represents the turbidity level

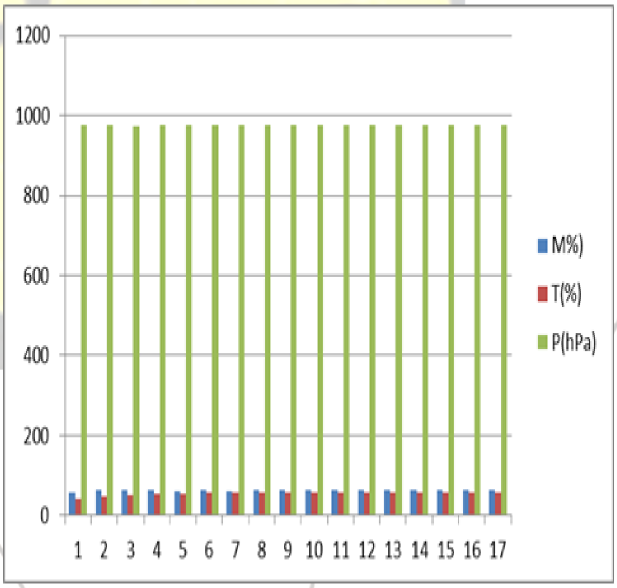

Figure 3.4: Graphical representation for LOC4 of Table 3.1

The fig 3.4 above shows the description of location 4 on a bar chart. The bar for turbidity and soil moisture seem to be very close. The green bar represents the atmospheric pressure; the blue bar represents the moisture level; the red bar represents the turbidity level.

Table 3.2: The data for 19-06-2020

	LOC1			LOC 2			LOC 3			L04		
TIME(am)	M(%)	T(%)	P(hPa)	M(%)	T(%)	P(hPa)	M(%)	T(%)	P(hPa)	M(%)	T(%)	P(hPa)
0:25	62	82	975.31	64	58	975.81	69	13	977.81	70	54	973.81
0:50	55	82	977.77	55	58	978.27	64	14	979.27	61	58	976.27
1:15	55	82	978.08	52	58	978.58	64	14	979.58	61	58	976.58
1:40	54	82	978.43	51	58	978.93	64	14	979.93	61	58	976.93
2:05	54	82	978.67	51	58	979.17	64	13	980.17	61	58	977.17
2:30	54	82	978.56	51	58	979.06	65	13	980.06	61	58	977.06
2:55	55	82	978.58	51	58	979.08	65	13	980.08	61	58	977.08
3:20	55	82	978.52	61	58	979.02	64	14	980.02	62	58	977.02
3:45	55	82	978.32	57	58	978.82	65	14	979.82	61	58	976.82
4:10	54	82	977.9	53	58	978.4	64	14	979.4	61	58	976.4
4:35	54	82	977.72	51	58	978.22	64	14	979.22	61	58	976.22
5:00	55	82	977.69	62	58	978.19	65	14	79.19	63	58	976.19
5:25	57	82	977.66	64	58	978.16	66	14	979.16	64	58	976.16
5:50	53	82	977.61	52	58	978.11	63	14	979.11	61	58	976.11
6:15	53	82	977.57	54	58	978.07	63	13	979.07	61	58	976.07
6:40	56	82	977.82	55	59	978.32	64	3	979.32	61	58	976.32
7:05	55	82	977.7	53	58	978.3	64	14	979.2	61	58	976.2
7:30	61	82	977.58	54	58	978.08	64	14	979.08	65	58	976.08
7:55	55	82	977.64	51	58	978.14	62	14	978.14	59	58	976.14
VAR	5.285	0	0.504	19.71	0	0.503	1.917	5.922	40403	5.252	0.8	0.504
S.DEV	2.299	0	0.7102	4.44	0	0.709	1.385	2.434	201.01	2.292	0.89	0.7102
MEAN	55.37	82	977.85	54.84	58	978.35	64.37	13.158	931.98	61.9	57.8	976.35

The table 3.2 above was extracted from the data gotten on 19-06-2020. From the table, there was a sort of flow in the sequence of the moisture content for LOC1, which is because of the water movement in the soil at time 05:00 which caused rise in the soil moisture content. As observed in the table also, the values gotten were very low which was due to the fact the turbidity sensor wasn't making contact with the water very well due to the shortness of the wire.

The atmospheric pressure flow was dependent on the wind of the farmland at different point in time. The mean, standard deviation and variance were calculated using Microsoft Excel.

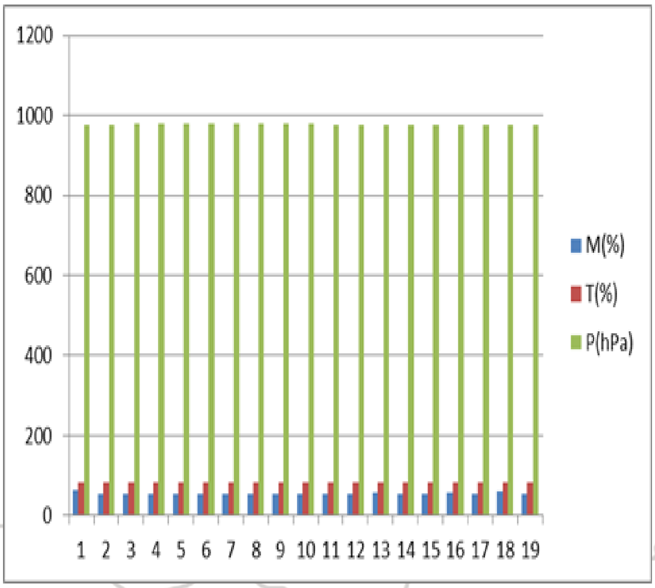

Figure 3.5: 2D Graphical Representation for LOC1 for Table 3.2

In Figure 3.5 above, location 1 for table 4.2 is represented. The green bar represents the atmospheric pressure; the blue bar represents the moisture level; the red bar represents the turbidity level.

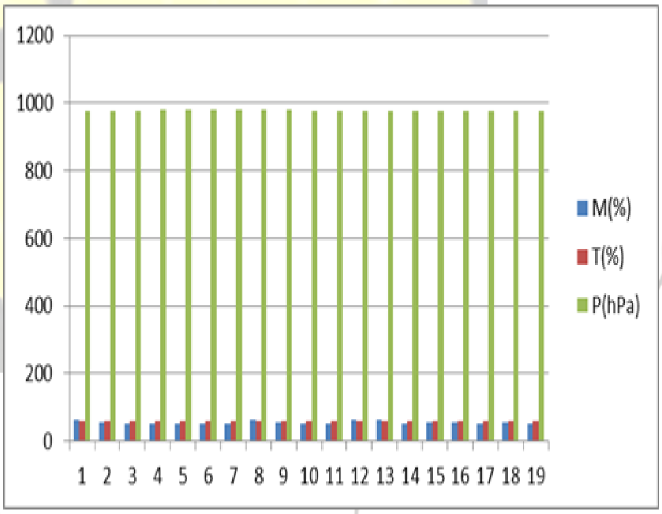

Figure 3.6: 2D Graphical representation for LOC2 for LOC2 for Table 3.2

In Figure 3.6, location 2 for table 3.2 is represented. The green bar represents the atmospheric pressure; the blue bar represents the moisture level; the red bar represents the turbidity level

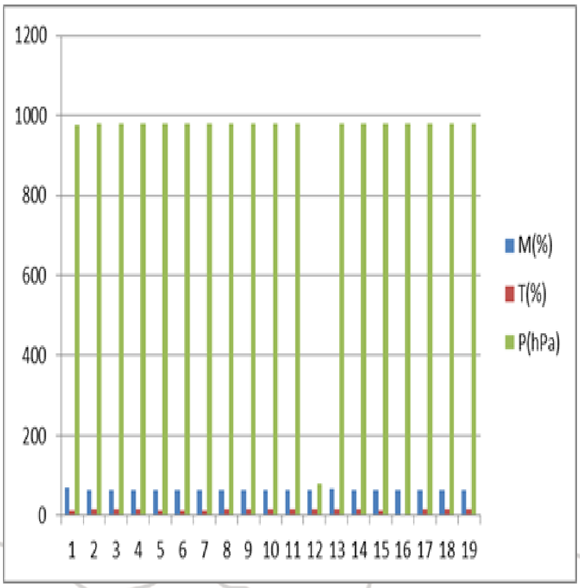

Figure 3.7: 2D Graphical representation for LOC3 of Table 3.2

The Figure 3.7 describes location 3 for table 3.2. At point 12 on the x-axis, there was a drop in the atmospheric pressure. The moisture level is also very low. The green bar represents the atmospheric pressure; the blue bar represents the moisture level; the red bar represents the turbidity level

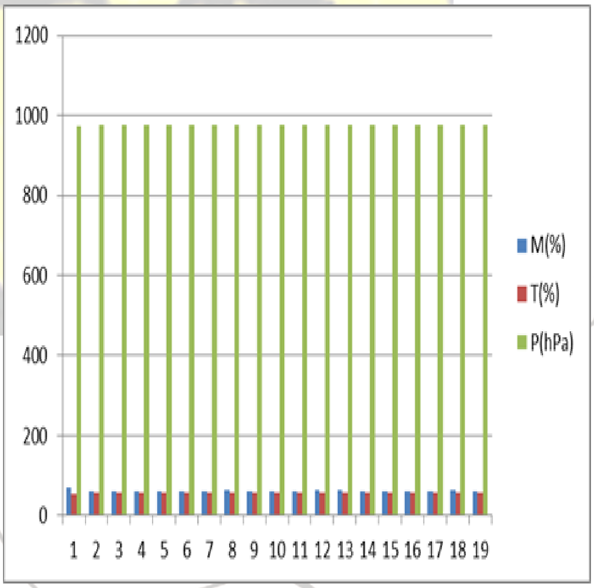

Figure 3.8: 2D Graphical representation for LOC4 of Table 3.2

NOTE: The cause for an obvious drop in the graph of Figur 3.6 was because there was a drop of atmospheric pressure from 979.32 to 79.19.

Plate 4: The complete design

CONCLUSION

The venture of this project helps in minimizing power and water utilization in the developments of plants. To aid this, some DC water pumps which were controlled by the microcontroller was used. The microcontroller was modified to actuate the water pump to water the plants when the threshold is below the set value.

The detecting and control circuits are direct current (DC) controlled. The control unit is actuated only when information is gotten from the microcontroller.

The following has been achieved upon the completion of the project:

i. Construction of a working data acquisition system.
ii. Successful design and implementation of a microcontroller-based automatic irrigation system.
iii. Energy efficiency, reduced manpower and water management.

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