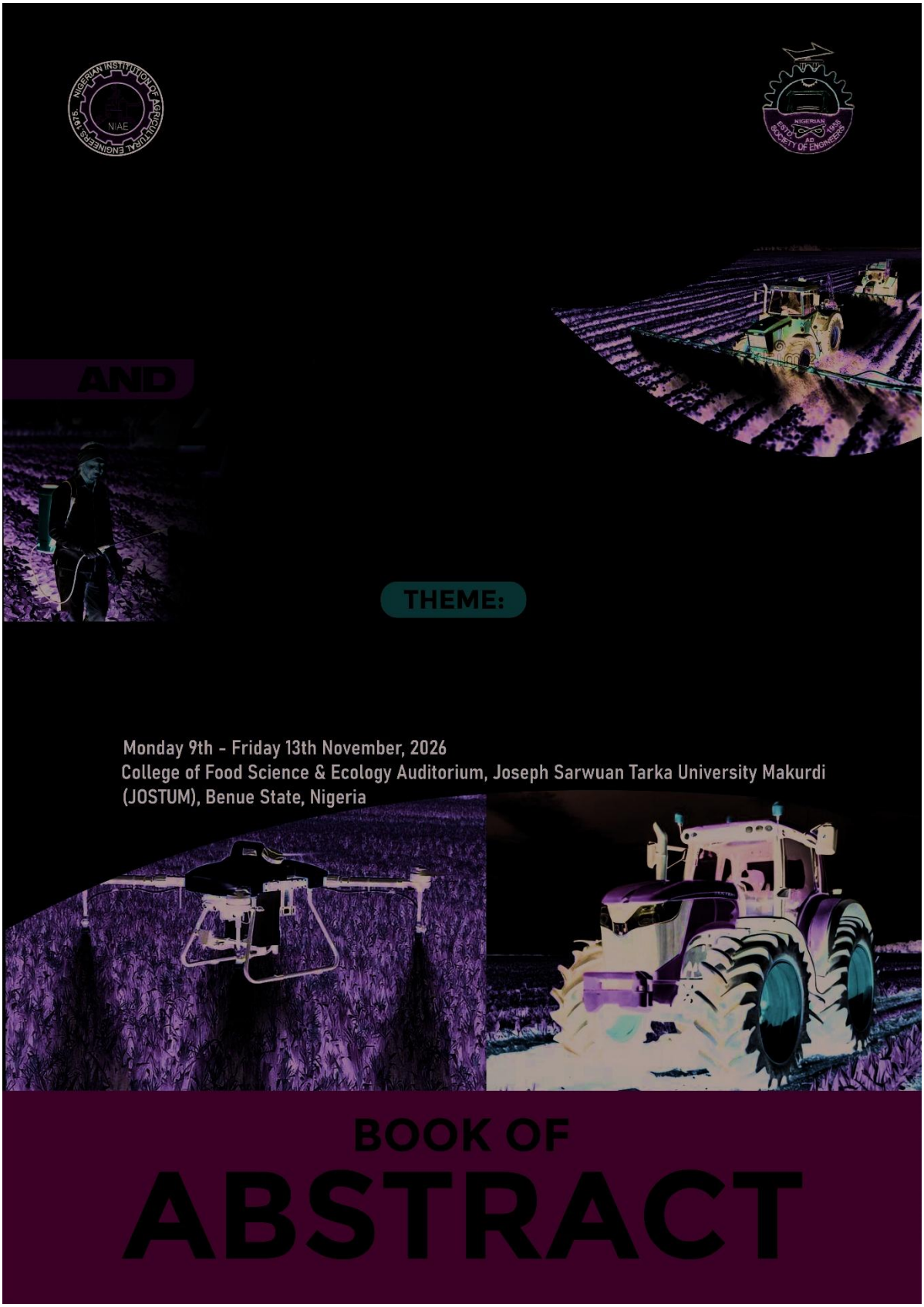

AND
THEME:
Monday 9th - Friday 13th November, 2026
College of Food Science & Ecology Auditorium, Joseph Sarwuan Tarka University Makurdi (JOSTUM), Benue State, Nigeria
BOOK OF
ABSTRACT

WELCOME ADDRESS BY THE NATIONAL CHAIRMAN, PROF. JOSEPH ADAMA

The President, Nigerian Society of Engineers and Chairman of the
Occasion, Engr. Ali Alimasuya Rabiu, FNSE, FASCE, FAENG, MFR
The Executive Governor of Benue State, His Excellency Rev. Fr. Dr. Hyacinth Alia
The Executive Governor of Borno State, His Excellency Engr. Prof. Babagana Umara Zulum, FNSE, FNIAE, mni
The Special Guest of Honour and Secretary to the Government of the Federation, His Excellency Distinguished Sen. (Dr.) George Akume, CON
The Hon. Minister of Water Resources and Sanitation, Engr. Prof. Joseph Utsev, FNSE, FNIAE
The President, Council for Regulation of Engineering in Nigeria, Engr. Prof. Sadiq Abubakar, FNIAE, FNSE, FAENG
The Permanent Secretary, Federal Ministry of Agriculture and Food Security, Engr. Dr. Marcus Ogunbiyi, FNSE, FNIAE
The Vice Chancellor, Joseph Sarwuan Tarka University, Makurdi Engr. Prof. Isaac Itodo
Members of the National Executive Council of the NIAE
Ladies and Gentlemen,
Good morning.
I feel highly honoured to stand here today to present this address which marks the opening ceremony of the 26th International Conference and 46th Annual General Meeting of our institution, the Nigerian Institution of Agricultural Engineers.

The Institution is the professional body of agricultural engineering practitioners dedicated to the application of engineering principles and technology to render services in the fields of food, agriculture, livestock, rural development, aquaculture and environment, etc. In 1975, it was officially registered as the Nigerian Society of Agricultural Engineers and transformed into the Nigerian Institution of Agricultural Engineers (A Division of the Nigerian Society of Engineers) in 1998.

Since registration, the institution has been holding conferences every year in different states of Nigeria. The last time it was hosted in Benue state and indeed this university, was from September 12th to 15th 1991.

The theme of this year's conference, **"Engineering Climate-Resilient and Smart Agricultural Systems for Sustainable Food Security and Agro-Industrial Growth,"** was carefully chosen to strategically align with Nigeria's drive to modernize agriculture, ensure food security, catalyze rural development, accelerate agro-industrial development and markedly alleviate poverty. It is also timely due to the crises caused by climate change and insecurity. These have led to poor crop yield, low meat production, displacement of farmers, destruction of farms and farm infrastructure, disease outbreak and increased hunger.

From the time of her formal registration to date, the institution has contributed in various ways to the growth of the Nigerian economy. The members have held and are still holding positions of responsibilities such as state governor and deputy governor, vice chancellor, rector and provost of higher institutions, members of national and state assemblies, commissioners, directors general and executive directors, etc. Also, members of the institution have served as chairmen/members of boards in many government parastatals, governing councils of higher institutions and consultants to many locally and internationally funded agencies such as IFAD, RAAMP,

FADAMA, NSPFS, etc. Our members have also headed international and regional professional organizations which include: ISTRO, PASAE, CIGR, AMA, WASAE, etc.

In conclusion, I wish to extend our appreciation to individuals and groups who sacrificed and contributed in different ways to ensure the success of this year's conference. Some of these people are The Executive Governor of Borno State, His Excellency Engr. Prof. Babagana Umara Zulum, the President of the Nigerian Society of Engineers and chairman of the occasion, Engr. Ali Alimasuya Rabiu, the Vice Chancellor, Joseph Sarwuan Tarka University, Makurdi, Engr. Prof. Isaac Itodo, The Vice Chancellor, Federal University Dusima, Engr. Prof. Khalid Othman, the President of COREN, Engr. Prof. Sadiq Abubakar.

Again, we say thank you! and thank you!!

Engr. Prof. Joseph Adama, fniae, mnse, mistro
National Chairman

NIGERIAN INSTITUTION OF AGRICULTURAL ENGINEERS (NIAE)

(A Division of Nigerian Society of Engineers)

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Table of Contents

Title/Cover Page

Welcome Address by the National Chairman of NIAE

National Executive Council

Conference Organizing Committee

Conference Organizing Sub-Committees

International Scientific Committee and Advisers

Table of Contents

Keynote Address

Engr. Prof. Akindele Folarin Alonge FNSE, FAEng, FNIAE, Former National Chairman of NIAE

Lead Papers

Lead Paper I: Engineering Climate-Resilient And Smart Agricultural Systems: The Role Of Sustainable Water Resources, Soil And Land Management In Food Security And Agro-Industrial Development	**Presenters** **Engr. Prof. Gabriel Delian Akpen,** FNSE, FNIWE Director General, Bureau of Special Projects and Infrastructure, Benue State
Lead Paper II: Restoring The Integrated Water Resources And Agricultural Development Mandate Of Nigeria's River Basin Development Authorities: A Strategic Pathway To Agricultural Mechanisation, Food Security, Climate Resilience And Rural Economic Transformation.	**Engr. Dr. Valerie Judith Omale,** FNSE, FNIAE, FNIWE Director, Construction, Operations and Maintenance (COM), Lower Benue River Basin Development Authority, Makurdi Past Chairman, APWEN
Lead Paper III: Interfacing Limateresident Agricultural System With Smart Systems For Sustainable Agricultural Production And Groindustrial Growth	**Engr. Dr. Bill Anaka** FNIAE, FNSE Former Managing Director of Benue State Oil Mill, Taraku

Lead Paper IV:

Beyond Automation: Harnessing Artificial Intelligence And Robotics For Intelligent, Precision-Driven And Climate-Smart Agricultural Transformation In Africa.

Engr. Dr. John Audu, MNIAE, MNSE

Chairman, NIAE Makurdi Chapter
Co-Chairman COC

Paper ID	Articles	Authors
02	Evaluation of historical and projected evapotranspiration for sustainable irrigation planning in the dansoshiya, Kano state.	M. D. Zakari[1]* and S. N. Usman[1] I. Arab
03	Development and Performance Evaluation of A Modified Active Evaporative Cooling System for Postharvest Preservation of Selected Vegetables.	A. Shehu[*], D. D. Nalado, A. A. Adamu, B. M. Sani, R. Abubakar, T. A. Timothy, U. M. Agbom, M. Atiku, and A. S. Abubakar
10	Postharvest Changes in Total Soluble Solids of Onions as Affected by Temperature and Relative Humidity.	Y. M. Bukar[1*], L. G. Abubakar[2], and B. G. Jahun[2]
11	Artificial Intelligence And Machine Vision For Precision Agricultural Mechanization In Southern Nigeria: Evidence Gaps, Barriers, And Frameworks	R. S. Bello[1*], C. I. Nwali[2], F. Orishamuko[2], E. U. Nebo[2], and A. A. Adedeji[2]
12	Hate Speech Detection Using Machine Learning Techniques	A. M. Yau[1*]
13	Smart Ai Invoice Generator: An Ai-Driven Web-Based System For Invoice Automation And Business Record Management In Small Enterprises	U. A. Umar[1*], A. Haruna[2], I. F. Jibrin[3], H. Ado[4], Z. M. Marafa[5], and H. Atiku[6]
14	Biochar Effectiveness for Organic Wastewater Decontamination	A. A. Lawal[1,3*], I. Mohammed[1], H. Alkali[1], U. A. Kawuyo[1], B. Mohammed[1], A. N. Aviara[2], A. U. Dzivama[1], H. Ariffin[3,4], and M. A. Hassan[3]
15	Characterization of Local Clays and Metakaolin for Porous Clay Pipes Applications in Efficient Irrigation Systems	G. U. Idris[1], S. A. Abubakar[2*], S. M. Musa[2], and A. S. Abdullahi[2]

16	Water Management And Nutrient Leaching In Rice Production In Nigeria: A Review	G. U. Idris[1], S. A. Abubakar[2*], S. M. Musa[2], and A. S. Abdullahi[2]
18	Effects Of Stem Characteristics And Blade Speed On The Cutting Force Required For Cassava Stems	M. O. Ale[1*], T. A. Abisuwa[1], T. Ewetumo[2], O. N. Obanoyen[3], and K. M. Kareem
20	Enhancing Farmers Safety Using Levy Flight Whale Optimization Algorithm In Wireless Sensor Networks	S. Gimba[1], H. A. Amshi[1], A. M. Bichi[1], and S. Ali[2]
22	Development And Evaluation Of An Automated Soil Macro Nutrient Testing Device Under Tropical Soils	M. J. Flayin[1] and E. O. Ezeh[1*]
24	Expanded Polystyrene Packaging For Cold Chain Applications: Performance, Tradeoffs, And Alternatives-A Review	K. E. Gbabe[1*], Y. D. Idris[1], S. E. Chukwu[1], C. B. Ikyo[1], J. T. Ate[2], and M. A. Omodara[1]
25	Performance Evaluation Of An Improved Traditional Rice Husk-Fired Parboiler	A. D. Musa[1], A. Saleh[2], and M. L. Suleiman[2]
26	Advancing Integration Of Smart Technologies In Nigerian Agriculture For Sustainable Development	O. A. Ogunjirin[1], O. C. Ogunjirin[2], S. E. Sunmonu[1], M. O. Hassan[1], O. R. Jimoh[1], and Saheed
27	Development And Performance Evaluation Of An Improved Chicken Feeder For Small-Scale Farmers	S. Aminu[1], J. Selchang[1], and T. A. Ishola[2]
29	Determination Of Some Heavy Metals In Processed Powdered Pepper Sold In Makurdi	P. A. Omale[1*], P. O. Ojebe[2], and T. E. Chin[2]
31	Hydrogen fuel cell technology for sustainable agricultural machinery: a review of opportunities, challenges and future prospects.	B. J. Bature*, T. K. Kaankuka, J. Audu, and T. Bako
32	Integrated Climate-Resilient And Smart Agricultural Engineering Framework For Sustainable Food Security In The Niger Delta: A Case Study Of Bayelsa State, Nigeria	K. M. P. Glory
33	Post-Harvest Engineering And Value Addition Technologies: A Case Study Of Bayelsa State, Nigeria	K. M. P. Glory

37	Mechanization of Palm Oil Processing in Southern Nigeria: Status, Challenges, Prospects and Opportunities – A Review	A. U. Omoruyi, L.A.S. Agbetoye and S.O. Oladele
38	Mechanical Properties Of Heat-Sealable Starch–Polyvinyl Alcohol Biopolymer Films Incorporated With Palm Kernel Oil For Sustainable Food Packaging	M. O. Zubair*, M. A. Omodara, S. O. Kamaldeen, O. Ajiboye, O. A. Akinyera, I. S. Ayanda, T. A. Fashanu, and F. M. Omapariola
39	Multi-Dimensional Flood Vulnerability Assessment: A Systematic Review Of Indicators, Weighting Engines, And Spatial Synthesis	O. B. Ajodo*, M. Y. Otache, and M. I. Animashaun
41	Effect Of Storage Conditions On The Quality Of Ground Melon Seed	P. A. Omale[1*], T. Wendeh, M. O. Oglekwu[2], and T. P. Nathan[2]
44	Optimization Of Thermal Processing Conditions And Sugarcane Juice Concentration For Quality Attributes Of Tamarind Juice Using Response Surface Methodology	M. S. Sanusi[1*], M. O. Sunmonu[1], N. B. Izuogu[2], A. T. Ahman[1], A. M. Bello[1], and F. M. Adetunji[1]
45	Impact Of Agricultural Engineering On Nigeria's Economy: A Review	T. O. Olanrewaju[1*], L. A. Zubair[2], I. U. Sillah[2], H. U. Hussaini[2], S. O. Isah[2], F. F. Kure[2], and N. S. Saddiq[2]
47	Interactive Mechanistic Simulation Of Municipal Wastewater Treatment Unit Operations For Engineering Education	A. A. Sulaiman[1*] and O. O. Kolajo[1]
48	Development Of Motorized Two-Row Irish-Potato Planter As Appropriate Technology For Improved Productivity Among Smallholder Farmers In Nigeria	A. M. Makolo, Y. D. Kantiok, and S. S. Igila
39	Raised-Bed Configuration Versus Deficit Irrigation In Wheat: An Evidence Synthesis Of Yield, Water Productivity And Context-Dependent Responses	J. Musa[1*], A. I. Arab, G. N. Ugama, J. Abdullah, and O. A. Qassim
51	Effects of Tillage Depth and Forward Speed on Tillage Performance Under Dryland Conditions	M. S. Abubakar*, A. Shehu, and A. S. Abubakar
53	Optimizing Water Harvesting Practices for Environmental Sustainability in Bomo, Sabon	G. Kalu[1], B. Ashiru[2], H. I. Atta[3], and G. N. Ugama[1]

	Gari Slocal Government Area, Kaduna State, Nigeria	
54	Determination of N-Factors for Draft Force of Tractor-Mounted Disc Plough in Nsukka Clayey Loam Soil	C. J. Ohagwu[1)*], E. E. Akachukwu[2)], and V. A. Ohagwu[3)]
56	AI-Enabled IoT-Based Precision Nutrient Management for Climate-Resilient Rice Production in Nigeria	J. A. Oyedokun[1*], O. C. Ogunjirin[2], O. W. Adelere[1], S. Salihu[3], and O. A. Ogunjirin[1]
59	Optimization of Vertical Grinding Disc Parameters for High-Efficiency Guinea Corn (*Sorghum bicolor*) Processing	N. I. Nwagugu*, J.O. Odenigbo, O. Ezeonu, U. A. Chukwudolue, G. O. Adiele, P. A. Mbah.
60	Environmental Impact Assessment of an Integrated Septic-Tank Biodigester System in Zaria, Nigeria	A. A. Wahab[1*], F. O. Issa[1], A. O. Lawal[1], T. O. Olanrewaju[1], A. A. Fagge[1], A. N. Sale[1], T. T. Adegboyega[2], and J. R. Mani[1]
61	Design and Evaluation of Growth-Stage Adaptive IoT Irrigation System for Bell Pepper in Semi-Arid Nigeria	S. U. Bwala[1*], U. D. Idris[2], and A. I. Arab[3]

THE 26TH INTERNATIONAL CONFERENCE AND 46TH ANNUAL GENERAL MEETING OF THE NIGERIAN INSTITUTION OF AGRICULTURAL ENGINEERS (NIAE)

(A DIVISION OF NIGERIAN SOCIETY OF ENGINEERS)

held at the

College of Food Science and Ecology Auditorium, Joseph Sarwuan Tarka University Makurdi, Nigeria.

Theme: Engineering Climate-Resilient and Smart Agricultural Systems for Sustainable Food Security and Agro-Industrial Growth

November 09 – 13, 2026.

BOOK OF ABSTRACT

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Book of Abstract

Lead Paper I

ENGINEERING CLIMATE-RESILIENT AND SMART AGRICULTURAL SYSTEMS: THE ROLE OF SUSTAINABLE WATER RESOURCES, SOIL AND LAND MANAGEMENT IN FOOD SECURITY AND AGRO-INDUSTRIAL DEVELOPMENT

Engr. Prof. G. D. Akpen

Abstract

Agricultural production in Nigeria must increasingly contend with rainfall uncertainty, damaging floods, dry spells, soil degradation and the uneven performance of irrigation and drainage infrastructure. These problems are often discussed separately from mechanization, automation and digital agriculture, although their effects are closely connected. This study examines climate-resilient and smart agricultural systems and then considers the place of sustainable water resources, soil and land engineering within it. The study argues that resilience depends less on the adoption of individual technologies than on the quality of resource assessment, infrastructure design, operation and long-term stewardship. It discusses integrated watershed planning, dependable irrigation and drainage, groundwater governance, soil-water conservation, erosion control, land suitability assessment and the selective use of geospatial and sensor-based information. Nigerian river basins and irrigation schemes are used to illustrate practical decisions and persistent institutional constraints. An integrated planning framework is proposed, linking catchment diagnosis, farm-level engineering, digital monitoring and accountable asset management. The central implication is that smart agriculture should be judged by measurable improvements in water productivity, soil condition, service reliability, risk reduction and farm livelihoods, not by the sophistication of equipment alone. Conclusively, agricultural engineers can make a more consequential contribution to food security and agro-industrial development when they work across hydrological, soil, land-use and institutional boundaries.

Keywords: Agricultural Engineering, Climate resilience, Irrigation, Water resources, Soil conservation, Land engineering, Nigeria

"RESTORING THE INTEGRATED WATER RESOURCES AND AGRICULTURAL DEVELOPMENT MANDATE OF NIGERIA'S RIVER BASIN DEVELOPMENT AUTHORITIES: A STRATEGIC PATHWAY TO AGRICULTURAL MECHANIZATION, FOOD SECURITY, CLIMATE RESILIENCE AND RURAL ECONOMIC TRANSFORMATION"

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ABSTRACT

Nigeria has about 79 million hectares of agricultural land, of which only 44% is reported to be cultivated, and an estimated 3.14 million hectares of irrigable land, of which less than 7% is reported to be in use [1]. The River Basin Development Authorities (RBDAs), created in the 1970s to harness water for irrigation, domestic and industrial supply and wider socio-economic development, hold a large share of the country's dams, irrigation schemes and agricultural project lands. Over time, however, the link between the water infrastructure they provide and the agricultural production it was meant to support has weakened. This paper advocates restoring that link. It proposes (i) a River Basin Agricultural Mechanization Service Scheme (RBAMSS), delivered by the RBDAs in partnership with contracted Private Sector Agents (PSAs), through which farmers access tractors, implements and trained operators at published, land-area-based tariffs; (ii) a River Basin Agricultural Land Leasing Scheme (RBALLS) that makes suitable, legally available and underused project land accessible to farmers, cooperatives and investors, in compliance with the RBDA Act and the Land Use Act; and (iii) rehabilitation of existing irrigation schemes, organized production clusters, climate-smart technologies, public-private partnerships, agro-industrial development, extension services and a dedicated development fund. A worked machinery-cost example shows that annual utilization, not purchase price alone, determines whether a hire scheme can recover its costs. A four-phase implementation plan with measurable indicators is proposed. The paper concludes that the RBDAs should be repositioned as integrated agricultural development institutions that connect water, land, mechanization, technical support and markets to increase food production, generate employment and stimulate rural economic transformation.

Keywords: River Basin Development Authorities; agricultural mechanization; irrigation; land leasing; public-private partnership; food security; Nigeria.

Book of Abstract

Paper Lead III

INTERFACING CLIMATE-RESILIENT AGRICULTURAL SYSTEMS WITH SMART SYSTEMS FOR SUSTAINABLE AGRICULTURAL PRODUCTION AND AGRO-INDUSTRIAL GROWTH

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ABSTRACT

Agriculture is central to Nigeria's food security, to employment generation, rural development and industrial growth. However, agricultural production is increasingly threatened by irregular rainfall, drought, flooding, high temperatures, soil degradation, inadequate mechanisation, post-harvest losses and unreliable energy supplies. These challenges require solutions that go beyond conventional farming methods and isolated technological interventions. This paper examines how climate-resilient agricultural systems can be interfaced with SMART System integrated technologies and intelligent management approaches that improve monitoring, decision-making, resource utilisation and operational efficiency. It discusses the complementary roles of agricultural engineering, precision agriculture, digital information, irrigation, mechanisation, renewable energy, post-harvest technologies and agro-processing in developing sustainable agricultural value chains. The paper proposes an integrated framework that connects climate intelligence, resilient infrastructure, smart farm management, efficient post-harvest systems, agro-industrial development and institutional support. It also highlights the roles of government, research institutions, manufacturers, financial institutions, farmers and the Nigerian Institution of Agricultural Engin7eers (NIAE). The paper concludes that Nigeria's sustainable agricultural transformation requires more than increased production or the acquisition of modern equipment. It requires a pleased National implementation roadmap supported by defined coordinated by systems that are climate-responsive, technologically appropriate, economically viable and environmentally sustainable.

Keywords: Climate resilience, SMART systems, agricultural engineering, sustainable production, food security, agro-industrial growth.

"BEYOND AUTOMATION: HARNESSING ARTIFICIAL INTELLIGENCE AND ROBOTICS FOR INTELLIGENT, PRECISION-DRIVEN AND CLIMATE-SMART AGRICULTURAL TRANSFORMATION IN AFRICA"

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ABSTRACT

Agriculture contributed 26.15% of Nigeria's real GDP in the second quarter of 2026 and grew by 4.39% [1], yet climate change has already reduced agricultural productivity growth in Africa by an estimated 34% since 1961, more than in any other region [2]. Mechanization has long been the engineering answer to low productivity. This paper argues that the next step is to go beyond automation: from machines that replace labour to systems that sense, decide, act and learn, and that are designed, built and governed locally. The paper reviews eight areas: AI-powered decision support; computer vision; IoT and edge AI; autonomous robots and unmanned machinery; robotics for planting, harvesting and postharvest handling; AI-driven climate-smart resource optimisation; indigenous innovation and commercialisation; and agricultural engineering education and practice. It relies on recent, online-verifiable evidence. Three findings recur. First, results obtained on laboratory datasets overstate field performance: a widely cited plant-disease model scored 99.35% on held-out laboratory images but only about 31% on images from other conditions [3], and fewer than 30% of the studies in a 2025 review of AI and robotics in agriculture validated their results in real agricultural conditions [4]. Second, the commercial robot market is concentrated elsewhere: a 2025 technical review of 145 commercial and prototype robots found that about 63% originated in Europe and 8% in Asia [5]. Third, low-cost edge hardware, locally assembled machines and generative-AI advisory services are already working in Nigeria and neighbouring countries, usually at pilot scale and often with developer-reported results. The paper proposes a layered "agricultural intelligence stack", worked examples for drone coverage, edge-model memory and screening accuracy, a regulatory map (NDPA 2023, NigCARs Part 21, the AU and Nigerian AI strategies), a curriculum framework for agricultural engineering education, a five-year phased implementation plan with measurable indicators, and twelve recommendations. The central message is that intelligence in agriculture is not delivered by buying robots; it is built by combining local data, field-validated models, robust and repairable hardware, enabling policy and trained people.

Keywords: artificial intelligence; agricultural robotics; precision agriculture; edge AI; computer vision; climate-smart agriculture; local manufacturing; agricultural engineering education; Nigeria; Africa.

26th International Conference and 46th Annual General Meeting of the Nigerian Institution of Agricultural Engineers (NIAE). ***November 9 - 13, 2026, JOSTUM, Makurdi, Nigeria***

Book of Abstract
Paper ID – 2

EVALUATION OF HISTORICAL AND PROJECTED EVAPOTRANSPIRATION FOR SUSTAINABLE IRRIGATION PLANNING IN THE DANSOSHIYA, KANO STATE.

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ABSTRACT

High evapotranspiration rates, erratic rainfall patterns, and increasing water scarcity in the semiarid Sudan Savanna zone of northern Nigeria pose serious challenges to sustainable irrigated agriculture, often resulting in low water-use efficiency due to inaccurate estimates of crop water requirements. This study aimed to determine key soil physical properties (moisture content, bulk density, field capacity, permanent wilting point, soil classification, and infiltration rate) and project historical (1985 - 2014) and future (2025–2084) reference evapotranspiration (ETo) in Dansoshiya, Kiru Local Government Area, Kano State, towards developing a climate-resilient irrigation scheme. Soil samples were collected from upstream, midstream, and downstream locations at three depths (0 - 30 cm, 30 - 60 cm, and 60 - 90 cm) and analyzed for moisture content, bulk density, field capacity, permanent wilting point, texture, and infiltration rate. The FAO-56 Penman-Monteith equation was used to calculate daily ETo using NASA POWER meteorological data and bias-corrected outputs from the HadGEM3 Global Climate Model under the SSP126, SSP245, and SSP585 scenarios. The results indicated that the soils were mainly sandy loam to clay loam with moderate total accessible water (average TAW = 110 mm/m), bulk density (1.42-1.49 g/cm3), and infiltration rates (6.8 cm/hr upstream and 0.6 cm/hr downstream). Historical average daily ETo ranged from 4.41 mm/d in August to 9.62mm/d in March, with an annual average of 6.73 mm/d. Under SSP585 (2055-2084), a growing trend in ETo was observed for future forecasts, with an average daily value of 7.29 mm/day. The highest increment was observed in October (+1.41 mm/day, +25.32%). These findings emphasize rising future evaporative demand and the need for adaptive water management. It is recommended that site-specific irrigation scheduling incorporating drip or sprinkler systems be adopted, with frequent low-volume applications in high-infiltration zones and controlled slow watering in low-infiltration downstream areas to enhance water-use efficiency and ensure sustainable irrigation planning in Dansoshiya.

Keywords: *Evapotranspiration (Eto); Irrigation Planning; Penman-Montieth model; Soil Physical Properties; Climate Change Projections (SSPs); Dansoshiya.*

Book of Abstract
Paper ID – 3

DEVELOPMENT AND PERFORMANCE EVALUATION OF A MODIFIED ACTIVE EVAPORATIVE COOLING SYSTEM FOR POSTHARVEST PRESERVATION OF SELECTED VEGETABLES

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In developing countries like Nigeria, postharvest losses of fruits and vegetables, particularly tomatoes, carrots and bell peppers, are estimated at 40–50% due to inadequate cold storage facilities and the high cost of refrigeration for small-scale farmers, thereby necessitating affordable alternatives. This study developed and evaluated a modified active direct evaporative cooling system with an 8 m³ storage chamber constructed from galvanised mild steel and aluminium. It comprised two suction fans (183.1 m³/hr, 25 W, 1250 rpm), a 0.05 m-thick cooling pad, and a 0.5 hp water pump discharging 30 l/min. A 500 L overhead tank supplied water to the cooling pads, while a 230 L bottom reservoir collected and recirculated drained water to ensure continuous pad saturation. Fresh tomatoes, carrots and bell peppers (5 kg each) were stored in triplicate under both evaporative cooling and ambient conditions for 14 days. The cooler achieved an 81% average cooling efficiency, maintaining an average temperature of 25.6°C and 76.2% relative humidity, compared to ambient averages of 30.8°C and 41.3%, respectively. Consequently, cooled produce exhibited reduced physiological weight loss and maintained acceptable colour and firmness up to 14 days, whereas ambient-stored produce remained marketable for only 4 – 8 days. Student's t-test showed significant differences ($p < 0.005$) between the storage environments and quality parameters. With fabrication and projected selling costs estimated at ₦480,000 and ₦550,000, respectively, this low-cost technology is economically viable for farmers, cooperatives, and marketers, as an effective tool for reducing postharvest losses, improving food security, and enhancing agricultural livelihoods.

Keywords: Evaporative cooling, Postharvest Technology, Vegetable Preservation, Shelf-Life Extension, Low-Cost Storage.

26th International Conference and 46th Annual General Meeting of the Nigerian Institution of Agricultural Engineers (NIAE). ***November 9 - 13, 2026, JOSTUM, Makurdi, Nigeria***

Book of Abstract
Paper ID – 10

POSTHARVEST CHANGES IN TOTAL SOLUBLE SOLIDS OF ONIONS AS AFFECTED BY TEMPERATURE AND RELATIVE HUMIDITY

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Total soluble solids (TSS) indicate compositional change in stored onion (Allium cepa L.), but the joint effects of storage temperature and relative humidity (RH) on Nigerian cultivars remain poorly documented. Dadin-Kowa Red onions were stored for eight weeks under nine temperature–RH combinations: 25, 30, and 35 °C combined with 60, 65, and 70% RH. The combinations were tested simultaneously in nine independently controlled sections formed by subdividing three main storage compartments. At weekly intervals, one fresh onion bulb was sampled from each section, and its juice was measured twice with a handheld refractometer. Because each treatment combination occupied one section and duplicate readings were technical measurements of the same juice sample, results are presented descriptively rather than as independent-replicate tests of treatment effects. Mean TSS rose from 9.99 °Bx at day 7 to 13.06–13.07 °Bx at days 42–49, then fell to 12.43 °Bx at day 56. Across the tested conditions, mean TSS was 11.04, 12.27, and 11.93 °Bx at 25, 30, and 35 °C, respectively, and 11.81, 11.78, and 11.66 °Bx at 60, 65, and 70% RH. Higher TSS did not necessarily indicate better bulbs because warmer conditions were also associated with greater weight loss and rottenness in the companion analysis. The combination of 25 °C and 65% RH is identified as a promising condition within the tested range based on the combined descriptive evidence, although confirmation requires an experiment with independent replication.

Keywords: Onion, Total soluble solids, Storage temperature, Relative humidity, Postharvest quality

Book of Abstract
Paper ID – 11

ARTIFICIAL INTELLIGENCE AND MACHINE VISION FOR PRECISION AGRICULTURAL MECHANIZATION IN SOUTHERN NIGERIA: EVIDENCE GAPS, BARRIERS, AND FRAMEWORKS.

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Nigeria's mechanisation level, measured in horsepower per hectare, falls far short of the Food and Agriculture Organisation (FAO) recommendation of 1.5 hp/ha. In African countries, this value is much lower, at only 0.027 hp/ha, and even lower in the country's southern part, where most farms are characterised by acidic, fragmented land in a humid climate. This study sought to determine the factors influencing the adoption of artificial intelligence/machine vision for precision mechanisation in speciality crops (e.g., rice, cassava, oil palm, yam, maize) in Nigeria. Published and unpublished works (Scopus, Web of Science, Google Scholar, PubMed, IEEE Xplore, African Journal Online, and grey literature resources) were reviewed according to the levels-of-evidence hierarchy. Works published between 2010 and 2026 were considered. The evidence level of algorithm-crop associations was then evaluated on the evidence hierarchy. Random Forest/Gradient Boosting for rice yield prediction was the only method with local (Cross River and other Nigerian) validation evidence; others—Convolutional Neural Networks (CNNs)/Support Vector Machine (SVM) for cassava disease detection, unsupervised learning-based soil zoning for oil palm, and Reinforcement Learning for irrigation scheduling—were either applied locally using non-local evidence or based on theoretical considerations. The strongest local evidence for using machine vision for post-harvest quality control came from real-time fruit grading and sorting with convolutional neural networks (CNNs). The key barriers to entry were unreliable electricity and broadband networks, high taxes, the cost of vision equipment, highly fragmented land distribution, and a lack of data governance and privacy rules, resulting in a data desert. Another issue was gender: female farmers, who accounted for 72% of cassava processors, were less inclined to adopt automated post-harvest mechanisation (18%) than their male counterparts. The article proposes Edge-Cloud collaborative intelligence; Smart-Mechanization-Hub-assisted local data governance and sandboxes; NATIP's gradual take-off in Nigeria using Cortex-M4/TinyML-Jetson/Coral; and prioritising a local data repository/sandbox and the collection of primary data.

Keywords: Artificial Intelligence; Machine Vision; Precision Agriculture; Agricultural Mechanization; Machine Learning; Smallholder Farmers

HATE SPEECH DETECTION USING MACHINE LEARNING TECHNIQUES

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Hate speech is any form of speech that causes an individual or a group of people to feel annoyed. It causes a lot of violence and misunderstanding among people. It is very important to provide a system that can detect whether speech is hate speech. This research focuses on training and evaluating machine learning algorithms for hate speech detection. The dataset used in this research was obtained from the Kaggle dataset repository; it contains about 31,962 real-world Twitter posts. The dataset was preprocessed using Python libraries to convert the Twitter posts to lowercase, remove punctuation and special characters, remove stop words and perform stemming. Count vectorizer was used for feature extraction; 80% of the dataset was used for training the algorithms and 20% for testing. Four machine learning algorithms, namely Logistic Regression, Multi-Layer Perceptron (MLP), Support Vector Machine (SVM) and Naïve Bayes, were trained and evaluated. Results show that Logistic Regression outperformed the other algorithms with an accuracy of 95.81%.

Keywords: Accuracy, Hate speech, Machine learning.

26th International Conference and 46th Annual General Meeting of the Nigerian Institution of Agricultural Engineers (NIAE). ***November 9 - 13, 2026, JOSTUM, Makurdi, Nigeria***

Book of Abstract
Paper ID – 13

SMART AI INVOICE GENERATOR: AN AI-DRIVEN WEB-BASED SYSTEM FOR INVOICE AUTOMATION AND BUSINESS RECORD MANAGEMENT IN SMALL ENTERPRISES

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This project presents the design and development of a Smart AI Invoice Generator aimed at improving invoice generation and business record management for small and local businesses. Many small businesses still rely on manual invoicing methods, which often lead to calculation errors, poor record-keeping, delays in invoice preparation, and difficulties managing customer and sales information. To address these challenges, this study developed a web-based invoice management system that integrates Artificial Intelligence through the Google Gemini API to automate invoice generation from natural language prompts. The system also provides features such as user authentication, customer management, product management, invoice creation and management, dashboard analytics, sales tracking, PDF invoice generation, and business profile management. The Waterfall Software Development Life Cycle (SDLC) model was adopted to guide the development process, while modern web technologies including React.js, Node.js, Express.js, MongoDB, and Tailwind CSS were used for implementation. The developed system was tested to ensure functionality, usability, and reliability, and the results showed that it generates invoices accurately, improves record management, reduces manual effort, and enhances operational efficiency. The study concludes that the Smart AI Invoice Generator provides an effective, user-friendly, and affordable solution for small businesses and recommends future enhancements such as customer account registration, integrated messaging and PDF invoice sharing, and graphical business analytics using bar charts and pie charts for improved decision-making.

Keywords: Artificial Intelligence, Invoice Automation, Small Business, Web Application, Google Gemini API, Business Record Management.

Book of Abstract
Paper ID – 14

BIOCHAR EFFECTIVENESS FOR ORGANIC WASTEWATER DECONTAMINATION

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Agro-based industries are characteristically associated with the generation of large amounts of biomass residues, which pose disposal challenges and strain their profitability. Current advancements in biomass conversion technologies hold potential benefits for industries by converting biomass into value-added products. Accordingly, there is increasing interest and attention in producing biochar from residues for a variety of applications, most notably the treatment of industrial effluents. To date, several lignocellulosic-based biomass residues have been considered for biochar production: date stones, olive stones, almond shells, orange seeds and pulp, groundnut shells, banana peels, and oil palm biomass. Despite their abundance, selecting biochar with a high adsorption capacity for effective treatment of agro-industrial effluents has always been challenging. Overcoming this limitation, therefore, requires knowledge of the prevailing adsorption mechanisms between the biochar surface and organic contaminants. Although the literature covers a wide variety of such investigations, this review offers further insight into how adsorption mechanisms and conditions contribute to the performance of pristine biochar in treating agro-industrial wastewater. The review indicates that tailoring biochar through controlled pyrolysis and feedstock selection can enhance its structural and chemical properties, thereby improving adsorption capacity for specific organic pollutants like phenol and tannic acid. Biochar adsorption performance depends on multiple interrelated factors, including biochar properties (surface area, pore size distribution, and surface functionality), contaminant properties, and adsorption medium conditions such as pH and temperature.

Keywords: biochar, adsorption capacity, contaminants, adsorption mechanism

26th International Conference and 46th Annual General Meeting of the Nigerian Institution of Agricultural Engineers (NIAE). ***November 9 - 13, 2026, JOSTUM, Makurdi, Nigeria***

Book of Abstract
Paper ID – 15

CHARACTERISATION OF LOCAL CLAYS AND METAKAOLIN FOR POROUS CLAY PIPES APPLICATIONS IN EFFICIENT IRRIGATION SYSTEMS

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Increasing global water scarcity, especially in arid and semi-arid regions, calls for efficient and affordable micro-irrigation technologies to maintain agricultural productivity. Porous clay pipes with low-pressure irrigation deliver water directly to the root zone, providing a viable and sustainable solution for smallholder farmers. However, its effectiveness depends largely on the material properties of the clay used, and inconsistent results have prevented widespread adoption. This study aims to address this knowledge gap by characterising the physical and chemical properties of locally sourced clay and metakaolin to assess their suitability for producing optimised porous irrigation pipes. The study investigated the use of metakaolin, a highly reactive pozzolanic material, as an additive to improve the mechanical strength and microstructural characteristics of the clay matrix. Building on earlier work performed on the impact of additives such as zeolite on clay workability and porosity, this study focuses on optimizing clay and metakaolin compositions. The physical Properties to be determined include Atterberg limit, liquid limit, Plastic limit, Plasticity index, Bulk density, porosity, chemical properties, mineralogical characterisation and microstructural analysis (via SEM), with a focus on the aluminosilicate content (SiO_2 and Al_2O_3). The findings from this characterisation will create an understanding of how metakaolin influences the hydraulic and mechanical behaviour of porous clay pipes. By optimising material properties, this research will contribute to the development of reliable, low-cost porous irrigation pipes, thereby improving water use efficiency.

Keywords: Porous Clay Pipe Irrigation, Metakaolin, Clay Characterisation, Water-Use Efficiency.

26th International Conference and 46th Annual General Meeting of the Nigerian Institution of Agricultural Engineers (NIAE). ***November 9 - 13, 2026, JOSTUM, Makurdi, Nigeria***

Book of Abstract
Paper ID – 16

WATER MANAGEMENT AND NUTRIENT LEACHING IN RICE PRODUCTION IN NIGERIA: A REVIEW

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Rice-based agro-ecosystems in Nigeria operate under increasingly fragile hydrological conditions characterised by climatic variability, inefficient water management systems, soil structural degradation, and nutrient losses. Although substantial research has examined water-saving irrigation and nutrient management, much of the available evidence originates from Asian rice systems, with limited synthesis of the interconnected water–soil–nutrient processes under Nigerian conditions. This review critically synthesises evidence on water management, soil-water dynamics, nutrient leaching, hydrological variability, and environmental implications in Nigerian rice production, drawing comparative insights from sub-Saharan Africa and Asia. A structured narrative review was conducted using peer-reviewed literature and relevant technical publications identified through keywords related to rice irrigation, Alternate Wetting and Drying (AWD), evapotranspiration, water productivity, nutrient leaching, nitrogen loss, soil-water dynamics, and eco-hydrology. Studies were screened for relevance and synthesised under four themes: irrigation and water-use dynamics; soil-water and hydrological processes; nutrient transport and leaching; and environmental sustainability. The review indicates that continuous flooding can cause substantial water losses through evaporation, seepage, and percolation, while inappropriate irrigation and fertiliser management may enhance nutrient movement below the root zone. Nitrogen is particularly vulnerable to leaching, denitrification, and runoff. The principal novelty of this review is its Nigeria-focused integration of irrigation management, soil-water dynamics, nutrient transport, leaching processes, water productivity, and environmental implications within a unified rice-production framework. Unlike reviews that primarily examine AWD, water productivity, or nutrient management independently, this review explicitly identifies a gap in quantitative understanding of irrigation interval–agrochemical interactions under Nigerian soil, climatic, hydrological, and management conditions and highlights lysimeter experimentation and process-based modelling as complementary approaches to address this gap.

Keywords: Water management; rice irrigation; nutrient leaching; soil-water dynamics; eco-hydrology; Nigeria; sustainable rice production

26th International Conference and 46th Annual General Meeting of the Nigerian Institution of Agricultural Engineers (NIAE). ***November 9 - 13, 2026, JOSTUM, Makurdi, Nigeria***

Book of Abstract
Paper ID – 18

EFFECTS OF STEM CHARACTERISTICS AND BLADE SPEED ON THE CUTTING FORCE REQUIRED FOR CASSAVA STEMS

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Stem characteristics and blade speed are very important parameters in the design and development of agricultural machinery, especially in computer-aided design (CAD) and discrete element modelling (DEM). To examine the effects of stem characteristics and blade speed on the cutting force required for cassava stems, four locally available cassava varieties (TMS 30572, TMS 4(2) 1425, TME 419, and TMS 30555) were examined at a mean moisture content of 35.2% and a mean stem diameter of 23.7 mm to determine the influence of cassava variety on the cutting force. The effect of stem diameter on the cutting force was examined using TMS 30555 stems with diameters ranging from 18.5 to 27.2 mm at a mean moisture content of 35.5%. The influence of stem moisture content was examined using stems with moisture contents ranging between 35.2 and 37.3% at a blade speed of 23 rpm and a mean stem diameter of 23.2 mm. The influence of blade speed on cutting force was also examined at 23, 39, and 50 rpm, with a mean moisture content of 37.0% and a mean stem diameter of 23.2 mm. The experiments were conducted in three replicates. The results showed significant varietal differences in cutting force, with TMS 30555 requiring the highest cutting force (654.91 N) and TME 419 the lowest (122.20 N). Cutting force increased with increasing stem diameter, exhibiting a positive nonlinear relationship with a diminishing rate of increase. Stem moisture content showed a significant quadratic relationship with cutting force, characterised by a concave downward trend and a peak cutting force at an intermediate moisture content. Blade speed also showed a quadratic relationship: the minimum cutting force occurred at 249 N at a blade speed of 39 rpm, while both lower and higher blade speeds required greater cutting forces. The study indicated that cutting force is significantly influenced by stem diameter, stem moisture content, and blade speed. This study provides valuable engineering data to optimise cassava stem-cutting mechanisms that improve the development and performance of cassava planting and harvesting equipment. Based on the results of this study, a blade speed of 39 rpm and stem moisture of 35.2% at stem diameters between 20 and 30 mm are recommended for optimum stem cutting.

Keywords: Characteristics, cutting force, effect, speed, stem.

26th International Conference and 46th Annual General Meeting of the Nigerian Institution of Agricultural Engineers (NIAE). ***November 9 - 13, 2026, JOSTUM, Makurdi, Nigeria***

Book of Abstract
Paper ID – 20

ENHANCING FARMERS SAFETY USING LEVY FLIGHT WHALE OPTIMIZATION ALGORITHM IN WIRELESS SENSOR NETWORKS

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The increasing occurrence of insecurity affecting farming communities in Nigeria has created a critical need for intelligent monitoring systems capable of detecting threats and providing timely alerts to enhance farmer safety. Wireless Sensor Networks (WSNs) have emerged as an effective technology for real-time environmental monitoring because of their distributed sensing capability and efficient wireless communication. However, WSN performance is constrained by limited energy resources, inefficient cluster head selection, uneven energy consumption, and unreliable communication, which reduce network lifetime and monitoring effectiveness. This study proposes an enhanced Levy Flight Whale Optimisation Algorithm (LWOA)-based framework to improve WSN performance for farmer safety monitoring in insecurity-prone agricultural environments. The proposed approach integrates the global search capability of the Levy Flight mechanism with the Whale Optimisation Algorithm to optimise cluster head selection, balance energy utilisation, and enhance network exploration. A simulation model comprising 100 sensor nodes randomly deployed over a 100 m × 100 m agricultural field was developed using MATLAB R2024a. The proposed model was evaluated against the Low-Energy Adaptive Clustering Hierarchy (LEACH) protocol and the standard Whale Optimisation Algorithm (WOA) using Packet Delivery Ratio, network lifetime, residual energy, sensing coverage, and Farmer Safety Index (FSI) as performance metrics. Simulation results showed that the proposed LWOA achieved the highest FSI of 98.4%, outperforming WOA (94.9%) and LEACH (92.0%). The findings demonstrate that integrating Levy Flight with WOA significantly improves energy efficiency, network reliability, sensing coverage, and monitoring effectiveness, making it a promising solution for enhancing farmer safety in insecure agricultural environments.

Keywords: Wireless Sensor Networks, Farmer Safety, Levy Flight, Whale Optimization Algorithm, Smart Agriculture

26th International Conference and 46th Annual General Meeting of the Nigerian Institution of Agricultural Engineers (NIAE). ***November 9 - 13, 2026, JOSTUM, Makurdi, Nigeria***

Book of Abstract
Paper ID – 22

DEVELOPMENT AND EVALUATION OF AN AUTOMATED SOIL MACRO NUTRIENT TESTING DEVICE UNDER TROPICAL SOILS

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Effective soil nutrient management is essential for optimising crop yield and promoting sustainable agricultural practices. Conventional methods for analysing soil macronutrients are often costly. An automated soil macronutrient detection device was developed and evaluated to measure, process and display soil nutrients of N, P, K, pH, temperature, and soil moisture content. The device's performance was evaluated in a field experiment by monitoring the growth of cowpea (beans) under both fertilised and unfertilised conditions. The results confirmed the device's capacity to accurately monitor nutrient changes in the soil. The device measured the initial concentration of Nitrogen (N) from 970 mg/kg in week 1 down to 725 mg/kg in week 6; phosphorus (P), from 8.30 to 2mg/kg; while Potassium (K) ranged from 190.50 to 91.48 mg/kg. On the control plot, Nitrogen (N) measured from 970mg/kg in week 1 down to 700 mg/kg in week 6, Phosphorus (P): 8.30 to 1mg/kg, Potassium (K) ranged from 190.50mg/kg to 83.48 mg/kg. The soil pH ranged from 6.32 to 6.1. The simulation results demonstrate that the developed device is highly responsive to increasing nitrogen concentrations, shows maximum range limitations for phosphorus and potassium sensors, and effectively detects pH variations associated with fertiliser dissolution. These findings confirm the device's functionality under controlled conditions and provide baseline calibration data needed to interpret its behaviour when deployed in field soil conditions. The developed automatic soil nutrient detection device offers a low-cost, rapid, and user-friendly alternative to traditional testing by enabling real-time nutrient monitoring and data-driven decisions.

Keywords: Micronutrients, Sensors, Soils

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Book of Abstract
Paper ID – 24

EXPANDED POLYSTYRENE PACKAGING FOR COLD CHAIN APPLICATIONS: PERFORMANCE, TRADE-OFFS, AND ALTERNATIVES-A REVIEW

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Expanded polystyrene (EPS) is the default choice wherever packaging needs to be light, cushioning, and thermally resistant, fitting a wide range of food and temperature-sensitive distribution systems. Yet its fossil origin, environmental persistence, and the patchy state of recovery infrastructure in many regions raise real questions about how sustainable its choice is. Rather than judging EPS as a standalone material, this review treats it as an integrated postharvest packaging system, shaped as much by package design, commodity behaviour, cooling arrangements, and transport conditions as by the polymer itself. EPS is compared against moulded-fibre, biobased, agro-residue-derived, mycelium-based, and reusable alternatives on criteria that matter in practice. examined. The study examined thermal protection, mechanical performance, moisture response, structural integrity, material efficiency, logistics, reuse and recycling potential, life-cycle impact, and economic feasibility. Evidence drawn from peer-reviewed literature and authoritative technical sources on fresh produce, fish and seafood distribution, cold chain logistics, and circular packaging systems points to a consistent conclusion: EPS earns its keep when properly designed and paired with adequate pre-cooling, but its environmental performance depends on collection, transport, recycling, reuse, and disposal conditions. None of the alternatives escapes this logic; judge a material as sustainable not by what it is made of, but by how it performs against EPS under matched commodity and supply-chain conditions. A performance-resource-environment framework is proposed to guide decisions on when to select, redesign, reuse, recycle, or replace EPS in climate-resilient postharvest systems.

Keywords: sustainability; life-cycle assessment; circular economy; agricultural value chains; alternative packaging.

Paper ID – 25

PERFORMANCE EVALUATION OF AN IMPROVED TRADITIONAL RICE HUSK-FIRED PARBOILER

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Small-scale processors often rely on traditional paddy rice parboilers that have issues such as low thermal efficiency, heavy dependence on firewood and operational constraints that can compromise rice quality. This study aimed to develop and test an improved version of the traditional paddy rice parboiler, using rice husk as the main energy source while using firewood as a control. The upgraded parboiler includes an insulated combustion chamber, a stainless-steel soaking and steaming vessel with a false bottom, dual gate valves for independent drainage of soaking and steaming water, and a specific outlet for paddy discharge. These features are designed to enhance heat utilisation, improve safety during operation, and boost overall process efficiency. Performance evaluation was conducted using a Completely Randomised Design with three replications to examine how the energy source (Rice Husk, Firewood), soaking temperature (50, 60, and 70°C), and soaking time (10, 14, and 18 hours) influence milling yield. The variance analysis indicated that energy source, soaking temperature, soaking time, and their interaction effects all significantly affected milling yield ($P < 0.05$). Among the factors studied, soaking temperature was the most influential. The highest average milling yield of 67.1% was achieved at 60°C, while firewood yielded a slightly better overall mean of 65.1% compared to rice husk's 64.1%. Interaction analysis revealed that the top milling yield of 71.0 % came from treatment $E_2T_2S_1$ (firewood, 60°C, 10 hours), whereas the best result for rice husk $E_1T_2S_2$ (Rice Husk, 60°C, 14 hours), was 65.9 kg, indicating that rice husk can match the performance of conventional fuels under the right conditions. These results show that the improved traditional paddy rice parboiler effectively controls the hydrothermal process and allows for the productive use of rice husk as a renewable biomass fuel without a significant drop in milling performance. This technology offers a viable and sustainable alternative for small- and medium-scale rice processors, reducing reliance on conventional firewood as an energy source

Key Words: Rice husk**,** improved traditional parboiler; Milling yield; Hydro-thermal treatment; Paddy rice;

Book of Abstract
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ADVANCING INTEGRATION OF SMART TECHNOLOGIES IN NIGERIAN AGRICULTURE FOR SUSTAINABLE DEVELOPMENT

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Agriculture remains a critical sector in Nigeria, contributing significantly to employment, food security, and national economic growth. However, persistent challenges such as low productivity, climate variability, post-harvest losses, and limited access to modern inputs continue to undermine its potential. The emergence of smart agricultural technologies that integrate digital tools, automation, data analytics, and precision farming offers new opportunities to transform Nigerian agriculture toward sustainable development. This paper examines the role of smart technologies in advancing sustainable agricultural development in Nigeria. It discusses key smart agricultural technologies, applications, benefits, and adoption challenges, while highlighting pathways and recommendations for effective implementation. The study concludes that strategically integrating smart technologies, supported by enabling policies, infrastructure development, and capacity building, can significantly enhance agricultural productivity, resilience, and sustainability in Nigeria.

Keywords: Smart agriculture, Precision farming, Digital agriculture, Sustainable development, Smart Technology

Paper ID – 27

DEVELOPMENT AND PERFORMANCE EVALUATION OF AN IMPROVED CHICKEN FEEDER FOR SMALL-SCALE FARMERS

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The objective of this study was to develop and evaluate the performance of an improved chicken feeder system utilising polyvinyl chloride (PVC) pipes in order to minimise feed wastage and enhance efficiency in poultry farming. The feeder's design considered factors such as bird comfort, ease of cleaning, environmental safety and durability. It has a total length of 263 cm with 14 holes, each accommodating 2 birds. Performance evaluation was conducted for twenty-eight (28) chickens to assess the feeder's effectiveness in reducing waste, feed conversion ratio, and bird growth rate. Results obtained show that the feeder has a capacity of carrying 170 g of feed per hole. It also has an efficiency of 88.24%. A significant reduction in feed wastage of 11.76% was recorded compared to conventional feeding systems. Additionally, bird growth rates were comparable to those in traditional feeding systems. The PVC pipe feeder proved to be a cost-effective, durable, sustainable, easy-to-maintain and efficient solution for poultry farmers, promoting environmentally friendly and profitable production practices. The results suggest that this innovative feeder system is worth adopting by poultry farmers. Its estimated cost is about ₦19,000:00.

Keywords: Chicken, Cost-Effective, Feeder, Poultry, PVC Pipes

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Book of Abstract
Paper ID – 29

DETERMINATION OF SOME HEAVY METALS IN PROCESSED POWDERED PEPPER SOLD IN MAKURDI

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Processed powdered pepper is widely consumed in Nigeria, yet contamination with potentially toxic metals can occur during production, drying, grinding, handling and marketing. This study determined the concentrations of cadmium (Cd), chromium (Cr), cobalt (Co), lead (Pb), and nickel (Ni) in processed powdered pepper sold in three major markets in Makurdi, Benue State, Nigeria. Samples were collected from Wurukum, Modern and North Bank markets, while a laboratory-prepared sample served as a control. Three replicate samples were analysed for each group. Approximately 0.5 g of each sample was digested with nitric acid and hydrogen peroxide and analysed by atomic absorption spectrophotometry. Results were expressed as mean ± standard deviation and compared using one-way analysis of variance (ANOVA), followed by Duncan's multiple range test at $p < 0.05$. The recalculated overall mean concentrations were 0.0242 mg/kg for Cd, 0.2992 mg/kg for Cr, 0.3308 mg/kg for Co, 0.1167 mg/kg for Pb and 0.2208 mg/kg for Ni. Cadmium did not differ significantly among sampling groups ($F = 1.923$, $p = 0.204$), whereas Cr ($F = 263.153$, $p < 0.001$), Co ($F = 445.284$, $p < 0.001$), Pb ($F = 9.000$, $p = 0.006$) and Ni ($F = 365.497$, $p < 0.001$) differed significantly. Modern Market recorded the highest Cr and Co concentrations, Wurukum Market the highest Pb concentration, and North Bank Market the highest Ni concentration. The findings demonstrate localised variation in metal concentrations and support continued food-safety surveillance of powdered pepper in Makurdi. However, the study measured concentrations only and did not estimate dietary exposure; therefore, it should not be described as a formal human-health risk assessment.

Keywords: heavy metals; powdered pepper; food safety; atomic absorption spectrophotometry

26th International Conference and 46th Annual General Meeting of the Nigerian Institution of Agricultural Engineers (NIAE). ***November 9 - 13, 2026, JOSTUM, Makurdi, Nigeria***

Book of Abstract
Paper ID – 31

HYDROGEN FUEL CELL TECHNOLOGY FOR SUSTAINABLE AGRICULTURAL MACHINERY: A REVIEW OF OPPORTUNITIES, CHALLENGES AND FUTURE PROSPECTS.

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Hydrogen fuel cells are emerging as a promising clean energy source for farm machinery, offering a sustainable alternative to traditional diesel-powered engines that contribute significantly to greenhouse gas emissions in the agricultural sector. Despite growing global interest in hydrogen fuel cell (HFC) technology, most applications remain in experimental or early commercial stages. The main objective of this work is to explore the hydrogen fuel cell as an emerging clean energy source for farm machinery. Data were generated from documents and other academic materials from major databases and analysed. The analysis revealed that adoption of hydrogen fuel cells worldwide is largely at the prototype stage. The current application of hydrogen fuel cells on farm machinery is low. Recommendations to overcome these challenges include investments in green hydrogen production and research and Development in fuel cell technology. By addressing these barriers, hydrogen fuel cells have the potential to reduce the carbon footprint of farming operations, lower fuel costs, and contribute to a more resilient and sustainable agriculture.

Key Words: Hydrogen, Fuel-cell, Agricultural machinery, Energy, sustainable mechanisation; Nigeria.

Book of Abstract
Paper ID – 32

INTEGRATED CLIMATE-RESILIENT AND SMART AGRICULTURAL ENGINEERING FRAMEWORK FOR SUSTAINABLE FOOD SECURITY IN THE NIGER DELTA: A CASE STUDY OF BAYELSA STATE, NIGERIA

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The Niger Delta of Nigeria possesses substantial agricultural, fisheries, forestry, and aquatic resources; yet its contribution to sustainable food security is increasingly threatened by flooding, climate variability, soil degradation, oil pollution, salinity intrusion, inadequate agricultural infrastructure, post-harvest losses, and limited access to modern technologies. Bayelsa State represents one of the most environmentally vulnerable parts of the Niger Delta because of its extensive network of rivers, creeks, wetlands, mangrove ecosystems, and low-lying agricultural landscapes. The state's riverine geography creates both opportunities and constraints for agricultural development. Recent studies have reported that farmers and fishermen in Bayelsa are experiencing declining crop yields, reduced fish resources, changing rainfall patterns, increasing temperatures, and recurrent flooding. This paper proposes an Integrated Climate-Resilient and Smart Agricultural Engineering Framework (ICRSAEF) for Bayelsa State. The framework combines climate-smart agriculture, geospatial technology, artificial intelligence, precision agriculture, water-resource engineering, sustainable soil and land management, renewable-energy systems, resilient agricultural structures, mechanisation, aquaculture, and post-harvest technologies. Geographic Information Systems (GIS), remote sensing, Internet of Things (IoT) sensors, and artificial intelligence can be integrated to identify flood-prone agricultural areas, monitor soil and water conditions, guide crop selection, and improve early-warning systems. Engineering interventions such as raised-bed and floating agriculture, controlled drainage, solar-powered irrigation, rainwater harvesting, elevated processing facilities, cold-chain systems, and renewable-energy-powered agro-processing are proposed. The paper argues that agricultural engineering interventions in Bayelsa should not simply attempt to reproduce conventional upland farming systems. Instead, agricultural development should be designed around the state's wetland, riverine, and coastal environment. A coordinated approach involving government, communities, universities, engineers, farmers, private investors, and environmental regulators is therefore recommended. The proposed framework can increase food production, reduce climate vulnerability, improve livelihoods, support environmental restoration, and promote sustainable agro-industrial development in the Niger Delta.

Keywords: Climate-smart agriculture, Bayelsa State, Niger Delta, agricultural engineering, GIS, artificial intelligence, flooding

26th International Conference and 46th Annual General Meeting of the Nigerian Institution of Agricultural Engineers (NIAE). ***November 9 - 13, 2026, JOSTUM, Makurdi, Nigeria***

Book of Abstract
Paper ID – 33

POST-HARVEST ENGINEERING AND VALUE ADDITION TECHNOLOGIES: A CASE STUDY OF BAYELSA STATE, NIGERIA

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Bayelsa State occupies a strategic position in Nigeria's Niger Delta agricultural economy, with substantial potential for cassava, plantain, rice, cocoyam, vegetables, oil palm, and fisheries. However, the benefits of agricultural production are substantially constrained by post-harvest losses, inadequate storage and processing facilities, poor rural logistics, flooding, high humidity, limited access to electricity, weak market linkages, and low adoption of appropriate technologies. These challenges are particularly important in Bayelsa because a large proportion of its communities are riverine and depend on waterways to move agricultural commodities. This paper examines post-harvest engineering and value-addition technologies applicable to Bayelsa State and develops a climate-resilient value-chain framework to reduce losses and increase the economic value of agricultural products. The study adopts a qualitative case-study approach based on a review of published studies, government information, and technical literature on post-harvest management, agricultural value chains, and Bayelsa's agricultural environment. Particular attention is given to cassava, plantain, rice, and fish value chains. Evidence from Bayelsa indicates that flooding can substantially reduce farm profitability and contribute to crop spoilage and forced early harvesting. Recent research on plantain production in Southern Ijaw, for example, found considerably lower net farm income during flooded years than during non-flooded years. The paper proposes integrated interventions including solar-powered cold rooms, improved fish smoking kilns, solar and hybrid dryers, hermetic storage, modular cassava processing units, improved rice milling, moisture monitoring, digital traceability, improved packaging, aggregation centres, waterway-based agro-logistics, and decentralised renewable-energy systems. The paper argues that post-harvest engineering should not be treated as a single storage intervention but as an integrated system linking harvesting, handling, transportation, drying, processing, packaging, storage, marketing, waste utilisation, and digital information. Such an approach can reduce food losses, create rural employment, improve food safety, and strengthen Bayelsa's transition from primary agricultural production to agro-industrial development.

Keywords: Post-harvest engineering; value addition; Bayelsa State; agricultural value chains; cold chain; solar drying.

Paper ID – 37

MECHANIZATION OF PALM OIL PROCESSING IN SOUTHERN NIGERIA: STATUS, CHALLENGES, PROSPECTS AND OPPORTUNITIES – A REVIEW

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Palm oil is one of Nigeria's most important agricultural commodities, and Southern Nigeria, where the oil palm (Elaeis guineensis) is indigenous and widely cultivated, is the centre of production. National output of about 1.4–1.5 million tonnes (Mt) falls short of demand, estimated at about 1.9 to over 2.5 Mt depending on the source, and the Federal Government puts annual palm oil import spending at USD 500–600 million. This narrative review examines the status of palm oil processing mechanisation in Southern Nigeria, its constraints and its prospects, using peer-reviewed literature and government, institutional and industry reports published between 2014 and 2026. Mechanisation is concentrated in digestion and oil extraction; harvesting, fruit bunch evacuation, packaging and waste handling remain largely manual. The sector has two tiers: industrial estates with imported, automated lines, and smallholders, who make up the majority of producers, using locally fabricated or semi-mechanised equipment with lower extraction efficiency, variable oil quality, and higher maintenance needs. The main constraints are capital cost and limited credit, unreliable power and poor rural roads, a shortage of skilled technicians, ageing plantations that limit fruit supply, weak research–industry linkages, inconsistent fabrication quality, and unmanaged mill waste. Prospects include addressing the demand gap, public–private estate programmes, improving indigenous fabrication, using mill residues for biomass and biogas, and low-cost process monitoring. Progress depends on fabrication standards and testing, finance and leasing models for smallholders, rural infrastructure and technical training.

Keywords: palm oil processing; mechanization; Southern Nigeria; digester; screw press; review

26th International Conference and 46th Annual General Meeting of the Nigerian Institution of Agricultural Engineers (NIAE). ***November 9 - 13, 2026, JOSTUM, Makurdi, Nigeria***

Book of Abstract
Paper ID – 38

MECHANICAL PROPERTIES OF HEAT-SEALABLE STARCH–POLYVINYL ALCOHOL BIOPOLYMER FILMS INCORPORATED WITH PALM KERNEL OIL FOR SUSTAINABLE FOOD PACKAGING

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The increasing environmental burden associated with petroleum-based food packaging has stimulated interest in renewable polymer-based alternatives with adequate mechanical and barrier performance. This study developed heat-sealable starch–polyvinyl alcohol (PVA) biopolymer films incorporating palm kernel oil and evaluated how formulation composition and oil concentration affect their functional properties. Films were prepared by solution casting using three starch concentrations (0.50, 0.75 and 1.00 g) and three palm kernel oil levels (0, 1 and 3 drops). Film thickness, tensile strength, Young's modulus, elongation at break, permeability, opacity and sealing temperature were determined, and the data were analysed using analysis of variance and Duncan's Multiple Range Test at $p < 0.05$. Increasing starch–PVA formulation from 0.50 to 1.00 g increased tensile strength from 23.32 to 27.18 MPa, Young's modulus from 98.49 to 123.92 N/m² and elongation at break from 132.88 to 147.66%, while permeability decreased from 1.3956 to 0.7633. Palm kernel oil produced a contrasting mechanical response: tensile strength decreased from 34.25 MPa in the oil-free film to 19.17 MPa at the highest oil level, whereas elongation at break increased from 102.89 to 179.02%. Oil incorporation also increased film thickness and opacity while reducing the measured permeability. The results demonstrate that starch–PVA composition and palm kernel oil concentration can be used to tailor the balance between strength, stiffness, flexibility and barrier performance. The developed films therefore show potential as renewable packaging materials for food applications, although further validation under actual food-storage conditions is required.

Keywords: Heat-sealable films; Cassava starch; Polyvinyl alcohol; Palm kernel oil; Tensile strength; Young's modulus.

26th International Conference and 46th Annual General Meeting of the Nigerian Institution of Agricultural Engineers (NIAE). ***November 9 - 13, 2026, JOSTUM, Makurdi, Nigeria***

Book of Abstract
Paper ID - 39

MULTI-DIMENSIONAL FLOOD VULNERABILITY ASSESSMENT: A SYSTEMATIC REVIEW OF INDICATORS, WEIGHTING ENGINES, AND SPATIAL SYNTHESIS

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Flood risk management has transitioned from single-variable hydraulic modelling to multidimensional vulnerability frameworks that evaluate the interplay between physical hazards, structural exposure, social sensitivity, and coping capacities. Despite rapid methodological growth, significant inconsistencies persist in how multi-dimensional indices are constructed, weighted, and geographically operationalised. This systematic review synthesises two decades (2005-2026) of empirical research on multi-dimensional flood vulnerability assessment, guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework across 180+ peer-reviewed studies. The review critically evaluated progress across three methodological pillars: (1) Indicator Selection: deconstructing the physical, socio-economic, infrastructural, and institutional metrics utilised in flood risk indexing; (2) Weighting Engines: comparative performance analysis of subjective (e.g., Analytic Hierarchy Process (AHP), Delphi), objective (e.g., Criteria Importance Through Intercriteria Correlation (CRITIC), Entropy, Principal Component Analysis (PCA)), and hybrid mathematical weighting frameworks; (3) Spatial Synthesis: the evolution of GIS-based multi-criteria overlay and machine learning integrations for mapping vulnerable hotspots. The analysis revealed major methodological bottlenecks in current literature: an over-reliance on static inundation depth while omitting hydrodynamic velocity and duration parameters, widespread selection bias in unvalidated indicator weighting, and a persistent disconnect between spatial vulnerability outputs and actionable adaptation pathways. To bridge these gaps, an integrated conceptual framework is needed that couples 2D hydrodynamic hazard parameters, hybrid-weighted indicator engines, and Dynamic Adaptive Policy Pathways (DAPP). In conclusion, the paper outlined priority research agendas for high-density, data-sparse basins, emphasising the need for open-access geospatial infrastructure and real-time, community-validated risk mapping.

Keywords: Flood vulnerability; multi-criteria decision analysis; Weighting engines; GIS-based multi-criteria decision analysis (GIS-MCDA); Climate adaptation; Systematic review

26th International Conference and 46th Annual General Meeting of the Nigerian Institution of Agricultural Engineers (NIAE). ***November 9 - 13, 2026, JOSTUM, Makurdi, Nigeria***

Book of Abstract
Paper ID – 41

EFFECT OF STORAGE CONDITIONS ON THE QUALITY OF GROUND MELON SEED

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Ground melon seed (Citrullus lanatus), locally called egusi, is a widely consumed and economically important oilseed product in Nigeria and West Africa, but it is highly susceptible to lipid oxidation, moisture uptake and microbial spoilage once milled. This study evaluated the effect of storage condition (ambient and refrigerated), packaging material (plastic and zip bag) and storage duration (Week 0, Week 2 and Week 4) on the peroxide value, total viable count (TVC), total fungal count (TFC), colour and odour of ground melon seed, using a 2 × 2 × 3 factorial design with three replicates per treatment combination. Results are presented as means with error bars representing the 95% confidence interval (5% significance level). Peroxide value rose from a baseline of 50.00 meq/kg at Week 0 to between 130.00 meq/kg (refrigerated/plastic) and 290.00 meq/kg (ambient/zip bag) by Week 4. TVC increased from about 2,300 cfu/g to between 153,333 and 300,000 cfu/g, and TFC rose from about 14 cfu/g to between 216.67 and 263.33 cfu/g over the same period. Colour darkened from light yellow to brownish yellow, and odour deteriorated from "Good" to "Nasty"/"Smelly", most severely under ambient storage in zip bags. Refrigerated storage in plastic packaging gave the best protection across all quality indices, while ambient storage in zip bags gave the highest peroxide value and TVC. Refrigerated storage in plastic packaging is recommended for ground melon seed.

Keywords: Ground melon seed; storage condition; packaging material; storage quality; shelf life

26th International Conference and 46th Annual General Meeting of the Nigerian Institution of Agricultural Engineers (NIAE). ***November 9 - 13, 2026, JOSTUM, Makurdi, Nigeria***

Book of Abstract
Paper ID – 44

OPTIMIZATION OF THERMAL PROCESSING CONDITIONS AND SUGARCANE JUICE CONCENTRATION FOR QUALITY ATTRIBUTES OF TAMARIND JUICE USING RESPONSE SURFACE METHODOLOGY

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Tamarind juice quality is highly sensitive to pasteurisation conditions, yet the interactive effects of temperature, time, and sugarcane juice concentration remain underexplored. This study evaluates the effects of pasteurisation temperature (75-95 °C), pasteurisation time (10-20 min), and sugarcane juice concentration (30-70% v/v) on ascorbic acid content, total phenolic content, total flavonoid content, titratable acidity, and total soluble solids of tamarind juice. Second-order polynomial models were fitted using response surface regression. Sugarcane juice concentration was the dominant factor governing ascorbic acid retention and total soluble solids, both increasing with higher juice concentration, while pasteurisation temperature primarily drove titratable acidity and total phenolic content, with phenolic content improving under moderate heating before declining at higher temperatures. A significant temperature-sugarcane interaction was obtained across several responses. Models for total phenolic content, titratable acidity, and total soluble solids showed strong predictive adequacy (R^2 > 90%), whereas the ascorbic acid and, particularly, the total flavonoid content models showed weaker fit, reflecting the thermal lability and analytical variability of these compounds. Multi-response optimization using the desirability function identified 82.07 °C, 15.45 min, and 70% v/v sugarcane juice concentration as the optimal condition (composite desirability = 0.727), predicting 68.08 mg/100 ml ascorbic acid, 49.32 mg GAE/100 ml total phenolic content, 27.43 mg QE/100 ml total flavonoid content, 0.308% titratable acidity, and 18.99 °Brix total soluble solids. Conclusively, this study demonstrated that tamarind juice can be pasteurised under moderate thermal conditions with minimal nutritional loss when sugarcane juice concentration is co-optimised with temperature.

Keywords: Tamarind juice; Response surface methodology; Sugarcane Juice; Pasteurization; Quality attributes

26th International Conference and 46th Annual General Meeting of the Nigerian Institution of Agricultural Engineers (NIAE). ***November 9 - 13, 2026, JOSTUM, Makurdi, Nigeria***

Book of Abstract
Paper ID – 45

IMPACT OF AGRICULTURAL ENGINEERING ON NIGERIA'S ECONOMY: A REVIEW

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Agricultural Engineering has transformed agricultural practices from subsistence-level to commercial large-scale production through mechanisation in developed nations. In Nigeria, it plays a key role in economic development by increasing agricultural productivity, creating employment, and stabilising food security. This review addresses three questions: What is the impact of agricultural engineering on Nigeria's economic growth? What is the acceptability of agricultural engineering innovations among smallholder farmers? What is the impact of Nigeria's large irrigation dams on small-scale farmers? This review uses data from the National Agricultural Extension and Research Liaison Services (NAERLS) database to estimate agricultural post-harvest losses from 2021 to 2025, focusing on grain and cereals (rice, sorghum and maize), root and tuber (cassava and yam) and vegetables (tomato). These crop groups are justified by their foundational role in national food security and extreme vulnerability to post-harvest handling. It further narrows its focus to the three branches most directly linked to Gross Domestic Product (GDP) data: farm power and mechanisation, irrigation and water engineering, and post-harvest and processing engineering. The review finds that farm mechanisation contributes a mean of 29.93% to Nigeria's agricultural GDP, while no comparable GDP figure exists for irrigation/water engineering or post-harvest/processing engineering, despite decades of documented activity in both areas. Across all three branches, smallholder adoption remains low, driven by financial constraints, weak policy implementation, and limited farmer confidence in new technology. It concludes by recommending standardised GDP data record-keeping for agricultural engineering, coordinated through professional bodies such as the Nigeria Institution of Agricultural Engineers (NIAE).

Keywords: Agricultural engineering; Agricultural GDP; Farm mechanization; Post-harvest losses; Smallholder Farmers

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Paper ID – 47

INTERACTIVE MECHANISTIC SIMULATION OF MUNICIPAL WASTEWATER TREATMENT UNIT OPERATIONS FOR ENGINEERING EDUCATION

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Municipal wastewater treatment is difficult to teach because governing processes occur inside opaque vessels. Static schematics show where units sit but not what happens within them, while professional simulators are costly and require expertise that learners lack. The objective of this study was to develop an interactive, browser-based simulator, driven by a validated engineering model, that renders these mechanisms visible and quantitatively accurate for learners. The application is a single self-contained HTML/CSS/JavaScript file rendered on the HTML5 canvas with no external libraries or servers. The process model couples the Crites–Tchobanoglous settling relation, steady-state Monod formulation for activated sludge, Chick–Watson disinfection law, and oxygen and biomass balances, with coefficients from recognised design references. Additional modules address sizing, cost, diurnal dynamics, energy and carbon accounting, and comparisons with ponds and wetlands. For a design flow of 10 ML/d from 100,000 persons at 96 L/capita·d, the model reduced biochemical oxygen demand from 300 to 5.2 mg/L and total suspended solids from 250 to 5.0 mg/L—removals of 98.3% and 98.0%—with a 5.4-log faecal-coliform reduction and effluent meeting national limits of 30 mg/L. Validation against accepted literature gave a mean absolute percentage error of 7.1 within accepted bands. Energy intensity was 0.35 kWh/m³ (aeration 55%, anaerobic digestion offsetting 37%); ponds required only 0.02 kWh/m³ but 3.0 m²/capita, quantifying the energy–land trade-off governing technology selection in developing regions. The work demonstrates that a lightweight, model-driven web simulator is technically feasible and quantitatively accurate, offering an accessible medium for teaching wastewater treatment mechanics and quantitative behaviour. Its effect on learning outcomes remains to be measured.

Keywords: Wastewater treatment, Interactive simulation, Process modelling, Aeration energy, Engineering education

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Book of Abstract
Paper ID – 48

DEVELOPMENT OF MOTORIZED TWO-ROW IRISH-POTATO PLANTER AS APPROPRIATE TECHNOLOGY FOR IMPROVED PRODUCTIVITY AMONG SMALLHOLDER FARMERS IN NIGERIA

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Irish potato (Solanum tuberosum L.) is a globally important food and cash crop that contributes significantly to food security, income generation, and nutrition, particularly in developing economies. Despite its importance, Irish potato production in many regions remains constrained by labour-intensive traditional planting methods that result in poor seed placement, inconsistent planting depth, and reduced field efficiency. Agricultural mechanisation of planting operations offers a viable pathway to improve productivity, uniformity, and timeliness, especially for smallholder farmers. This study presents the design, development, and performance evaluation of a motorised Irish potato planter suitable for small- to medium-scale farming systems. The planter was developed using locally available materials and evaluated under field conditions, including tractor-tilled sandy-loam soil, flat topography, and operating speeds of 1.8 kmh^{-1}, 2.5 kmh^{-1}, and 3.0 kmh^{-1}, for seed spacing accuracy, planting depth uniformity, field capacity, field efficiency, and seed damage. Performance results demonstrate significant improvements in planting uniformity of 307 ± 20 mm and operational efficiency of 83% compared with manual planting practices. The study demonstrated that the developed Irish potato planter performed satisfactorily under field conditions, achieving optimum performance at an operational speed of 2.5 km h^{-1} with a metering efficiency of 95%. The findings further indicate that adopting the planter has significant potential to improve Irish potato production while providing a technically feasible and economically affordable planting option for smallholder farmers.

Keywords: Agricultural mechanisation; Solanum tuberosum L.; Irish-potato planter; Metering efficiency; Planting uniformity; Smallholder farming.

26th International Conference and 46th Annual General Meeting of the Nigerian Institution of Agricultural Engineers (NIAE). ***November 9 - 13, 2026, JOSTUM, Makurdi, Nigeria***

Book of Abstract
Paper ID – 49

RAISED-BED CONFIGURATION VERSUS DEFICIT IRRIGATION IN WHEAT: AN EVIDENCE SYNTHESIS OF YIELD, WATER PRODUCTIVITY AND CONTEXT-DEPENDENT RESPONSES

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Water scarcity increasingly constrains irrigated wheat production, particularly in semi-arid environments where conventional surface irrigation can result in evaporation, runoff and deep-percolation losses. Raised-bed planting and deficit irrigation have each been investigated as strategies for improving agricultural water use; however, their interaction and the conditions under which their combination produces favourable yield–water-productivity outcomes require clearer synthesis. This review examines the combined influence of raised-bed configuration, deficit-irrigation intensity and irrigation timing on wheat grain yield and water productivity. Particular attention is given to the mechanisms through which bed geometry modifies soil-water redistribution and root-zone conditions under controlled water stress, and to the roles of soil, climate, cultivar and irrigation management in modifying crop response. Evidence in the supplied literature indicates that raised beds can improve irrigation efficiency and root-zone conditions, while moderate deficit irrigation can improve water productivity when stress is controlled and appropriately timed. However, responses are not universal: bed width, soil texture, irrigation method, deficit intensity, deficit timing and local environmental conditions can alter the balance between yield and water productivity. The central knowledge gap is therefore not whether either practice can save water, but how their interaction can be optimised for specific production environments. The review further highlights the need for context-specific evidence for irrigated wheat production in Northern Nigeria and proposes a framework linking bed configuration, deficit regime, environmental conditions and crop response.

Keywords: wheat, raised beds, flat-basin irrigation, deficit irrigation, grain yield, water productivity.

26th International Conference and 46th Annual General Meeting of the Nigerian Institution of Agricultural Engineers (NIAE). ***November 9 - 13, 2026, JOSTUM, Makurdi, Nigeria***

Book of Abstract
Paper ID – 51

EFFECTS OF TILLAGE DEPTH AND FORWARD SPEED ON TILLAGE PERFORMANCE UNDER DRYLAND CONDITIONS

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Abstract

Soil-tillage interactions critically influence field performance, energy consumption, soil disturbance, and seedbed preparation quality. The complex relationship between inherent soil properties and machine operating parameters governs tillage performance, making soil–tillage interaction essential for efficient and sustainable agricultural mechanisation. This study investigated the effects of tillage depth and forward speed on the performance of a tractor-mounted tillage implement under baseline dryland loamy-sand soil conditions (Soil moisture 9.40 ± 0.40 %, bulk density 1.56 ± 0.03 g cm^{-3}, penetration resistance 1.41 ± 0.22 MPa). The experiment was conducted at three tillage depths (10, 15, and 20 cm) and three forward speeds (3, 5, and 7 km h^{-1}). Soil moisture content, bulk density, and penetration resistance were determined before tillage, while draft force, specific draft, disturbed soil width, fuel consumption, and field capacity were evaluated during operation. The draft force increased significantly with both tillage depth and forward speed ($p < 0.001$, accounting for 83.76% of variance) and forward speed ($p < 0.001$, 12.75% of variance). Mean draft increased from 1.43 kN at 10 cm depth to 2.81 kN at 20 cm (+96.5%), while increasing forward speed from 3 to 7 km h^{-1} increased mean draft from 1.81 to 2.35 kN (+29.8%). Analysis of variance indicated that tillage depth and forward speed significantly affected draft force ($p < 0.05$), whereas their interaction was not statistically significant. Specific draft ranged from 38.6 to 55.7 kNm^2, while fuel consumption increased from 15.8 to 30.4 L ha^{-1} across the tested conditions. Evaluated against criteria of minimising draft force and fuel consumption while maximising field capacity within effective seedbed depth requirements, the 15 cm depth at 5 km h^{-1} provided the optimal operational trade-off. The findings demonstrate the importance of matching tillage depth and forward speed to soil conditions for improved energy efficiency and sustainable drylands agricultural mechanisation.

Keywords: Soil–tillage interaction; tillage depth; forward speed; draft force; soil disturbance

26th International Conference and 46th Annual General Meeting of the Nigerian Institution of Agricultural Engineers (NIAE). ***November 9 - 13, 2026, JOSTUM, Makurdi, Nigeria***

Book of Abstract
Paper ID – 53

OPTIMISING WATER HARVESTING PRACTICES FOR ENVIRONMENTAL SUSTAINABILITY IN BOMO, SABON GARI LOCAL GOVERNMENT AREA, KADUNA STATE, NIGERIA

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Sustainable water harvesting requires more than constructing or adopting water collection systems; it also requires appropriate technology, financial resources, technical knowledge, institutional support, and community participation. This study examined approaches for improving water harvesting practices for environmental sustainability in Bomo, Sabon Gari Local Government Area, Kaduna State, Nigeria. The paper was developed from the fourth objective of a broader study, which sought to provide recommendations for improving water harvesting techniques and enhancing environmental sustainability. A cross-sectional descriptive mixed-methods design was adopted. Data were obtained through structured questionnaires and qualitative discussions, based on responses from 300 respondents. Descriptive statistics were used to identify the forms of support residents require and their awareness of, and participation in, government and non-governmental programs. Financial assistance was identified by 53.3% of respondents as a major support requirement, followed by access to better materials (46.7%) and technical training (40.0%). Community support was reported by 33.3%, while government policies were identified by 26.7%. Although 60.0% of respondents were aware of government or NGO programs related to water harvesting, only 26.7% reported participation. Among the program-impact responses presented in the study, 16.7% described impacts as very positive and 26.7% as positive. The findings demonstrate that financial, material, technical, institutional, and participatory factors are relevant to improving water harvesting in Bomo. The study concludes that sustainable improvement requires an integrated approach combining appropriate system design, regular maintenance, technical capacity building, financial support, community participation, and stronger institutional engagement.

Keywords: Water harvesting, environmental sustainability, technical training, financial assistance, community participation, Bomo, water management.

26th International Conference and 46th Annual General Meeting of the Nigerian Institution of Agricultural Engineers (NIAE). ***November 9 - 13, 2026, JOSTUM, Makurdi, Nigeria***

Book of Abstract
Paper ID – 54

DETERMINATION OF N-FACTORS FOR DRAFT FORCE OF TRACTOR-MOUNTED DISC PLOUGH IN NSUKKA CLAYEY LOAM SOIL

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The five N-factors were obtained analytically governing the draft force of a tractor-mounted disc plough operating on Nsukka clay loam soil. Field work was conducted at the Crop Cultivation Section of the Teaching and Research Farm, University of Nigeria, Nsukka, using a Massey Ferguson 435 tractor and a Fieldking FKMDP-3 mounted disc plough. Ten experimental runs were conducted at different cutting depths replicated twice. Soil moisture content, bulk density and cone index were measured, while soil unit weight, surcharge pressure, cohesion, and adhesion were obtained using the adopted calculation procedures. Average moisture content was 8.71% and average cone index was approximately 1.38 MPa. The Universal Earthmoving Equation (UEE) was adopted as the analytical framework. The five N-factors were obtained directly from their individual soil-wedge equations rather than by regression. Using a rake angle of 45°, internal friction angle of 33°, soil–metal friction angle of 23.3° and failure angle of 28°, the resulting factors were:(Ny, Nc, Nca, Nq, and Na) (1.274395, 2.564008, 0.503735, 2.548790, and 0.776632) respectively. These factors were subsequently applied to the UEE to calculate draft force for each experimental run. Calculated draft force ranged from 3.59 to 10.96 kN. The results highlighted the synergistic effects of cutting depth, the soil properties and operating conditions of Nsukka soil.

Keywords: N-factors; disc plough; draft force; Nsukka soil; soil cutting; Universal Earthmoving Equation

26th International Conference and 46th Annual General Meeting of the Nigerian Institution of Agricultural Engineers (NIAE). ***November 9 - 13, 2026, JOSTUM, Makurdi, Nigeria***

Book of Abstract
Paper ID – 56

AI-ENABLED IoT-BASED PRECISION NUTRIENT MANAGEMENT FOR CLIMATE-RESILIENT RICE PRODUCTION IN NIGERIA

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Rice production in Nigeria is affected by fluctuating soil nutrients, inefficient fertiliser application, climatic changes, and a lack of timely, field-specific agronomic advisories. Generic fertiliser advisories and visual evaluation of the crop can be helpful but may overlook variations in soil nutrient status, crop growth stage, weather, and management practices. In this study, we propose an architecture for intelligent nutrient management in Nigerian rice production using artificial intelligence (AI)-enabled Internet of Things (IoT). The proposed framework comprises soil and microclimate sensing, crop imagery, wireless networking, data handling, CNN-based diagnosis, multimodal data fusion, decision rules and site-specific nutrient recommendations and follow-up. Soil pH, electrical conductivity, soil moisture content, soil temperature, soil NPK, microclimate temperature, relative humidity, rainfall, crop growth stage, leaf parameters, fertiliser and yield data, and geographical information system constitute the primary variables of the system. Recommendation generation predicts the nutrient type, rate, timing, and management zones under agronomically validated limitations; recommendations may first be provided via an advisory mobile application interface and secondly be used to drive semi-automatic variable-rate machines. In Nigeria, customised digital advisory services for rice have been shown to increase yields and profitability, while rice research in other parts of the world highlights the importance of data fusion for nitrogen analysis. As this framework represents a proposed solution and not yet a proven one, its agronomic, technological, economic, and environmental advantages need to be demonstrated through sequential tests.

Keywords: artificial intelligence; internet of things; precision agriculture; rice; nutrient management.

26th International Conference and 46th Annual General Meeting of the Nigerian Institution of Agricultural Engineers (NIAE). ***November 9 - 13, 2026, JOSTUM, Makurdi, Nigeria***

Book of Abstract
Paper ID – 59

Optimisation of Vertical Grinding Disc Parameters for High-Efficiency Guinea Corn (*Sorghum bicolour*) Processing

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ABSTRACT
Historically, ineffective trial-and-error methods have been used to manage the operating configurations of small-scale Guinea corn disk milling in underdeveloped nations. The variable process optimisation of a local grinding disk milling operation powered by a 4 HP (2.98 kW) electric motor is presented in this study. The study standardises the percentage milling efficiency at 13% conditioned moisture content for Guinea corn (Sorghum bicolour). The system was modelled using Response Surface Methodology (RSM), which is based on a 3-factor, 5-level face-centred Central Composite Design (CCD). The studied range of factors included: Disk speed (X1: 300 - 900 rpm), feed rate (X2: 30 -90 kg/hr), and Adjustable disk clearance (X3: 0.5 - 1.25 mm), which were the selected independent process parameters. The output performance was measured using a single response variable: Percentage Milling Efficiency (Y). The percentage milling efficiency is calculated through mechanical sieve analysis using a 1mm standard mesh. A total of 20 experimental runs were conducted. The optimal process parameters include: disc speed (X1 = 600 rpm), Feed rate (X2 = 55 kghr), and Adjustable clearance gaps (X3 = 1.25 mm), which generated strong shear forces that significantly improved milling efficiency to 93 per cent. However, when the feed rate exceeded 90 kg/hr under tight clearances, the 4 HP motor reached structural load limits, causing belt slippage. The final statistical outputs yielded a second-order polynomial regression equation capable of predicting flour yield based on optimal settings. This work replaces empirical guesswork with a structured mathematical framework, helping local agro-processors minimise product wastage and maximise single-pass milling efficiency.

Keywords: Vertical disk, Milling operation, Guinea corn processing, Performance assessment, and Process optimization

26th International Conference and 46th Annual General Meeting of the Nigerian Institution of Agricultural Engineers (NIAE). ***November 9 - 13, 2026, JOSTUM, Makurdi, Nigeria***

Book of Abstract

Paper ID – 60

ENVIRONMENTAL IMPACT ASSESSMENT OF AN INTEGRATED SEPTIC-TANK BIODIGESTER SYSTEM IN ZARIA, NIGERIA

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Conventional septic-tank systems present environmental challenges associated with wastewater management, potential soil and water contamination, and uncontrolled greenhouse-gas emissions. Integrating biodigesters with existing sanitation systems offers opportunities for improved waste treatment and renewable energy recovery, although the associated environmental risks require careful assessment. This paper evaluated the environmental impacts of integrating a biodigester with a conventional septic-tank system at Ahmadu Bello University, Zaria, Nigeria. A case-study environmental impact assessment was undertaken through critical analysis of the project's Environmental Impact Statement (EIS), covering site preparation, construction, operation and decommissioning. Environmental impacts were classified by direction, duration, reversibility and directness, while the EIS significance ratings and mitigation measures were synthesised. The assessment identified potential benefits of biogas recovery for cooking and lighting, as well as local employment. Key adverse impacts included vegetation and topsoil disturbance, construction dust and exhaust emissions, noise, solid waste, drainage disruption, worker injury and possible soil or water contamination. The EIS rated several construction impacts as high before mitigation, including material-transport emissions, excavation emissions and noise, solid waste, and installation-related accidents. Proposed controls included vehicle maintenance, dust suppression, drainage management, protective equipment, daytime work, approved waste handling and emergency procedures. Because the assessment was predictive, measured biogas production, methane leakage, effluent quality, fuel displacement and greenhouse-gas savings were not available. The findings establish a project-specific environmental-management basis for subsequent commissioning and monitoring, rather than proof of achieved environmental benefits.

Keywords: anaerobic digestion; environmental impact assessment; septic tank; biodigester

26th International Conference and 46th Annual General Meeting of the Nigerian Institution of Agricultural Engineers (NIAE). ***November 9 - 13, 2026, JOSTUM, Makurdi, Nigeria***

Book of Abstract

Paper ID – 61

DESIGN AND EVALUATION OF GROWTH-STAGE ADAPTIVE IoT IRRIGATION SYSTEM FOR BELL PEPPER IN SEMI-ARID NIGERIA

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Efficient irrigation is important for crop production in semi-arid environments, where temperature, humidity, and soil-water conditions can change considerably within short periods. This study presents the development and evaluation of a low-cost, growth-stage adaptive Internet of Things (IoT)-based drip irrigation system for bell pepper production. The prototype integrates an ESP32 microcontroller with a capacitive soil-moisture sensor, DHT22 air-temperature and relative-humidity sensor, DS18B20 soil-temperature sensor, YF-S201 flow sensor, DS3231 real-time clock, relay-controlled pump, and local LCD interface. Five bell pepper seedlings, approximately four weeks old at transplanting on 21 August 2026, were monitored from 22 August to 26 September 2026, corresponding to approximately four to nine weeks of crop age. The project log recorded 11.25 L of irrigation water during the observation period. Mean morning and evening water applications were 150 mL and 195 mL, respectively. Exploratory Pearson correlation analysis showed a moderate positive association between morning air temperature and morning irrigation volume ($r = 0.388$, $p = 0.019$), and a moderate negative association between morning soil moisture and morning irrigation volume ($r = -0.443$, $p = 0.007$). These results describe associations rather than causal effects. The study demonstrates the practical potential of combining low-cost sensing, scheduled control, and growth-stage-oriented irrigation for sustainable agricultural water management in semi-arid Nigeria.

Keywords: Smart irrigation, Internet of Things, ESP32, Bell pepper, Water management

26th International Conference and 46th Annual General Meeting of the Nigerian Institution of Agricultural Engineers (NIAE). ***November 9 - 13, 2026, JOSTUM, Makurdi, Nigeria***

Book of Abstract

