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About the Journal

The Journal of Digital Food, Energy & Water Systems (JD-FEWS) is a peer-reviewed bi-annual publication that publishes recent and innovative deployment of emerging digital technologies in Food, Energy, and WaterSystems. Food, energy, and water resources are interconnected scarce resources that require systems and technologies to foster sustainable management and effective utilization. The journal is also interested in articles that explore the nexus between at least two of these resources. Thejournal considers the following topics as long as they are deployed in the Food, Energy & Water space:

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TECHNICAL COMPARISON OF HYBRID RENEWABLE ENERGY SYSTEMS FOR INFORMATION TECHNOLOGY SERVICES

John ADEBISI,
University of Namibia, Namibia; adebisi_tunji@yahoo.com

Olumuyiwa AMUSAN,
University Lagos, Akoka, Nigeria; University of Johannesburg, South Africa

Ponmile OLAWOORE,
Alex Ekwueme Federal University, Ebonyi, Nigeria

Chukwebuka IGWE
Alex Ekwueme Federal University, Ebonyi, Nigeria

Abstract: In a bid to reduce the negative effect of atmospheric and environmental pollution and its consequent negative effect, a mix of renewable energy generation options is being considered across the globe. Hence, the technical comparison of an eco-friendly, cost-effective, and near zero carbon footprint for sustainable power solutions is still of core interest in the research space. Solar, wind and its hybrids can be further explored to meet the ever-increasing load demand of energy consumers, especially in high energy demand facilities including information technology (IT) services. Critical IT infrastructures represent a core backbone in research institutions, hence the need for hybrid energy solutions is pertinent for increased sustainability. This work compared hybrid energy sources of solar and wind against its independent sources using the IT laboratory in Alex Ekwueme Federal University, Ebonyi, Nigeria. An appropriate sizing of individual and a hybrid of wind, solar, and battery energy source was done, after which the input-output voltages across the set-ups was measured during peak and off-peak periods for a 300W laboratory IT load. The experimental result showed the input/output peak and off-peak DC voltages for solar, wind, and its hybrid energy are 12.67V/12.02V / 12.47V/11.61V, 12.53V / 11.90V / 12.48V / 11.87V, and 12.78V / 12.09V / 12.57 / 11.95V respectively signifying a significant increase from the on-load peak period while the on-load off-peak period is seen to be lower. The results also show that a hybrid solar-wind-battery system tested at 5 minutes time intervals gives a superior output voltage regulation and efficiency when compared to the solar or wind individual systems. It was concluded that the hybrid system of solar, wind, and battery energy source is an ideal standalone renewable energy power option for IT laboratory in the university.

Keywords*:* Solar PV system, Wind energy system, Solar-Wind-Battery hybrid system, Information technology

1.0 Background

Human existence couldn't have been so interesting without reliable energy [1]. Additionally, human economy and fostered quality of life depend largely on energy for its reality [2]. Energy has the capability of machinery to result an external action [3]. To this view, various grades of energy are discriminated: the mechanical form which is of potential or kinetic energy, the thermal, nuclear, electric, chemical, and solar energies. For work to be done using the chemical, nuclear and solar energy there must be a form of transformation to its mechanical or thermal energy equivalence [4]. The quantity measure of the available energy is termed as energy basis [5]. The foundation of power is made of predominantly exhaustible assets and electricity from large part renewable sources. In respect to this, energy resources fossil and recent resources are distinguished: Fossil energy – a stock of energy that came into existence during the ancient geological age by biological or geological process. It has been further divided into bio-genous energy resources and fossil energy resources [6]. The hard coal, crude oil, and natural gas make up the biogenous resources [7]. Recent energy resources are those, which are currently generated by biological process. These are the biomass's energy content and the natural reservoir's potential energy. Energy sources necessitate a stream of energy to an extended period of time. In regards energy sources are termed inexhaustible [5].

However, the enormous variety of environmental impact significantly result during the affair of energy provision or more exactly of the related energy services all of which are heating living spaces, information, and mobility are less lived with by the society of the 21st century [6]. This is why energy problems, in conjunction with the underlying environmental problem will continue to be a major topic in energy engineering [8]. But the splendor of a surroundings now no longer mainly aggressive, plentiful, and value effective electricity sources have led growing range of industrialized nations to aid public financing of renewable electricity [9]. In Europe 2020, the European commission set a target of 20% of the share of renewable energy from renewable energy to foster obedience to an international agreement on greenhouse sending reduction and to make out a chance for employment and district growth [10].

Replacement of fossil gasoline with the aid of using exclusive sources of renewable power is one of the three concerned technological modifications in sustainable energy improvement strategy [10]. Renewable electricity is a sort of power made from self-renewing reassets along with solar light, wind, flowing water etc. In critical service organisations such as financial enterprise and information technology services such as video conferencing, telemedicine, e-government, e-leaning and several other services that has depended on IT especially in the post COVID era and those assets that require uninterrupted and economically viable electricity supply has informed the need for this research. Renewable strength technology in comparison with the traditional assets of strength bring about weightier merit. The electricity from the wind is generated from airflow via wind to automatically power generators for electricity. These turbines then convert the mechanical power brought on to electric power. Wind electricity, as an alternative to burning fossil fuels, is plentiful, renewable, broadly distributed, clean, produces no greenhouse gas emissions at some stage in operation, and uses little land. Generation of electrical electricity from sun energy can be executed with the aid of using the conversion of daylight into electricity, both directly using photovoltaics (PV) or not directly the usage of focused sun electricity (CSP) [11]. Invariably, technology promotes society's growth standard of existence, and combining solar, wind, and hybrid power systems will increase efficiency.

Consequently, improving energy efficiency will reduce the greenhouse effect, lower demand for energy, and cost on house and economy wide level. This can be obtained from renewable energy source [9]. To this extent this research is carried out on the basis of comparative technical analysis of the efficiency of solar, wind, and hybrid power system. It evaluates individual sizes of the energy mix and implements the mix with the most efficient power source through storage for maximum power supply.

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2.0 Review of Related Concepts

Energy will depend on solar and wind in the future because they are much available as a natural resource. The nature of energy generated will become more reliable to support the high demand for information technology services of the 21st century in all sectors [5]. Due to the pollution, high cost, and transmission power loss posed by the convectional power sources; future services will require clean energy, making the current energy source a difficult task. Constant power source and efficiency will be available when a combination of solar and wind plants are deployed as a single source with a battery as storage element [7]. Efficiency of energy will reduce its consumption and increase saves of consumer's money [2].

2.1 Solar energy Model

Sun provides the solar that reaches the earth's surface, and several amounts of it are absorbed in different places as a result of the geographical condition [8]. 1,367w of the power reaches each rectangular meter of the outer fringe of the earth's ecosystem. The environment as a result absorbs the power and reflects it. The radiation from the solar passes via the environment and because of the thickness of the environment, the sun electricity is reduced [13]. This sun power is renewable and unearths utility in water heaters, sun lamps etc. [8]. The Air mass 1 or AM1 radiation which is about 1000 W/meter square [3] is another concept during the noon time when the sky is clear there is an amount of radiation that reaches the earth sea level. Similarly, the sun's mild rays that reach a location as properly known as incident sun radiation is insolation. The daylight is erratically dispensed within-side the areas of the earth; equator areas get hold of greater radiation than some other part. Sunlight varies with the seasons because the rotational axis of the Earth shifts to prolong and shorten the darkish or mild days with the changing seasons. The amount of daylight attaining any location is likewise affected by the time of day, the climate (specifically the cloud cover, which scatters the sun's rays), and the air pollutants in that location. Likewise, those climatic elements all affect the quantity of sun power that is to be had to PV systems [13].

2.2 Types of solar power system

a. ***On-Grid solar:*** this consists of the sun panels, inverter, meter and software grid. Solar sources direct current. The inverter converts the DC from the sun to AC for maximum home equipment that don't use DC [14]. The alternating current flows via the meter this is connected to device. This is illustrated in Figure 2.1

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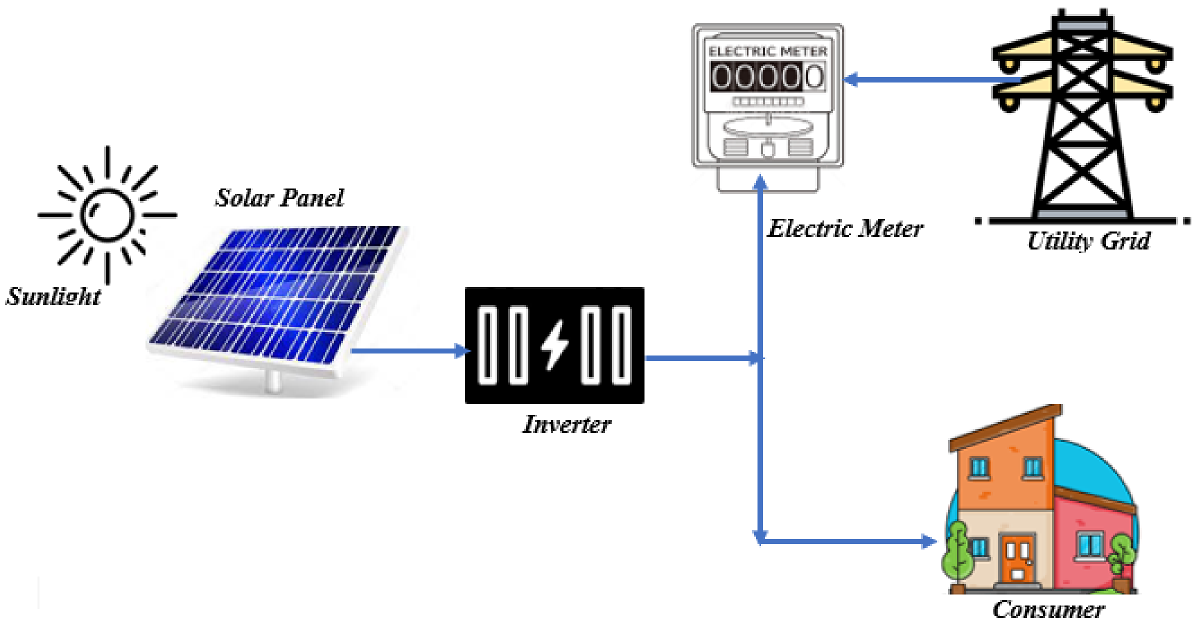

Figure 2.1: *On-grid solar illustration*

b. ***Off-Grid solar****:* this comprises of solar cells for conversion of solar light into direct current electricity, inverters are used for conversion of the direct current electricity from an alternating current [15], and battery bank for storage of the left energy [16]. A modified concept of 2.1 is as shown in figure 2.2.

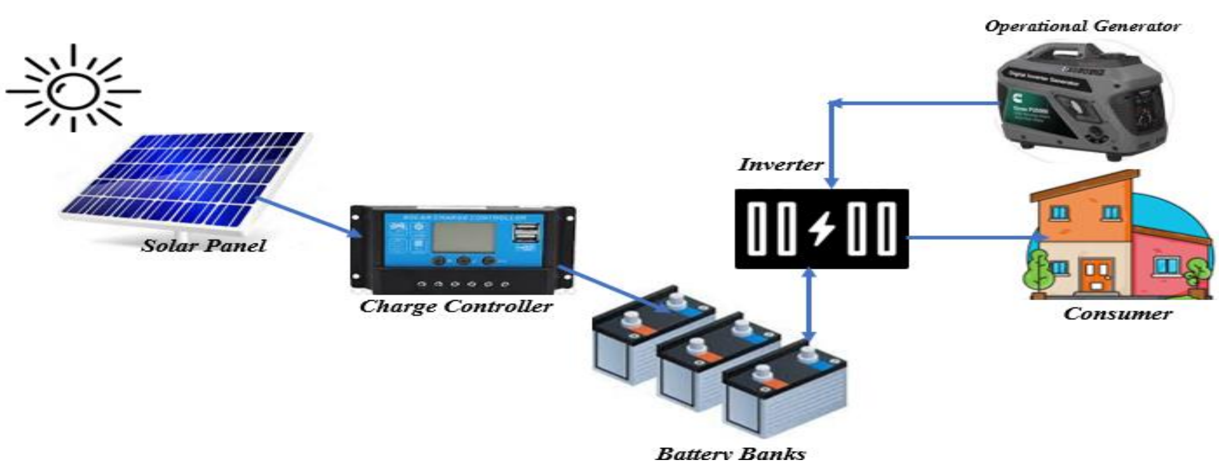

Figure 2.2*: Off-grid AC Solar Illustration*

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c. *Hybrid Solar*: The operation of hybrid solar integrates the working of On-Grid and Off-grid as indicated in figures 2.1 and 2.2 respectively. It stores energy through the batteries and is used when needed. At times when there's no support from both on and off grid solar causing no energy left in the storage battery. Uninterrupted electricity keeps it working and the battery could be charged [16]. System of this nature is required for high availability services such as information technology. Considering the various methods of harnessing the solar energy such as solar-thermal process which changes continuously for solar energy to obtain equivalent heat. This principle reflects concentrated solar light unto a load point. Heat form converted is applied to heat up water and dry crops [15].

Other methods include but are not limited to Solar-PV - that converts solar sunlight into its equivalent direct current electricity using photovoltaic cells [10]. Solar panel module - a module that is shaped while photo-voltaic cells are assembled together. The sun panel uses solar light to supply direct current electricity [14]. The panel works comparable precept just like the PN junction of a semiconductor. As photon fall at the panel, P-type and the N-type alternate their majority carriers constituting follow of current. As the technique continues, the battery connected to it gets charged. Solar cells are connected in series in order that it sums up the voltage [17]. Percentages of 15% to 22% of the strength from the sun are processed into usable strength. This relies upon on how the panel is placed, the climate condition, orientation and different comparable. Panel overall performance is decided through the quantity of daylight it may convert to electric powered contemporary indicating panel performance [9]. A general Test Condition this performance at an exact temperature of 25 ^{O} C and 1000W/meter square. This is the equal of a sunny day with the incident light hitting a solar-facing 37°-tilted floor. Under standard check conditions, a sun panel performance of 15% with a 1 m^2 floor location might produce 150 Watts [17]. Different types of solar panels are Mono-crystalline Solar Panel, Polycrystalline Solar Panel and the Thin film solar panels**.**

2.3 Panel efficiency at extreme condition

Nowadays, commonly used solar panels deliver an energy efficiency rating that ranges between 11% to 15%, this results to the proportion of solar energy that is actually converted into operational electricity. One of the extreme conditions is the Snow - the quantity of snow at the floor of a panel if far thicker than 5cm. might have a negative impact and decrease the performance of a solar panel by 100%. The inclined position of the panel permits the snow to slip off. It can be eliminated manually [18]. Another serious condition is wind - when there's massive boom in speed of the wind, the panel performance reduces. Wind causes principal harm to panels, making producer's behavior huge tunnel check to lessen the harm. Although wind impact cools panel. At 1^0 cool the panel will increase in efficiency of 0.05% [8]. Other conditions are Hail, Ice, Chemical Residue, UV Degradation and Damp heat testing.

2.4 Wind power and Conversion

Since this work compares different renewable energy sources, the place of wind power and its conversion is very important. In the 1980's the USA started the wind farm through the establishment of 10,000 turbines [19]. Each of the station produced 80-200Kw. Denmark pioneered wind energy in Europe [20]. Germany at the end of the 21st century took the lead in wind energy production until 2008[21]. 2020 was the best year for the global wind industry when 93GW of new capacity was installed and the development continues. Wind power provides natural energy. The flow of wind is from the higher pressure to the lower pressure level as a result of radiation falling unto the earth. The wind power is available day and night and is more in coastal regions. Moment past and location, wind varies and is unpredictable. The wind motion virtue gave rise to its kinetic energy. This kinetic energy of the wind is surrounded by wind Turbine, which extract the wind energy by conversion to Mechanical Power. The mechanical form of energy powers the electric power generator and causes it to turn. The amount of power generated is equivalent to the amount of wind available in the place.

2.5 Hybrid power

Based on the concept anchored upon by this work, the need for hybrid power cannot be overstressed because it is the future of energy generation for improved efficiency and sustainability of critical services such as Information technology [22]. The process of hybrid power generation, especially in renewable power systems, comprises of merging distinctive energy device correctly (in this case solar and wind) into a single system to enhance the overall gain compared to a single device with a single supply. It was initially designed as an aggregate of conventional, nonrenewable generation (e.g., diesel generators) with battery power storage structures (BESSs). Efficiency and cost of solar and wind energy depend on their parts, parameters, and topologies. Solar energy is extra efficient than wind. However, it isn't usually relevant as efficiency is predicated at the technological revolution of individual additives use in the PV or wind device [23]. Generally, wind turbine device is more expensive than the sun. Consideration of each value and performance normally imposes the consumer to compromise, which is more vital than the opposite. Increasing performance way making use of evolved strategies and putting in extra highly-priced device which bring about elevating the overall value of the device [24]. The method used for this technical comparison are detailed in the next section.

3.0 Methodology

Previous related works used incentive mechanisms [25], mathematical analysis methods[26], and other modelling software tools such as Advanced Interactive Multidimensional Modelling System (AIMMS)[27], Hybrid Optimization of Multiple Energy Resources (HOMER) [28-29]. In this work, different materials and methods through which the research is implemented is discussed using the following materials: A mono crystalline 12V 100W solar panel, Battery: 100A 12V DC Deep-cycle battery, Wind Generator: A 500W 12V wind generator, Inverter, 1000W 12V DC inverter with Output of 220-230V AC output, 20A 12V DC PWM Charge Controller, and a 300W IT laboratory load. The individual components areas described below.

3.1 Wind Generator: 500W, 12V

The effectiveness of independent wind solar hybrid energy systems is compared to that of solar panels and wind turbines working on their own as renewable energy sources in this study. There is a 500W wind turbine. The calculations for power (output/input) and efficiency of wind turbine and solar panel systems are made using historical data from the research region that was gathered by the institution's weather section. The energy provided by the wind is provided by [28];

$$P_w = \frac{1}{2}\rho A v^3 \quad (1)$$

3.2 Mono-crystalline Solar PV: 100W, 12V

In order to disperse the surface area across various orientations and receive more solar energy, the monocrystalline solar panels employed in this study have varying dimensions. The same amount of power is generated by smaller solar panels (16X24 cm) that have the same surface area as one large solar panel (35X62.5cm). Hence the dimension solar

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PV used is 60cm X 24cm. This does not include employing a solar tracking system to maximize the solar panels' exposure to sunlight. Efficiency is assessed using:

$$\eta_{solar} = \frac{P_{max}(Watt)}{I_r\left(\frac{W}{m^2}\right)A} \qquad (2)$$

3.3 Hybrid Solar and Wind System

In order to build the hybrid renewable energy system under investigation, three-bladed wind turbine and the solar PV are employed to the same specifications. The overall power output of the hybrid is determined by equation 3 [29], where Nw and Ns represents the number of wind turbines and solar modules respectively.

$$P_{hybrid} = (N_w P_w) + (N_s P_s) \qquad (3)$$

The power production is measured and tested for the wind turbine alone. The energy production from solar is evaluated first with a single large solar panel, then with six smaller solar panels with comparable characteristics. Each system's efficiency is calculated. The wind turbine is initially connected to the one giant solar PV and six smaller solar panels to test the hybrid system. The performance for each arrangement is again calculated for comparison. The integration of energy from two different renewable energy sources—solar panels and wind turbines—to produce a single output depends on the solar-wind hybrid controller. In order to store the energy, a rechargeable battery will be attached to the controller that mixes solar and wind energy. The controller's ability to prevent high or fluctuating voltage and guard against overcharging and prolong battery life is one of its additional functions. The renewable energy hybrid system's efficiency is determined by

$$P_{hybrid} = (\tfrac{1}{2} N_w \rho A_w v^3) + (N_s \eta_s I_r A_s) \qquad (4)$$

3.4 Deep Cycle Battery: 100A, 12V DC

Battery is used to store the energy generated from the solar panel. They are connected in series such that the appropriate voltage is obtained. The battery used is the deep cycle.

$$\text{Battery capacity(Ah)} = \frac{\text{total watt−hour perday x days of autonomy}}{\text{0.85 x 0.6 x norminal voltage}} \qquad (5)$$

Autonomy is the number of days the battery will work without using the solar panel. This is taken as 2days

3.5 PWM Charge Controller: 20A, 12V DC

This charge controller is used to ensure that the dc signal from the wind turbine and solar is connected directed to the battery. It also prevents overcharging of the battery, excess temperature on the battery and it prevents reverse-discharge from the battery [26].

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3.6 IT Services and the Hybrid System Layout

Various information technology services are available in the laboratory used as a case study of this research. Most of these services compete for high power supply with critical server infrastructures spanning application servers, network infrastructures, database servers, security architecture and management, virtualization solutions, automation and analytics, data center and Webhosting, remote infrastructure services, among others. Some of these services are out of reach, especially during power outages and occurrences of power interruptions. The hybrid system is such that a common DC bus connects all the energy sources of wind, solar, and battery together. The PV array is connected to the charge controller to limit the output for battery charging. The battery is a bidirectional power flow that can be charged from the DC line and supply power. The DC output from the wind turbine is connected to the general bus. The bidirectional inverter reverses the DC to AC for load use in the IT laboratory of the Alex Ekwueme Federal University, Ebonyi State, Nigeria.

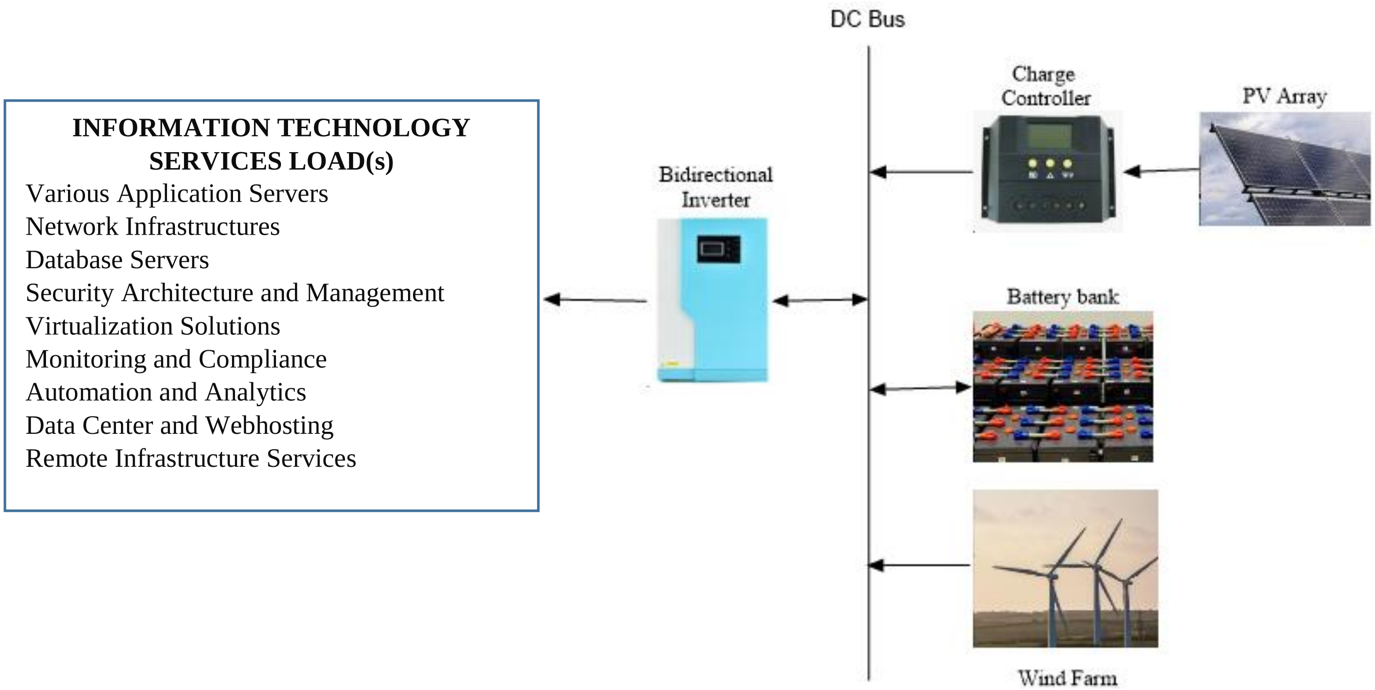

Figure 3.1: Overall Hybrid System for IT Services

Four (4) solar panels with individual outputs of 60W, 70W, 90W, and 90W making an overall output power of 310W was connected to power the 300W IT load. It is important to note that the combined area of small solar panels will produce the same output power if a single solar panel is used. However, for reduced cost, multiple solar units are connected in series. Because of this, it is necessary to connect the negative terminal of one solar panel to the positive terminal of the second solar panel. Since the voltage is cumulative in series connections, the ampere stays constant.

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The connections to the controller for the wind turbine and the negative and positive terminals for each group will remain the same as they were in the previous step. The solar panel size varies in each approach, despite the fact that the wind turbines in both cases have the same structure and dimensions. The associated components smoothed and decreased the voltage to a maximum output value of 14V, while the controller was designed to handle high input voltages from both sources. The components of the hybrid controller included a bridge rectifier to guarantee that all voltage was 100 percent direct current (DC), a capacitor to store energy in the form of an electrostatic field, similar to a small rechargeable battery, a resistor with an electrical resistance used in an electric circuit for operation, protection, or current control, and a diode to allow electric current to flow in only one direction.

4.0 Results and Discussion

The wind turbine and large solar panel each produce 24.9 W and 33 W of power, respectively. As was already established, the hybrid controller has every component from both systems in a single unit. The experimental setup is shown in Figure 4.1. The experiment took one day to complete for one run, and it was then performed four more times to gather five sets of data from which the average was calculated. This is being done to ensure that there aren't any significant changes in the data caused by changing weather and system changes. In order to measure the current and voltage, a multimeter is also used; it is linked to the battery in parallel for measuring the voltage and in series for measuring the current.

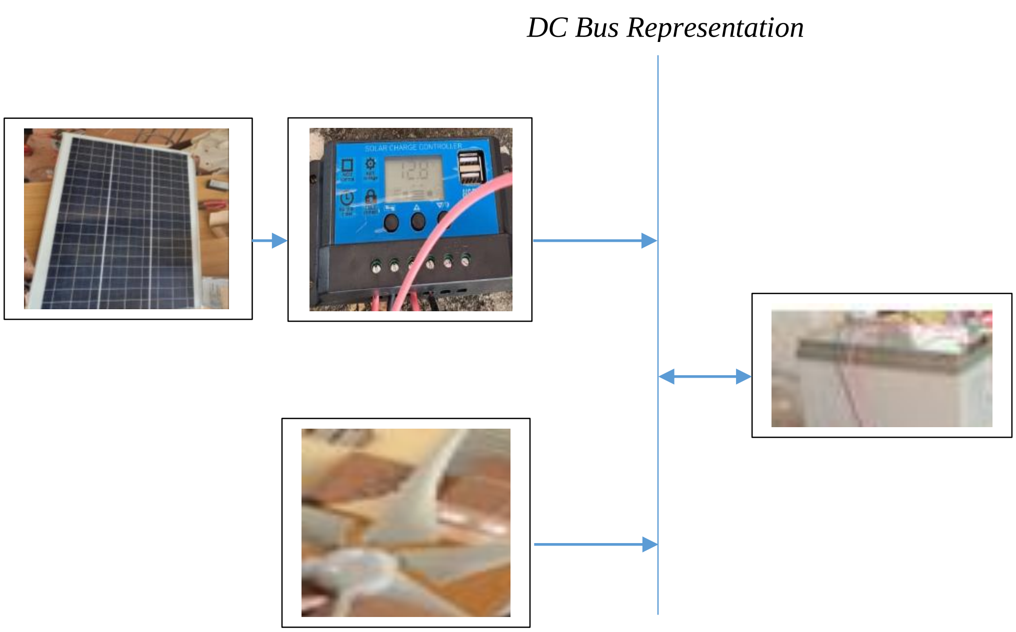

Figure 4.1: *Experimental Setup*

Averaging 30°C and 2.53 m/s of wind speed during the testing period. There are instances when there is no wind and the wind turbine cannot produce any power. But the solar panels kept their output power steady throughout the testing day. The output of the huge solar panel was 16.9 W at the least and 24.3 W at the highest. It was found from the testing

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of separate systems that the wind turbine did not consistently deliver an energy supply on testing days. When there is no wind, the wind turbine doesn't generate any power. In addition, the bigger solar panel generated more power than the smaller ones. This is due to the type of connection utilized to combine the tiny solar panels, which affects the voltage and current the solar panel generates following the first base-line analysis of the individual systems. Testing is done on the hybrid system. The initial hybrid system consisted of a wind turbine coupled with a sizable solar panel. Six miniature solar panels are coupled to a wind turbine in the second hybrid setup. Six days and five hours and a half, from 10:00 AM to 3:30 PM, are allotted for testing the separate systems. Each thirty minutes, the readings are recorded. After being tested separately, the hybrid system which combines solar panels and a wind turbine—has undergone additional testing. There are two main kinds of hybrid systems: one combines a wind turbine with a big solar panel (Hybrid System 1), and the other combines a wind turbine with six little solar panels wired in series (Hybrid System 2).

The testing window, which runs from 10:00 AM to 3:30 PM for each system, is the same as that window for the individual systems (five and a half hours). By doing so, the distinctions between hybrid and individual systems will be made clear. The wind turbine and huge solar panel were put to the test initially. The temperature was 31°C with an average wind speed of 4.89 m/s. The weather was sunny and clear. The hybrid system produced electricity from 19 W to 46 W, with an average of 39.11W. The comparison of the individual system against the hybrid experimental setup are depicted in tables 1, 2 and 3 showing the increment in output power. The hybrid system is compared to the separate systems with the most equivalent weather. It demonstrates that the power output significantly increased with a hybrid system. The large solar panel, however, produces more power than the little solar panel. In addition, the hybrid system's power output is continuous in contrast to the individual system, where the wind turbine's power is zero when there is no wind.

Table 4.1: *Solar Charge Measured Values*

S/N	SOLAR CHARGE	
1	PEAK PERIOD (Before Load)	12.67V
2	PEAK PERIOD (On-Load)	12.02V
3	OFF-PEAK PERIOD (Before Load)	12.47V
4	OFF-PEAK PERIOD (On-Load)	11.61V

Table 4.2: *Wind Charge Measured Values*

S/N	WIND CHARGE	
1	PEAK PERIOD (Before Load)	12.53V
2	PEAK PERIOD (On-Load)	11.90V
3	OFF-PEAK PERIOD (Before Load)	12.48V
4	OFF-PEAK PERIOD (On-Load)	11.87V

Table 4.3: *Hybrid Charge Measured Values*

S/N	HYBRID CHARGE	
1	PEAK PERIOD (Before Load)	12.78V
2	PEAK PERIOD (On-Load)	12.09V
3	OFF-PEAK PERIOD (Before Load)	12.57V
4	OFF-PEAK PERIOD (On-Load)	11.95V

5.0 Conclusion

The research investigated the performance implementation of an efficient hybrid solar-wind-battery energy system against independent solar and wind energy systems that can provide clean back-up power supply to information technology infrastructures in the IT laboratory of Alex Ekwueme Federal University, Ebonyi State, Nigeria. The result indicated that the developed system performs better than an independent solar or wind energy system in terms of voltage regulation and efficiency. The hybrid system's output produces more power than a single power installation system as it closes the energy supply gap due to insufficient solar irradiation or inadequate wind speeds. Summarily, this work revealed that; a hybrid energy system helps to ensure critical IT loads are kept on even during power outage during the hours when a single power source fails. This further enhances service reliability and environmentally friendly energy sources. Other key takeaways from the work are lower cost compared to the other power generation systems in use for same application, easier setup since no programming is required, and better efficiency as against independent solar PV or wind energy generator. Finally, it has been established that the uniqueness of this work is the application of hybrid solar and wind power system as an efficient standby power source for critical IT loads and infrastructure since the output power of the hybrid system is much higher in comparison with the individual solar and wind energy systems. Since the study considered the Load for 300W, in the future, the hybrid system capacity can be scaled up to power more IT Infrastructure, in addition, an algorithm that will automatically distribute energy across different IT services can be developed to priotize more critical servers for power supply stability and efficiency.

6.0 **ACKNOWLEDGMENT**

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Food Security in Nigeria: Enhancing Workers' Productivity in Precision Agriculture

Omoseni Oyindamola, ADEPOJU (Phd)
Lead City University Ibadan, omoseni.adepoju@lcu.edu.ng
Oluwadamilola ESAN
Federal University of Technology Akure
Oluwarotimi AKINYOMI
University of Johannesburg, South Africa

Abstract: Food security has gained international attention in recent years and Nigeria, with its abundant human and natural resources, is not exempted from this, as improving food security requires a strong focus on agricultural development. Innovations like precision agriculture tools and other advancements in modern agriculture provide farmers worldwide with the tools and expertise to improve workers' productivity in the agricultural sector and combat food insecurity. This paper examined the state of food security in Nigeria and how precision agriculture enhances workers' productivity in Nigeria. The study adopted a systematic review of relevant literature on the various issues addressed in the research. The paper revealed that there is a high level of food insecurity in Nigeria, with estimates of more than 65% of the Nigerian population being food insecure, and the average productivity of Nigerian farmers is several times lower compared to farmers in a developed economy. The study revealed that precision agriculture boosts workers' productivity by utilizing cutting-edge sensor and analysis techniques, increasing agricultural yields, and assisting management decisions which boost output, shorten labor hours, and guarantee efficient control of irrigation and fertilizer systems. Therefore, the paper recommends that Nigeria's farming sector incorporate precision agriculture equipment and technology, including drones, remote sensing, and artificial intelligence tools. Additionally, workers must be trained to use these innovative instruments and procedures to boost worker productivity and improve food security.

Keywords: Food security, workers' productivity, precision agriculture

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1.0 Introduction

Globally, food security remains one of the essential considerations as all hands are on deck on how to feed the ever-increasing population of more than seven billion people in the world. The 2019 statistics revealed that more than 690 million people worldwide were being affected by hunger [9]. The African nations are not left out in this struggle for food security as most nations are characterized by increasing populations with high levels of poverty, the prevalence of conflicts and terrorism, extreme corruption, unfavorable climatic conditions that affect food production, as well as low-level human capital [16, 9]. According to Abraham's Maslow hierarchy of needs theory, food is classified as a basic physiological need required for the survival of all humans. Hence, food security has become a basic human need, and ensuring food security is a pivotal task for every nation [27].

Several studies have adopted the FAO definition of Food security as "when all people, at all times, have physical and economic access to sufficient, safe, and nutritious food to meet their dietary needs and food preferences for an active and healthy life" [19, 26, 49]. The first experience of food insecurity came after the First World War when countries experienced hunger, starvation, and malnutrition as a result of unemployment, diseases, poverty, and a consequence of war, a situation that was combatted with increased food production leading to greater food availability. Countries experienced improved quality of life and better feeding conditions until 2015, when the global population geometrically increased and the number of people living with hunger began to escalate. This led to the establishment of the Food and Agricultural Organization, the use of precision agriculture, and the creation of Sustainable Development Goals-SDGs [9, 26, 27].

The concept of food security is hinged on variables: availability, accessibility, utilization, and sustainability, which are closely related but independent [20]. Food availability emphasizes that adequate quantities and appropriate food quality should be available, while accessibility focuses on physical and economic access to sufficient food. Utilization relates to the security aspect of food safety, how food is utilized in the body, and the risks involved, among other factors, while food stability relates to a time-bound aspect of food availability, access, and utilization. These variables are accepted globally as the dimensions of food security [9]. However, it is essential to note that the attainment of one of these dimensions does not assure the accomplishment of another, but the overall attainment of all dimensions is essential to achieve food security in a nation [20].

Agricultural productivity is the increase in an economy's output of agricultural goods per capita over a specific period [8]. All production elements, including labor, capital, farming expertise, water availability, management, and other biological components, are included in agricultural productivity [8]. Agriculture made up 22.35 percent of the overall Gross Domestic Product between January and March 2021, and Over 70% of Nigerians work in agriculture, primarily for subsistence [19]. Despite its importance to the economy, Nigeria's agricultural industry productivity is ranked low, and suffers numerous difficulties that impact its productivity. Nigerian agriculture relies heavily on rainfall, which is characterized by low productivity, little technological advancement, and high labor intensity. The minimal use of fertilizer, the decline in soil fertility, and the usage of traditional, low-tech rain-fed farming practices have all been blamed for the low agricultural production. Research has shown that Nigerian farmers are below their production boundaries in all regions, meaning there is room to boost agricultural productivity.

Precision Agriculture, also known as precision farming or smart farming is a merger of the fourth industrial revolution(4IR) tools and technologies such as artificial intelligence, global navigation satellite systems (GNSS), robotics, geographic information systems (GISs), use of ICT tools, remote sensing, data analytics and other new technologies with Agriculture and farming enterprise to achieve enhanced productivity [31]. The International Society for Precision Agriculture (ISPA) defined Precision agriculture as a management approach that gathers, processes, and analyses temporal, spatial, and individual data on farms and in agriculture and combines it with other information, tools,

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and technologies to support management decisions according to estimated variability for improved resource use efficiency, productivity, quality, profitability and sustainability of agricultural production [24]. The adoption of precision agriculture entails monitoring and analyzing data and information associated with soil, animals, crops, weather, pest or diseases, and hydration conditions of farms to make precise and predictive farming decisions, an approach that is said to increase food production and combat food insecurity by 50% in 2035 [39].

According to the 2020 Global Report on Food Crises, a survey of 55 countries in the world revealed that over 135 million persons were suffering from severe food insecurity, with Africa accounting for more than 73 million of this figure in 36 countries. The global food insecurity level is anticipated to rise to 841.4 million (9.8%) in which African countries will have 433.2 million people (51.5%) living with undernourishment by 2030 [48]. Research has revealed that Nigeria is one of the countries in the developing nations that is highly affected by food insecurity [27] and was ranked by the Global food security index in 2019 as the 94th nation among 113 countries experiencing high food insecurity [9]. Furthermore, in May 2018, Nigeria was ranked the nation with the highest population living in poverty and food insecurity. Research revealed that more than 102.4 million inhabitants of the nation were living below $1.90 per day. A situation that made Nigeria overtake India as the World Poverty capital [9]. This high level of severe food insecurity in Nigeria can be attributed to chronic and hidden hunger, extreme poverty, Food crises, corruption, herders - farmers' conflicts events, insurgency in the North East, and unfavorable climate change, among other factors.

Many Sub-Saharan countries, including Nigeria, depend on weather conditions for agricultural production through adequate rainfall, appropriate sun energy for crop germination, and preservation of the ecosystem [45]. However, the adverse climatic change attributed to the depletion of the ozone layer and several other factors have impacted agricultural production through inconsistency observed in the intensity and regularity of rainfall, the occurrence of famines, floods, changes in soil moisture and nutrient, soil deprivation, increase in pests and diseases of livestock and crops, heat stress, desertification, increase in sea level. All these factors have affected crop and livestock production, fish farming, and hunting in Nigeria and consequently negatively impact on food security [6]. However, Studies have revealed that the implementation of precision agriculture can increase productivity, improve the allocation of inputs resources such as seedlings, pesticides, water fertilizers, feed, and labour allocation to ensure more sustainable production, and reduce environmental effects on agricultural production [18].

Insurgency, which was first recorded in Nigeria in 2009 has become a national menace that continues to threaten food security in the country. According to the results of a survey conducted in 2019, agricultural activities in Nigeria were more widespread in North than in South with the north east accounting for 83.6% of crop production in the country. The rise in the insurgency, mostly in the northern part of Nigeria has continued to plunge the population into severe food security challenges as the incidence of diseases and deaths, displacements from shelter and farmland, destruction of agricultural produce, unemployment, violation of human rights had continued to increase rapidly [29]. Insecurity, as instituted by the Boko Haram sects in the North Eastern part of Nigeria, has given rise to conflicts amongst religious sects and farmer-herders and has caused many people to abandon their farmland and farming activities for safety. This continuous violence has led to food scarcity, high cost of foodstuff, unemployment, destruction of property, market closure, and security checkpoints, all of which have further worsened food insecurity in the region [34]. Adopting remote sensing, ICT, and geographic information systems (GIS), aerial drones in precision agriculture have been revealed to help reduce the overall cost of production, limit exposure of farmers to insecurity as well as improve production process control, thereby increasing quality and value of production [62].

The industrial revolution, which brought about farm mechanization, was asserted to have led to a paradigm shift in food security, however, Precision agriculture and information technology have the capacity to improve production efficiency and stability, which in turn positively impacts food security [18]. The adoption of Precision Agriculture-based practices has been researched to give rise to enhanced and more precise management of farming activities and operations which will result in inclusive growth in the productivity of farms and positively impact profitability. This will in turn create incentives for more investments in the farming systems, leading to an increase in crop outputs and consequently reducing food deficits [36]. Zakka et al., [62] highlighted the numerous benefits of precision agriculture as efficient use of production inputs, increased size and scope of farming operations with no additional labour cost, improved site selection, improve record keeping techniques, and trackability of product for food security and environmental benefits as well as reduction of probable pollution due to the inefficient or ineffective application of input.

Several studies have been carried out on the challenge of food security in Nigeria as well as the role of precision agriculture in combating Food security [3, 28, 30, 41, 44, 47, 55]. However, there is a dearth of research that has established the state of Precision Agriculture in Nigeria, the level of adoption of its tools and technologies, and how workers' productivity can be enhanced through precision agriculture towards food security in Nigeria. This study attempts to examine the state of food security in Nigeria and how precision agriculture enhances workers' productivity through precision Agriculture in Nigeria. The following objectives are to guide the study:

(i) to examine the extent to which food security is achieved in Nigeria

(ii) to assess the level of workers’ productivity in Nigeria’s Agricultural Sector

(iii) to examine the extent at which precision agriculture is adopted in Nigeria’s Agricultural Sector

(iv) to evaluate the extent at which food security can be achieved in Nigeria through precision Agriculture

2.0 Review of Related Literature

2.1 Food Security

The concept of food security simply denotes the availability and accessibility of food. Food in this context is referred to as any substance that people consume and drink to sustain life and growth. The United Nations Committee on World Food Security defined food security to mean that all people have physical, social, and economic access to sufficient, safe, and nutritious food that meets their food preferences and dietary needs for an active and healthy life at all times [21]. It also implies that a population or group has consistent access to adequate, decent, healthy, and culturally appropriate food.

Food insecurity has become an emergent public concern that continues to pose several adverse risks to the mental and physical health of the global population as well as negatively impact productivity, hence it has become imperative for so many nations to find novel solutions to this menace capable of hampering the sustainability and development of any economy [58]. According to the FSIN [21], the rate of food insecurity and malnutrition increased alarmingly in 2021, a record that has surpassed previous years. Statistics revealed that nearly 193 million people in the world are extremely food insecure, with insecurity and conflict ranked high as the major causes of the increased food insecurity [19]. From this report. It was revealed that the food insecurity level in Sweden increased from 4.5% to 5.8% in 2019 and has continued to increase steadily. Factors responsible for this insecurity include varying climatic conditions, the growing price of food, the increasing global population, and environmental stressors [19].
Most African countries are faced with an unprecedented rate of malnutrition, malnourishment, famine, and starvation, all symptoms of food insecurity. This food insecurity has been ascribed to a combination of reasons, including adverse weather patterns and climatic change, protracted droughts, political-economic challenges, conflicts, and wars, amongst others [37]. Literatures reviewed stated that Sub-Saharan Africa, including Nigeria is more susceptible to the impacts of climate change and inconsistency than many developing regions. Changes in climate conditions have been asserted

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to affect the dimensions of food security, i.e. availability, accessibility, and utilization, and this can be attributed to the country's heavy reliance on rainfall, high inconsistency of production, low institutional capacity to adapt, poor and small producers, recurring food scarcities and net traders, and delicate farming environments [63].

2.2 Precision Agriculture

Precision agriculture via the set of information technologies allows the water and soil factors required for agriculture production are managed effectively. Remote sensors have been asserted to be the most adopted technology in precision agriculture to enhance productivity. Precision agriculture has been investigated in wheat, corn, and sugarcane production to increase yield and productivity. Considering the constant increase in population and the need to feed this ever-teeming population, there is an inevitable need to enhance agricultural productivity. In light of this, the transformation of the agricultural sector becomes imperative. The use of fourth industrial revolution technologies is asserted to be able to combat the many restraints that are liable for the low production in the agricultural sector [23].

The use of drones in precision agriculture is helpful in soil and drainage analysis, animal and crop health monitoring, application of pesticides and fertilizer spraying, and yield prediction. The incorporation of Artificial Intelligence (AI) into agriculture is also useful in real-time data analysis which has been proven to have positively improved farm productivity through mapping spatial variability in the field [23]. Precision agriculture (PA) is referred to as engaging current methodologies, tools, and technologies such as artificial intelligence and image processing into Livestock farming, Pest and disease management, crop management, soil and irrigation Management, and the challenges of a conservative farming system. The use of precision agriculture has been proven highly efficient, improves productivity, and is viable and cost-effective to the farmer, enhancing the economy and alleviating food insecurity [13].

A study conducted on the drivers of precision Agriculture revealed that the size of the farm, total income of the farm in terms of perceived decrease in the cost of production or expected increase in revenue, land tenure, level of education of farmers, acquaintance, and access to computers and ICT tools, access to information through private or public service providers & extension services are factors that affect the adoption of precision agriculture [17]. Bucci et al., [11], in a study examining the state of precision agriculture as a driver for sustainable farming systems, asserted that adopting precision agriculture would help the agricultural sector develop and provide sustainable resolutions and solutions to existing and impending global challenges. He opined that precision agriculture would aid in ensuring the safe and sustainable provision of quality food, develop the global economy, combat climate change, enhance resource efficiency and eradicate food insecurity [11].

Wolfert et al., [61] asserted that the incorporation of wireless and remote sensors, as well as the development of agricultural mobile apps and cloud platforms, will enhance the collection of essential data and information relating to factors that affect production such as rainfall temperature, wind speed, humidity, disease, and pest invasion, soil moisture content, soil composition, and nutrients and also assist in the automation of the farming system. Furthermore, the implementation of precision agriculture technologies such as robots, Big Data, and the Internet of Things (IoT) can lead to a more sustainable, productive, and ecologically viable farming system and food production. Precision Agricultural systems can support farmers in effective decision-making regarding quality and quantity of production, develop efficient processes and management procedures, mitigate risks, and limit wastes [61]. Also, the integration of wireless sensors with agricultural mobile apps and cloud platforms helps in collecting vital information pertaining to the environmental conditions (temperature, rainfall, humidity, wind speed, pest infestation, soil humus content or nutrients), besides others, linked with farmland, can be used to improve and automate farming, techniques, take informed decisions to improve quality and quantity and minimize risks and wastes. For instance, adopting modern farming technologies, including those based on robots, the Internet of Things (IoT), and Big Data, has great potential to lead to more productive, sustainable, and environmentally responsible food production. Smart farming systems can help farmers improve decision-making and develop more efficient operations and management.

2.3 The Role of ICT on Workers' Productivity in Agriculture

Productivity is a measure of the effectiveness and efficiency of production. It is also defined as the appropriate application of tools and resources to produce goods and services [32]. Information Communication Technology has been accredited as a structure necessary for any enterprise to minimize cost, align with global technological trends, and increase profitability. Considering the current global situation of increased population and productivity gap, it has become highly imperative to increase agricultural productivity through extensive agriculture. This increased productivity can only be achieved through ICT [4].

Ali et al., [4] revealed that ICT positively impacted agricultural productivity. The study also asserted that employing information communication technology (ICT) in production activities enhanced and increased workers' productivity [4]. The implementation of ICTs into agriculture provides an exceptional prospect of bringing production-enhancing tools and technologies to farming in a cost-effective approach. A lot has been done in assessing the impact of ICT on Agriculture, only a few studies have been carried out to assess the impact of ICT on workers' productivity in the agricultural sector, hence this study.

3.0 Methodology

This paper utilized qualitative research methodology through collecting and analyzing empirical literature and non-numerical data to contextualize opinions, understand the experience, and juxtapose concepts which helps a researcher to gather in-depth insights into a problem for the generation of new ideas [12]. Therefore, the study critically analyzed relevant research journals, articles, publications, opinions, and editorials. They were all reviewed logically, strategically, and structurally in accordance with the study's objectives of examining the state of food security in Nigeria and how precision agriculture enhances workers' productivity through precision Agriculture in Nigeria.

4.0 Result and Discussion

4.1 The extent of food security in Nigeria

It has been recognized that food availability remained a fundamental component of comprehending what food security meant, and that food availability was not a sufficient condition for access to food at the household level [25]. The most widely accepted definition of "food security" is the one posited by FAO, which evolved after the 1996 World Food Summit, which states that "food security exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" [19].

It can also be simply put that food security is the condition in which all have access to sufficient food to live healthy and productive lives. In addition, Food and Agriculture Organization (FAO) identified it as a world without hunger, where social safety nets ensure that those who lack resources still get enough to eat [19]. This implied that food security critically depends more on socio-climatic conditions and access to food rather than food production or physical availability.

Four key variables have been widely accepted as the major dimensions of food security (i.e. food availability, access, utilization, and stability) [25]. Food sufficiency focuses on the availability and adequate quantities of food of appropriate quality; physical and economic access focuses on individuals' access to sufficient food; the security aspect relates to food utilization by the body, food safety, and risks involved among other factors while food stability relates to time-bound aspect of food availability, access, and utilization [25].

On the other hand, food insecurity may be referred to as the absence of one or more of these components. Nigeria's ranking in the Global Food Security Index (GFSI) has continued to increase since 2013 (ranked 86 among 107 countries with 33/100 score) and reached a disturbing rank of 94 (with 48.4/100 score) among 113 countries behind Ethiopia, Niger and Cameroon in 2019 GFSI overall ranking table (the closer to 100 score the better) [16]. According to World Data Lab, Nigeria has an estimated population of 205,323,520 persons and 102,407,327 people living in extreme poverty (50% of the total population). Even though, International Fund for Agricultural Development (IFAD) rated Nigeria the highest producer of cassava, yam, and cowpea globally in 2012 and currently the highest producer of cassava and yam globally, the country still persistently remained food insecure and heavily import-dependent.

Agriculture has remained an important aspect of any economy. Viable agricultural programmes and activities in any polity are capable of sustaining the food supply and reserves needed for the welfare of the citizens. But in Nigeria, agriculture is despised as able-bodied young people do not have an interest in Agriculture. Climate change and clashes between herdsmen and farmers and the activities of Boko Haram sect have added to food insecurity challenges in the polity as population displacement, death, and non-cultivation of farmlands and the burning down of farm produce have reduced the quality and quantity of food demand. From Benue to Taraba, Nasarawa and Plateau in the North Central region and Zamfara and Kaduna States in the North West, clashes between farmers and herdsmen have left in its trail heavy losses of lives and property. These losses of lives have adversely affected farming activities and other related businesses. This has resulted in a drastic reduction in farm outputs, a development that has heightened the fear of hunger. Already most farmers in the affected states have abandoned farms for fear of being attacked by the herdsmen.

For the predominantly farming communities of Benue and border communities of Nasarawa and Taraba states, farming is no longer business as usual. The effects of the sustained Fulani war in the affected localities have led to farmers' reluctance to go back to their farms even as the current farming season is far gone. In Benue state, for example, women from Guma and Gwer west local governments have stayed away from farms for fear of being killed or raped by the marauders.

Agricultural and development experts are unanimous in their predictions that the gains recorded in the agricultural sector of the economy, especially in food production, may suffer a serious setback due to the negative effects of terrorist activities on farmers in Benue and neighbouring states. Already, seven out of the 23 local governments in Benue state, namely Guma, Gwer-West, Agatu, Logo, Kwande and the Northern part of Makurdi mostly affected by the rampaging herdsmen have tale of woes to tell.

As a result of the growing fears of insecurity over the past in the country prices of essential commodities and food products have skyrocketed making them unaffordable to the common man, caused by well-meaning but seemingly impractical policies of the federal government in these segments. For instance, prices of rice have been hitting historic highs of N42,500 per bag, triggering panic among the people across the country. Persistent increase in prices of other staple products such as fish, bread, meat, cereals, chicken, yam, onions, beans, vegetable oil, tomatoes, groundnut oil, and others have aggravated the continued woes of the common man. Shortage of products and ever-increasing prices has created unsettling sentiments across communities, dampening the country's efforts to end poverty. There are estimates that more than 65 percent of the Nigerian population is food insecure.

4.2 Level of Workers' Productivity in Nigeria's Agricultural Sector

Productivity, in its broad sense, is a measure of how efficient and effective resources are used as inputs to produce products and services needed by society in the long run. It is the rate of flow of output when compared with the flow of resources used to produce the output of goods and services. In financial terms, productivity is the value of output divided by the cost of inputs used in a given period. Labour productivity is essentially output per worker employed in a given enterprise. Thus, agricultural labour productivity is commonly measured as gross value added in agriculture (agricultural GDP) divided by the economically active population in agriculture.

Productivity is the production of goods and services in abundance or applying the factors of production to create favourable output/result [51]. Productivity is the total output/total input; that is the relationship between unit of labour input and unit of output. It is the output resulting from a given resource at a given time. It is the ratio of output to input. But output can be compared with various kinds of inputs: hours worked the total of labour and capital inputs, or something in between.

In the economic terms, it means the efficient and effective creation of goods and services to produce wealth or value. Productivity is usually associated with efficiency, which is defined as "a ratio between input and output, effort and result, expenditure and income, cost and the resulting pleasure" [54] Whereas, efficiency seeing to be synonymous with effectiveness, it (effectiveness) is generally referred to as achievement of high output/result based on the policy goal at minimal cost. There is a direct relationship between individual resource productivity and nation building because each worker or farmer's productivity leads to improvement in investors' earnings, more financial capital for management, and more revenue for the government. Since waged agricultural workers make up such a significant segment of the rural workforce, workers and their trade unions need to be recognized as playing a vital role in sustainable agriculture and rural development, industrial change, and protecting the environment.

If output per farm worker or per man hour expended in producing a given amount of output is calculated, substantial differences in productivity exist among individual countries. Average productivity of a farmer from a developed economy is several times higher than that of his compeers in Nigeria. This difference is traceable largely to technical factors, with the use of a tractor a farmer could plough almost 100 hectares a day as against about 2 or 3 hectares in Nigeria, where the farmer spends the whole day behind the plough drawn by a pair of bullocks or using cutlasses and hoes. In 2019, Nigeria's agriculture value added per worker was 5,591 US dollars. Agriculture value added per worker of Nigeria increased from 1,569 US dollars in 2000 to 5,591 US dollars in 2019 growing at an average annual rate of 7.43%.

4.3 Extent of precision agriculture adopted in Nigeria Agricultural Sector

Since the country's independence, agriculture has been crucial to Nigeria's growth, contributing to both the nation's food security and its ability to generate income. The average Nigerian needs to work in this industry because 70% of the country's people depend on it. Nigeria still imports most of its food crops, making it insufficient in terms of agriculture. Many Nigerian governments have implemented various farming programs and policies to enhance agricultural production to accommodate the rising demand from the population and agro-businesses [46].

These programs and policies are related to the subpar farming practices used, the absence of necessary farming inputs such as fertilizer, herbicides, improved seeds, irrigation crop protection, and the support required from the many agricultural schemes [57]. The development of industries and urbanization has greatly diminished farmland and farming resources. The agricultural sector's productivity, sustainability, and profitability have recently become challenges due to population growth and a lack of agrarian support resources. Currently,

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Nigeria is considered one of Africa's least productive producers of grain crops, including rice, maize, sorghum, etc. As a result, using the traditional agricultural method and implementing technology both need to be improved [28].

However, the quest of the Federal and some State governments into the development of large scale agriculture and mechanized farming in order to shore up food security and foreign exchange earnings, there is need for adoption of uses of technologies of Precision Agriculture, which offer a wide range of applications in order to effectively harness human, natural and man-made resources for sustainable agricultural production and improved crop yields in Nigeria.

Precision agriculture is a form of agricultural mechanization that heavily relies on electronics, information technology, and communications. It also necessitates technical expertise and labor for the creation of site- and animal-specific plants and animals, respectively [4, 9]. In affluent nations like the State of Israel, the United States of America, Canada, and Western Europe, the concept of precision agriculture emerged several decades ago [25]. This has evolved over the past three decades, becoming more sophisticated and moving away from other developing nations, including Nigeria [28].

Precision Agriculture is not widely used in emerging and underdeveloped nations due to numerous obstacles [52]. These difficulties are caused by a number of issues, including the lack of essential technologies, a shortage of electricity, a lack of water, the techniques used to allocate land to farmers, and governmental policies [34]. With all these difficulties, the development of modern agricultural technologies becomes all but impossible. Nigeria, one of the emerging nations, has not yet begun using precision agriculture [28].

4.4 Extent of food security achieved through precision Agriculture in Nigeria

For researchers, the sustainability of the many resources involved and the availability of food and other agricultural products in sufficient supply and quality under environmentally safe conditions are of utmost importance [22]. Precision agriculture emerged in the 1990s as a scientifically driven way to enhance industrialized agriculture, despite being long performed intuitively by subsistence farmers [60]. It promised advantages for farmers and society by boosting production effectiveness and enhancing environmental stewardship [54].

However, when oil was discovered in Nigeria in 1956, the country's agriculture industry started to decline. Interest in agriculture starts to decline in 1958, when exports of petroleum products begin. The effect of the loss is gradual but constant, and food prices, especially those of staple goods, are rising. For instance, since 2006, the cost of rice has climbed considerably by more than 100%. According to the Minister of Agriculture and Water Resources of Nigeria, less than half of the 2.5 million metric tons of rice needed to maintain Nigeria each year are actually produced. These numbers suggest Nigeria has a 2-million-ton rice shortage, necessitating imports to satisfy the annual demand [43].

Despite the engagement of about 70% of Nigerians in the agricultural sector, crop production has not been sufficient enough to fulfil demand so the import policy is fully implemented. This is due to the utilization of conventional farming techniques that are geared towards giving equal treatment to crop fields. In order to ensure food security and raise the level of life in Nigeria, crop production efficiency must be increased through precision agriculture [2]. Precision farming will enable the targeted use of agricultural inputs to particular fields, maximizing their use. Additionally, waste of those inputs will be avoided, lowering agricultural costs and preventing environmental contamination. In general, yield will increase and farmers will reap greater financial rewards. The agriculture sector in Nigeria will greatly benefit from the adoption of precision farming. Now that Nigeria has entered the orbit of space technology and remote sensing, it is crucial for the country to follow global technological trends and take full advantage of the advantages they present in order to transform its agriculture from a low-tech level to a high-tech level of precision farming [5].

It is estimated that 30 million people faced food insecurity in semi-arid West African countries in 2017, and 4.7 million children under are acutely malnourished [42]. The poverty rate in these countries is above the average for sub-Saharan Africa as a whole. Self-sufficiency in cereals is currently about 80% in the dry lands of West Africa; it has been predicted to be below 40% in 2050 on an extrapolation of yield trends [59].
A recent study on food demand confirms the need for a rapid increase in food production in West African dryland countries [64]. Therefore, it is important to develop farming practices that increase yields, make efficient use of resources, and reduce farmers' risks. Precision farming, as described, fits well within the paradigm of "sustainable intensification", an approach that focuses on producing more food with less environmental impact [56]. It can furthermore be considered as a form of "Climate Smart Agriculture" [19] as precision farming can increase yields, adapt agriculture to climate change, and reduce GHG emissions from farming through more efficient use of inputs.

4.5 Worker's Productivity in Precision Agriculture

In order to quantify the term "workers/labor productivity," labor costs must be compared to the entire efficiency of labor, which is typically represented by the volume of goods produced. The phrase is occasionally used in literature to convey labor productivity and other times to express the overall profitability of the production variables and coefficients. Productivity is a term used to describe production processes more broadly and is quantified as the quantity of items produced (output) divided by the units of the production coefficients used (input) [51].
However, farmers in West Africa's semi-arid regions confront difficulties due to poor crop establishment, erratic rainfall, low soil fertility, and a labor scarcity during periods of high demand. Farmers typically lack resources, though. Given these circumstances, it's critical to create farming techniques that effectively utilize the resources at hand and minimize hazards [7].
Utilizing cutting-edge sensor and analysis techniques, precision agriculture is the science of increasing agricultural yields and assisting management decisions. It is a novel idea that has been widely used in order to boost output, shorten labor hours, and guarantee efficient control of irrigation and fertilizer systems. It makes extensive use of data and information to increase crop yields, quality, and efficiency in the utilization of agricultural resources. In order to increase the productivity of resources on agricultural fields, precision agriculture is a cutting-edge innovation and field level management method. In order to increase productivity, quality, and output, farmers use this advanced technique, which involves providing optimum inputs like water and fertilizer [22].
High spatial resolution data about the crop condition or crop health during the growing season are essential. The most important goal of PA, regardless of the data source, is to assist farmers in running their businesses. Although there are many different forms of this help, the ultimate outcome is often a reduction in the resources required. Monitoring crop status through observations and measurements of factors like soil quality, plant health, the effectiveness of fertilizers and pesticides, irrigation, and crop yield is essential to modern agricultural operations. Crop growers and labor face a major task in controlling these variables. It's critical to quickly improve the accuracy of agricultural growth monitoring and crop production management in order to make wise use of farming resources [40]. These difficulties can be overcome by using remote sensing technologies, such as hyperspectral imaging, to create precise biophysical indicator maps across the many crop growth cycles.
The basic presumption of sustainable economic development of every branch of national economy and also of agriculture is an efficient use of basic production factors, I.e., labour, land, and capital. Labour activates and improve other production factors. However, the efficiency of labour use as a production factor is generally expressed by the level of labour productivity. On a more precise note, labour productivity is defined as the efficiency of human work utilized in the creation of useful goods. It is expressed by the amount of these goods per unit of the labour input [10]. However, labour productivity is influenced partly by the value of production and partly by the amount of consumed production factors [10].

5.0 Conclusion and Recommendation

Food security remains one of the essential areas of focus for sustaining an ever-increasing population in the world. This concept of food security is hinged on availability, accessibility, utilization, and sustainability. This paper shows the importance of enhancing workers' productivity in Precision Agriculture; it equally sheds light on Food Security and Precision Agriculture by examining the extent of food security in Nigeria, the level of workers' productivity in Nigeria's agricultural sector, Precision Agriculture adoption in Nigeria and its extent on food security.

This paper concludes that the high spatial resolution data that precision agriculture offers about crop condition or crop health during the growing season is essential and assist farmers in monitoring crop status through observations and measurements of factors like soil quality, plant health, the effectiveness of fertilizers and pesticides, irrigation, and crop yield, which ultimately promote modern agricultural operations. Also, precision agriculture boasts workers' productivity by utilizing cutting-edge sensor and analysis techniques, precision agriculture is the science of increasing agricultural yields and assisting management decisions which by so doing boost output, shorten labor hours, and guarantee efficient control of irrigation and fertilizer systems. Furthermore, the use of advanced technique offered by precision agriculture increase workers' productivity, quality, and output within a short time span.

Precision Agriculture offers huge potential for food security and provides an impetus to drive Nigeria's agriculture sector to an industrialized one, fully optimized to meet demands. However, since Precision Agriculture offers smart farming within the purview of the fourth industrial revolution (4IR) the paper, therefore, recommends that the use of precision agriculture tools and technologies such as drones, remote sensing, and artificial intelligence tools should be inculcated into Nigeria's farming system to increase workers' productivity and enhance food security. Also, workers need to be trained on adopting these smart tools and techniques for optimal benefit to the agricultural sector.

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