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88th INAUGURAL LECTURE

AGRICULTURAL MACHINERY ENGINEERING: KEY TOWARDS SUSTAINABLE NATIONAL FOOD SECURITY AND INDUSTRIAL DEVELOPMENT

by

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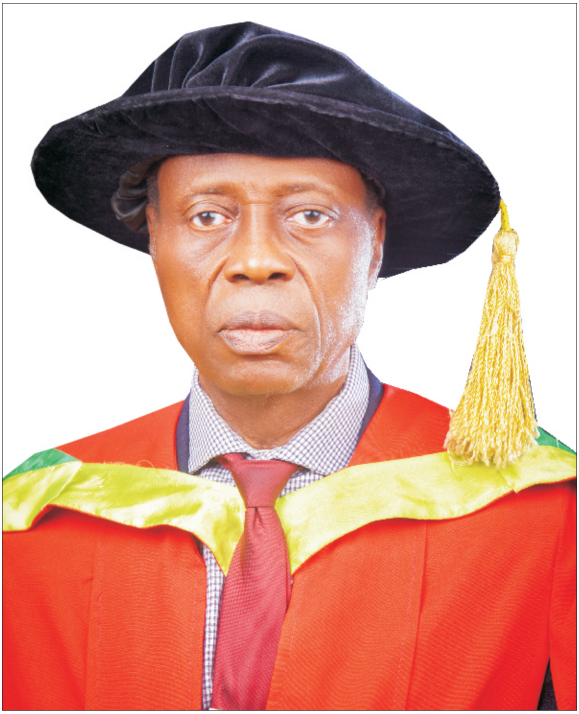

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I welcome you all to this inaugural lecture.

1.0 INTRODUCTION

This inaugural lecture is the 88th one in the University and the fourth in the Department of Agricultural and Bioresources Engineering, the first was delivered by Prof. B. A. Adewumi, the second was delivered by Prof. T. M. A. Olayanju, while the third was delivered by Prof. J. K. Adewumi.

Mr Vice Chancellor sir, out of my 43 years post-graduation working experience, 25 years was spent on the field outside the classroom while 4 years was spent at Federal University of Technology, Minna, Nigeria as Lecturer II and I got employed from 2009 as Lecturer I at FUNAAB till date. While on the field, I have worked as Soil Conservation Engineer, Irrigation Engineer, Land Development Engineer, Chief Consulting and Technical Engineer in various large-scale farms, with sizes ranging from 500 to 5,600 ha for sugarcane, maize, soybean, and rice production. Research is a concrete expression of concern with the ambient world by an individual or group of people desirous of making progress or a change for the better by systemically organizing quest for new knowledge, based on the scientific method. The ability and familiarity of working with different types of agricultural equipment gave me close range opportunities to identify which areas of research activities to concentrate my effort. This made it possible for me to concentrate my research attention on identified areas as soon as I got employed in this great University with various research teams at different stages of my career.
This inaugural lecture is titled AGRICULTURAL MACHINERY ENGINEERING: A KEY TOWARDS SUSTAINABLE NATIONAL FOOD SECURITY AND INDUSTRIAL DEVELOPMENT.

1.1 Food Security and Sustainable Development in a Nation

The general definition of sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. Sustainable

Development Goals 2 (SDG2) aims to "end hunger, achieve food security and improved nutrition, and promote sustainable agriculture" by 2030, as outlined by the (UN-GA, 2015). The aim is to ensure that everyone everywhere has enough good-quality food to live healthy life. This can be facilitated by better access to food and the widespread promotion of sustainable agriculture. It involves improving the productivity and incomes of small-scale farmers with good access to land, sound technology and markets, sustainable food production systems, and resilient agricultural practices. Through technology development and utilization in response to the diverse needs related to food systems, there will be a need to build a new food system to contribute to stable food production in the target area, international food supply and demand, resulting in food and nutrition security (JIRCAS, 2021).

Ahmedabad (2020) described food security and sustainable development in the agricultural sector as being subject to a wide range of economic policies, which also serve as important measures for the sector itself. Food security aspects under sustainable development can further be developed with gained experience in implementing it across a diversity of different nations and regions. The relationship between a nation's economic stability and agriculture is achieved through crucial food security factors such as: agricultural policies and productivity, sustainability outcomes, price volatility, public-private partnerships, and agricultural potential.

The hunger experienced in many people's homes is not solely due to a lack of food in the world but rather because food cannot be afforded or there are no means to produce it. The ultimate issue lies in access to food, its effective demand, and distribution within nations, households, and across genders. A high percentage of the world population produces food primarily for self-consumption.
A nation achieves food security and sustainable development when it has enough available food and agricultural nutrition products for

its inhabitants and livestock. There must be sufficient provision of these, even during times of human-induced disasters or political instability, or challenges posed by climate change and increasing scarcity of natural resources, which can result in food insecurity for a large percentage of the population of some nations (UN-GA, 2015). The difficulties of food security can be classified into two areas: quality and quantity, which have significant effects on the following aspects of food security (Ahmedabad, 2020): food availability, price volatility, population access to food availability, food utilization, and stability of food.

The ever-increasing and rapidly emerging food demand are creating huge opportunities for agricultural development, though it comes with its antecedent challenges for sustainability. Agricultural Engineering offers countries all over the world, some direct ways of solving the pressing problems of growing, processing, and distributing food. Agricultural Engineers are in the business of working to solve agricultural and environmental problems worldwide and reduce food insecurity.

1.2 Agricultural Engineering

Agricultural Engineering is as extensive as agriculture and as diversified as engineering.

Agricultural Engineering can be described as the application of engineering knowledge and techniques to agriculture. The basic differences between agriculture and other industries, which involve biological factors such as soil and plants, require that agricultural engineers have a solid understanding of the basic principles and practices in agriculture. Agricultural Engineering as a profession broadly offers some of the most direct ways of solving the pressing problems of growing, processing, and distributing food and fibre. Soil, water, and equipment are utilized to achieve the aforementioned goals through advanced engineering and technology, which are developed by leveraging a broad sweep of knowledge across various subjects.

Food production up to the farm gate depends upon the technology and management inputs, many of which are provided by the agricultural engineer. With modern techniques, one person can manage a herd of 80 cows or carry out all the operations to grow, harvest, and store the crops from 100 hectares of arable land. This is a trend gradually being repeated throughout the world, hence increasing the farmer's need for the knowledge and skills of the agricultural engineer.

Agricultural engineering offers prospects and opportunities for employment and career development because it is an integral part of the specialist groups of skills involved in maintaining and developing the food chain. Apart from working closely with farmers and other agricultural service providers, agricultural engineers also collaborate with food processors, biotechnologists, genetic engineers, and nutritionists.

The roles of agricultural engineers in the manufacturing industry sector include designing, developing, planning, and marketing new machinery and equipment for a wide range of farm uses. It involves conducting outdoor on-farm trials, demonstrations, and distributing equipment and technologies around the country. Additionally, agricultural engineers are involved in advisory and consultancy work. This is essential to curb mishandling and protect the high investments made in buildings and equipment by the farmer, which sometimes leads them to directly employ agricultural engineers. The civil engineering aspect of agricultural engineering training enables the implementation of dryland and desert irrigation, swamps draining, forest clearing, erosion control, and, most importantly, the planning of efficient and economic use of soil and water resources.

The agricultural engineer is an engineer who incorporates a biological dimension into their engineering practice. All these aspects can be summarized when critically examining and reevaluating the social and industrial needs. The future for agricultural engineers is very bright and cannot be disputed, as we all must eat to live.

1.2.1 Agricultural Engineering Basic Units

Agricultural engineering basically is divided into three units:

- Farm power and machinery engineering/machine design and manufacture and mechanization.
- Soil and water engineering/field engineering
- Crop processing and storage engineering/building and processing

Farm power and machinery engineering/machine design and manufacture and mechanization are concerned with achieving improvements in agricultural production through tractors, farm machinery and equipment design, development, and manufacture. This is possible through the integration of a wide range of engineering and agricultural skills, Biology, Economics, and Operational research, along with an understanding of the interaction between crops, soil, weather, machines, and humans. The emergence of new engineering technology presents a challenge for agricultural engineers to seek more effective applications of power on the land.

Soil and water engineering/field engineering is basically concerned with engineering and management of soil and water resources. These resources, along with solar energy, provide the essential elements for crop and animal production, highlighting the importance of soil and water conservation and their effective utilization. It requires sound knowledge of soil chemistry, soil physics and mechanics, hydraulics, hydrology, mathematical techniques, and the inter-relationships between soil, plants, and water. It requires land use planning and development with application of survey and assessment techniques covering aerial photography, remote sensing from satellites, surface exploration of soils and water supplies, and sub-surface investigation of geology and groundwater.

Crop processing and storage engineering/building and processing covers provision of appropriate environments for plants and animals considered at all stages of growth and development. The post-harvest treatment of crops features prominently in teaching and research, emphasizing a clear understanding of the principles of drying and storage structures and machines to minimize the losses of hard-won crops. Most cereals, after storage, undergo a series of processes such as shelling, hulling, cleaning, and milling, which are performed by machines ranging from hand or pedal-operated units to larger diesel engine or electrically motor-powered units. The areas of engineering and science relevant for this include the properties of materials, thermodynamics, fluid mechanics, flow processes, and crop environment/building structure engineering.

1.3 Farm Power and Machinery Engineering

Agricultural engineering encompasses farm power and machinery, food processing and crop storage, post-harvest handling, land, and water management (including irrigation and drainage systems, erosion control, pesticide/fertilizer use/management), farm electrification, and farm structures. Farm power and machinery engineering involves the application of engineering principles to agricultural mechanization, crop production, food processing, and the conservation of land and water resources.

1.3.1 Farm Power

Farm power is agriculturally necessary for timely field operations for increasing the production and productivity of the land. The power required on the farm is needed for two kinds of work: tractive work, which involves pulling or drawing effort, and stationary work, usually accomplished by means of a belt, gears, power take-off, or direct drive. Tractive jobs include (1) plowing and land preparation, (2) planting and seeding, (3) crop cultivation, (4) harvesting, and (5) hauling. Stationary jobs include (1) water pumping, (2) processing, (3) ensilage cutting, and other jobs of a similar nature. Several farm operations are performed by machines for which the tractor supplies power in two ways simultaneously, namely (1) for pulling the machine and (2) for operating its mechanism through a power take-off. Examples include hay harvesting machines, forage harvesters, and weed coulters.

Sources of farm power for various types of agricultural operations are as follows:

(i) Human power is the main source for operating small implements and tools on the farm for stationary work such as chaff cutting, lifting, watering, threshing, winnowing, and manual labour. An average man can develop a maximum power of about 0.1 hp for farm work.

(ii) Animal powers are still widely used as a major power source in many countries for land preparation, weed management, crop threshing, and transport. On average, a draft animal can exert a force which is nearly one-tenth of its body weight.

(iii) Mechanical power broadly speaking includes stationary oil engines, tractors, power tillers, and self-propelled combines. The internal combustion engine converts liquid fuel into useful work (mechanical work). Two types of these engines are spark ignition engines (petrol and kerosene engine) with thermal efficiency range from 25 to 32%, and compression ignition engines (diesel engines) with thermal efficiency range from 32 to 38%.

(iv) Electrical power is mostly used in the form of electrical motors on farms, which is a very useful machine for farmers. It is clean, quiet, and smooth running, and is used for water pumping, the dairy industry, cold storage, farm product processing, the fruit industry, and many similar things.

(v) Renewable energy, including biogas, solar energy, and wind energy, is mainly obtained from renewable sources such as the sun, wind, biomass, etc. Renewable energy is inexhaustible in nature and can be used for lighting, cooking, water heating, space heating, water distillation, food processing, water pumping, and electricity generation.

1.3.2 Farm machinery engineering
Agricultural or farm machines include two kinds of systems called process systems, which are the parts that actually perform functions like cutting, separating, mixing, etc. The other systems are called support systems, which are the part that support or aid the process systems in performing their functions.

Process systems are divided into three types: reversible processes, which include separation and compaction; non-reversible processes, such as cutting and grinding; and non-directional processes, including conveying, metering, and storing materials.
Support systems can be divided into three subsystems: framing, which consists of all structural parts holding the pieces together for proper functioning; control, which can be automatic or manual; and power subsystems, which supply the needed power for the process system. For self-propelled machines, this includes the power source (engine) and power transmission devices (drivetrain). Machines that depend solely on the tractor as a power source must contain power transmission devices such as chains, belts, gears, PTO shafts, etc.

1.4 Agricultural Mechanization
Several factors contribute to agricultural mechanization, resulting in reducing human drudgery, increasing productivity, improving the timeliness of agricultural operations such as planting and harvesting, and reducing peak labour demands, which are among the most compelling. Farm work, by its nature, is physically demanding, and the working conditions are often harsh. Tractor driving is less strenuous than tilling the soil with a hoe and spade all day long. Plowing with a tractor can cultivate a larger area than a human with a hoe and spade in the same amount of time, thereby increasing productivity and timeliness in field operations, which is an important factor in agricultural production. Completing certain farming operations such as planting, weeding, and harvesting in a

timely manner increases yields and improves profitability. Farming operations are seasonal, with fluctuating labour demand, requiring more labour during planting and harvesting than during other periods of plant growth. Labour management problems always occur due to fluctuation in labour demand. With mechanization, it is optimally possible to reduce peak labour demand and maintain a more stable labour force on the farm. Mechanization of agriculture is of two objectives which are:

- Increasing of agricultural worker productivity.
- Changing of farm work character, making it less tedious and more attractive.

1.5 The Need for Indigenous Design and Development of Agricultural Machinery

Some examples:

1. There was an issue with the functionality of a sugar cane planter purchased from America for Nigeria Sugar Company (NISUCO) in Bacita, Kwara State. The problem arose because the sugar cane varieties available at the farm had tougher fibers than the varieties the planter was designed for. This mismatch in specifications rendered the planter ineffective for the conditions it encountered at Nigeria Sugar Company, Bacita (NISUCO). Adjustments or modifications may have been needed to adapt the planter to the specific characteristics of the sugar cane varieties grown at the farm. However, the set of the planters were found abandoned in the scrap yard.
2. Imported floating fish cage for fish production was deemed too expensive (costing several million Naira) and was not affordable for local fishermen. However, an alternative solution was developed using bamboo and plastic, which cost within ₦300,000.00 as at 2017. This alternative solution brought excitement to local fish farmers as it provided them with a more affordable option for fish cage production. This initiative was supposed to facilitate

increased participation and engagement of local fish farmers in fish production activities.

3. The tall height of the crop head has been a challenge for harvesting guinea corn, requiring varieties with shorter breed. While this has been achieved for sorghum, it has not yet been accomplished for guinea corn. Similarly, soybean faced a similar harvesting challenge, but new varieties with shorter height and lower shattering problems have been developed by plant breeders. This development opens up the possibility for the development of mechanical harvesters, which could make harvesting easier and more efficient for these crops.

2.0 MY RESEARCH CONTRIBUTIONS

Agricultural machinery for various field operations can be categorized into equipment for land clearing and land development, land preparation, crop planting, fertilizer and manure application, crop cultivation, weed and insect/pest control, crop harvesting and post harvesting, livestock and aquaculture production, and water provision for crop and rural water supply.

Mr. Vice-Chancellor Sir, I wish to use this opportunity to highlight some of my contributions in the field, as an engineer, and academic experiences in addressing the challenges associated with sustainable national food security and industrial development using agricultural machinery engineering. My basic research efforts which led to my appointment as a professor and even after, focused on the following areas:

1. Agricultural machinery development for various field operations.
2. Agricultural instrumentation and mechatronics equipment development.
3. Water supply for rural use equipment development.
4. Tillage and terral mechanic equipment development.
5. Fishery and aquaculture production equipment.

6. Agricultural machinery field operation performance evaluation and engineering production economics.

In year 2012, I published a book titled, "Agricultural Machinery Development Procedure" by Lambert Academic Publishing, Germany which serves as part of my basic template for machinery development.

2.1 Agricultural Machinery Development for Various Field Operations

Agricultural machine can be described as a machine made of components or a collection of systems composed of several subcomponents or subsystems that work together as a system in order for the machine to perform or carry out its intended function(s). I designed and constructed many machines to ease drudgery and facilitate high productivity. The first is this:

2.1.1 *Design and construction of manually operated flute planter with fertilizer distributor.*

Planting requires careful control of seed planting depth and uniform plant spacing which improves crop stand levels that produces more even plant emergence for good crop yield. Seed planting can be accomplished by broadcasting (seed uniformly scattered over field surface per unit area, kg/m^2) and also by placing and covering seeds in the soil at definite distance apart and definite depth either mechanically or manually (Kepner *et al.,* 2005). Planting is still mostly done manually in Nigeria which is tedious, inefficient and time consuming. Precision row crops planter performs uniform seed metering (seed spacing), proper depth of soil opening and covering of the seed with proper compaction.

There are three types of planters which are representing the range of current planting technology. The vacuum meter type represents a well- maintained planter with the most current technology for ensuring accurate seed singulation and placement. Air seeder type represents a planter with poor seed singulation and placement capabilities. The finger- pickup planter type represents a commonly used planter with intermediate seed singulation and placement capabilities. Overall performance on plant spacing uniformity is in the order of vacuum meter which is greater than finger- pickup which is also greater than air seeder. Under different tillage systems, spacing uniformity, timing and rate of emergence, and plant population in a corn (maize) stand are the most common characteristics used by producers in evaluating planter performance.

Adisa (2011) developed a manually operated flute planter with fertilizer distributor to plant grain crops as shown in Figures 1 and 2. The precision planter was designed to plant at constant seed spacing, row spacing and planting depth for uniform plant density and seed rate of emergence. The gage wheel was designed and constructed to keep furrow opening depth constant. A 16 cm diameter cylinder made of sheet metal was used as the gage wheel. Runner type of furrow opener was fabricated from mild steel with adjustable depth of soil opening of between 3 - 6 cm. This would allow for various grain crops to be planted.

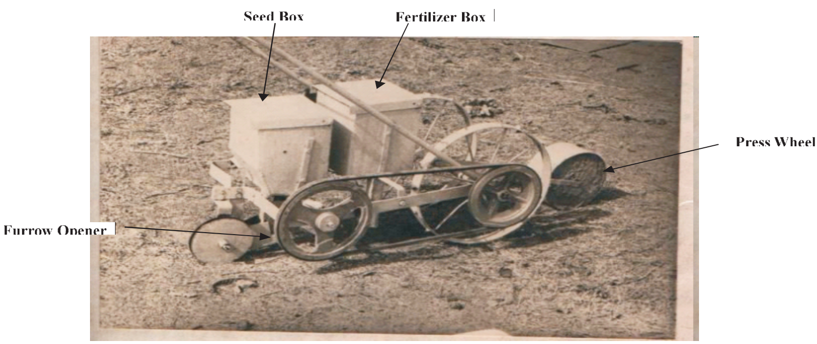


Figure 1: Manually operated planter/fertilizer applicator

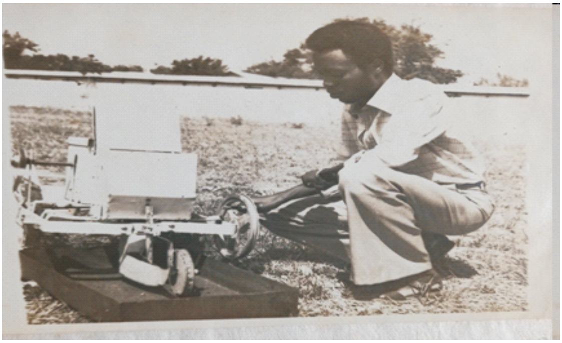


Figure 2: Calibrating planter/fertilizer applicator metering units

Table 1: Field Test Result of Planter Performance for maize

No. of Run	Duration of run (s)	No. of seeds expected (se)	Actual no. of seeds (sa)	Filling efficiency (sa/se) (%)	Average seed spacing (cm)	Planter speed (km/h)	planter field capacity (ha/h)
1	7	12	13.0	108.3	31.40	2.06	0.21
2	9	12	8.0	66.7	35.86	1.60	0.16
3	8	12	10.0	83.3	33.13	1.80	0.18
4	7	12	12.0	100.0	34.78	2.06	0.21
5	9	12	11.0	91.7	33.75	1.60	0.16
Average	8	12	10.8	90.0	33.78	1.82	0.18

From test result on fertilizer distribution, calibration of granulated type of fertilizer was found suitable for drilling for crops that are planted by drilling and for spot dropping if applied when crops are been planted. Average planter's seed filling efficiency of the seed metering unit was found to be 90% at average speed of 1.82 km/h as shown in Table 1. The concept of the greater the speed of a planter, the greater is the draft requirement (Kepner *et al.,* 2005) was proved in the result shown in Table 2. At the average speed of 1.96 km/h the average draft demand of this planter was found to be 149.5 N which did not show in the Table but was recorded on the field. The gross weight of this planter was 39.4 kg. There was a need to improve on seed furrow opening unit to obtain more uniform seed spacing or placement and reduce occasional seed plugging of the seed metering device. The average single row planter's field capacity was 0.18 ha/h as shown in Table 1 and can be as high as 2.10 ha/h for six rows mounted on tractor at 5 km/h speed and 70% field efficiency as evaluated using equation 1.

$$C = \frac{SWE}{10}, \text{ ha/hr} \quad (1)$$

Where: C = effective capacity, ha/hr
W = rated width of implement, m
E = field efficiency, %

Table 2: Field Test Result of the Effect of speed on Draft (Maize)

No. of run	Horizontal pull (N)	Time Taken (s)	Length of run (m)	Speed (km/hr)	Draft (N)
1	117.72	11.0	8	2.63.	183.08
2	98.10	10.0	8	2.83	152.57
3	107.91	8.6	8	3.35	167.82
4	98.10	15.0	16	3.85	152.57
5	156.00	12.0	16	4.79	244.11
6	127.53	10.0	16	5.76	198.34

From Tables 1 and 2, the test result obtained shows that the planter was able to plant on zero tillage flat field while the seed spacing and planting depth could be varied for maize and guinea corn crops. The seed spacing for planting maize was obtained to be 94% efficient, 64 cm was obtained for planting guinea corn and average seed filling efficiency was 90% when planting at 1.82 km/h speed. The planting field capacity was found to be 0.18 ha/h and the draft requirement was found to be 149.5 N.

2.1.2 Calibration and determination of optimum power and operational conditions of a developed template row planter

It is essential in integrated farming system which utilizes advanced agronomic practices, seed genetics and on-farm technology to deliver optimal yield while using fewer resources. Precision plant's goal is to boost yields through equipment innovation which traditional tools could not achieve. A newly developed equipment is calibrated to prove its ability to perform its function reliably at optimum operational settings. Basic requirements for small scale cropping machines are suitability for small farms, simple in design and technology and versatile for use in different farm operations. There was a need to develop a template row planter to improve planting efficiency and reduce drudgery involved in manual planting method.

For the aforementioned reasons, Adisa and Braide (2018) developed a template row planter, with determined optimum settings of operational critical parameters, Figure 3. Also, it increased seed planting, seed/fertilizer placement accuracies and it was made of durable and cheap material affordable for the small-scale peasant farmers. The operating, adjusting, and maintaining principles were made simple for effective handling by unskilled operators (farmers).

The tested planter from Figures 3 and 4 and Table 3` weighed less than 9 kg, while the draft required to push the planter was found to be 85 N at 2.16 km/h average speed and power required at best planting performance was found to be 42.5 W. It was found suitable for manual operation at 0.20 ha/hr capacity. The power required at best planting performance of 42.5 W, is less than average 70.0 W, which a man can supply continuously for single row. Seed filling efficiency of the metering unit was found to be 88% at standard deviation of 0.45 which is an indication of high and reliable performance of the developed machine.

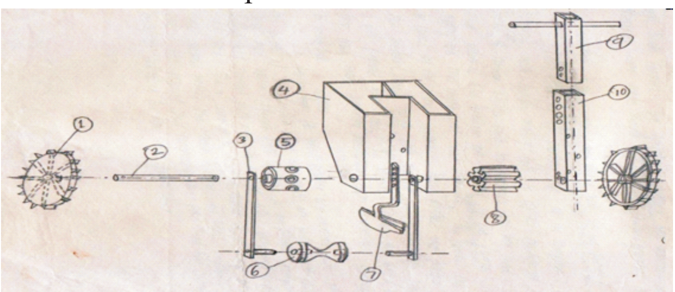


Figure 3: Exploded isometric view of template row planter.

KEY: (1) Drive wheel (2) Shaft
(3) Furrow cover frame (4) Seed/ fertilizer hopper
(5) Seed metering mechanism (6) Furrow cover/ press wheel
(7) Furrow opener (8) Fertilizer metering mechanism
(9) Male handle (10) Female handle

Table 3: Laboratory and field test result

No of Runs	Duration of Run (s)	No of seeds expected. (Se)	Actual No of seeds dropped (Sa)	Filling efficiency (%)	Planter Speed (km/h)	Power (watts)	Rate of planting Planting (field capacity) (ha/h)
1	15	60	50	83.33	3.40	60.30	0.46
2	13	60	55	91.67	3.90	69.10	0.53
3	19	60	48	80.00	2.70	47.90	0.36
4	21	60	72	100.00	2.40	42.50	0.33
5	17	60	46	76.67	2.90	51.40	0.41
6	24	60	54	90.00	2.10	37.20	0.29
7	22	60	68	87.20	2.30	40.80	0.31
Average	19	60	56	88.0	2.70	47.90	0.39

The cost of planter production in 2013 was twenty five thousand five hundred Naira only (₦25, 500.00). The template row planter was able to plant on both ridged and flat seed bed at average field capacity of 0.2 ha/h (effective planting rate) which was quite adequate for small scale farming.

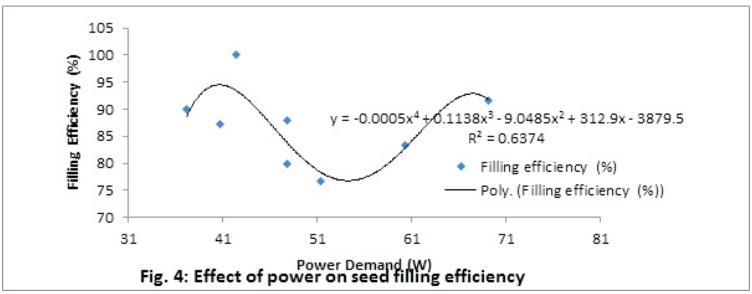


Fig. 4: Effect of power on seed filling efficiency

2.1.3 Stripper header development and determination of its optimum operational conditions for rice harvesting in Nigeria

Developing and adopting new technology for different farming systems is a vital challenge for future years. Although stripper harvester has been developed and tested in places like Britain, some Asian countries and Europe, its performance on rice harvesting was highly affected by setting of its critical operating parameters, therefore not practically accepted in some places. **Adisa et al., (2012) developed a** 30 cm width self propelled prototype pedestrian-controlled grain stripper header which was carried out at Ahmadu Bello University, Zaria (2008)**.**

The stripper rotor of the harvester simultaneously carried out four functions of crop lifting, harvesting, partial threshing and grain transporting in one operation. This was amounting to crop gathering, cutting, threshing and crop conveying in a conventional combine harvester. Figures 5, 6a and 6b shows the eight-stripping comb-like resilient elements made of a rubber material with keyhole- shaped recess slots between each pair of teeth root which were mounted horizontally on an upward rotating drum. These rotor elements engaged crop stalks as machine advances forward and detaches ears and grains at high speed from the stalk and throws the materials that was removed into the grain box. The grains were later discharged by an auger conveyor located at the lower backward end of the grain box for final threshing/cleaning. Figure 5 is the developed 30 cm width grain stripping harvester. Furrow dividers were coupled to both sides of the stripping header to provide clear demarcation between stripped and unstripped rows. Dislodging mechanism was made to dislodge the lodged crops with three L shaped iron rod that were mounted on the front end of the hood nose ahead stripping unit. Figures 6a, 6b, and 6c show the stripper units and harvester, Adisa (2016).

Figures 7a and 7b shows the tested field before and after harvesting operation while Table 4 is the stripper optimum settings result of the critical operating parameters. From this study, the

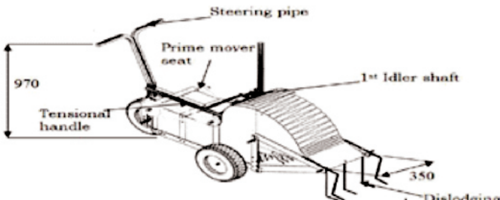
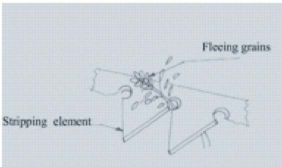


Fig. 5: Isometric View of the Stripper Harvester



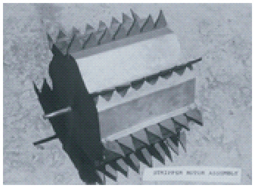


Fig. 6a: Stripping operation **Fig. 6b:** Stripper rotor assembly **Fig. 6c:** Rice harvester

Fig. 7a: Rice intercropped with corn field before harvesting. **Fig.7b:** Harvester in field operation.

Table 4: Rice Stripper Optimum Settings of Critical Operating Parameters

S/No	Parameters	At rotor height 270 mm	At rotor height 220 mm
1	Harvester forward speed	3 km/h	4 km/h
2	Stripper rotor speed	17.55 m/s	14.67 m/s
3	Harvester nose height above ground	530 mm	480 mm
4	Field capacity	0.078 ha/h	0.075 ha/h
5	Fuel consumption rate	27.60 litre/ha	26.60 litre/ha
6	Harvester efficiency	81%	77%
7	Grain purity	90.20%	87.50%
8	Threshed grains, percent of total stripped	97.50%	92.70%

best machine settings were at 270 mm rotor height, stripper rotor speed 17.55 m/s and forward speed of 3 km/h, the field capacity was at 0.078 ha/h, harvester efficiency was 81.00%, grain purity was 90.20% and grain threshed was 97.50% of the total grains stripped. Similarly, at 220 mm rotor height, 4.00 km/h forward speed, and 14.67m/s rotor speed settings, the field capacity was 0.075 ha/h, harvester efficiency was 77.00%, grain purity was 87.50%, and the threshed grains was 92.70% of the total grains stripped. The performance of small capacity stripper harvester on row planted crop field was better in overcoming tyre rolling resistance problem than on spot planted rice field.

2.1.4 An overview of development of a rice processing plant for rural use

The shortfall in capacity and quality between locally produced rice for example in developing countries like Nigeria was 2.8 million tons and the domestic consumption was 5.9 million tons, Ozigbo *et al.,* (2013) which called for developing a low cost and efficient rice processing machine for improved capacity and quality for sustainable agricultural production. Rice dehusking is the process by which it grain is separated from the glumes that enclose it.

Apart from the labour-intensive type of small-scale rice dehusking by pestle and mortar, there are generally two major principles of mechanical dehusking of paddy rice which are shearing and impact types. According to International Rice Research Institute (IRRI, 2009), three different husking technologies are commonly used which are steel husker, under runner disk husker and rubber roller husker. Roller husker method of hulling can achieve hulling efficiencies of 85% to 90% with minimum broken or cracked grain. Many simple and sophisticated machines have been developed to carry out these processing operations in developed countries. There is need to move from making use of hand tools and develop more efficient simple rice processing machines to meet rural farmers' need in food production.

Mr Vice Chancellor a team of researchers headed by Adisa in March 2010 commenced work on rice dehusking/destoning machine project at Institute of Food Security, Environmental Resources and Agricultural Research (IFSERAR) of Federal University of Agriculture, Abeokuta, Nigeria. The target was for the use in rural areas where most of the rice production comes from and it was a further work Adisa started, (Adisa *et al* (2016). The machine prototype was first developed as a continuation of earlier work done which all started in 1987 at Silsoe Campus of Cranfield Institute of Technology (now Cranfield University), England (an MSc. Project). These includes design of small capacity roller rice dehusking machine, assessment of power demand with minimized power requirement, incorporation of a destoning unit, grain metering unit and selection of suitable roller material and alternative sources of power like petrol engine and electricity.

Figure 8 shows the first produced dehusker, coupled with a developed epicyclic dynamometer at Silsoe Campus of Cranfield Institute of Technology, England in 1987. The total power machine required was found to be 110 watts while 41 watts was absorbed by the machine to dehusk 49 kg/h of paddy rice (Adisa and Inns, 2012).

Figure 9 is a picture of one of the tested peeled-up shoe leather cover on roller which was the case for searching for best alternative out of four roller types that were tried. About 4.5 kg of parboiled paddy rice was used for trial runs which began to peel off during dehulling and got worn out because of friction. About 15% of paddy was dehulled with 50% wholeness which then resulted in the search for other alternative roller materials of more superior property. Knolled *Teflon* rollers shown in Figures 10 and 11 are the second developed prototype with destoner.

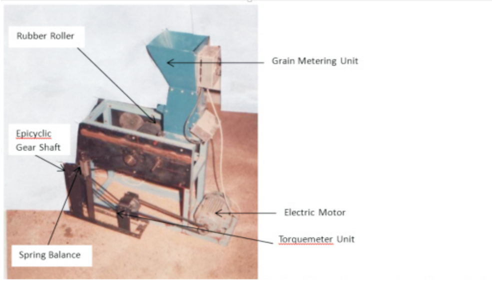


Figure 8: Electric motor, prony brake, grain metering unit and huller of first machine assembly at Silsoe, England.

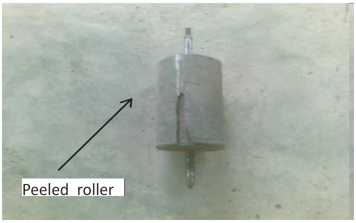


Figure 9. One of the peeled shoe leather on roller.

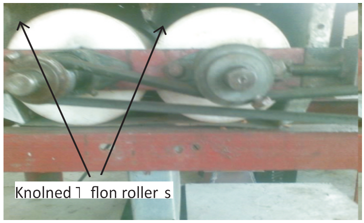


Figure 10. Teflon rollers on the second machine.

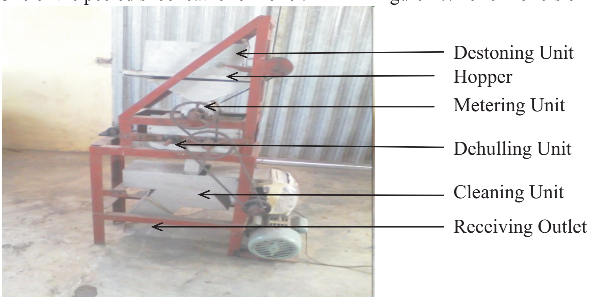


Figure 11; Second prototype rice dehusking / destoning machine with Teflon rollers

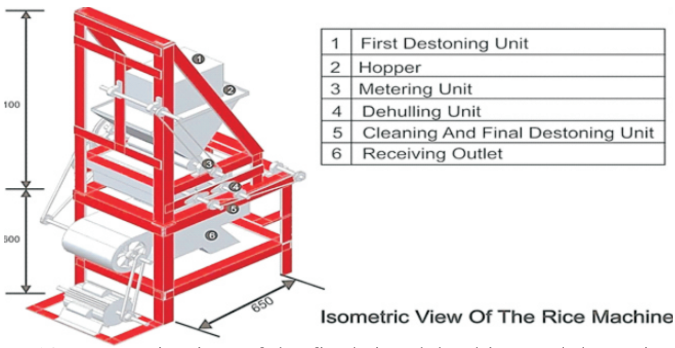


Figure 12: Isometric view of the final rice dehusking and destoning machine

Table 5. . Operating parameters of the prototype dehuller

S/No	Performance Parameters	Maximum Values
	Coefficient of dehulling	0.77
2	Coefficient of wholeness	0.88
3	Dehulling efficiency, %	66
4	Dehulling recovery, %	76
5	Cleaning efficiency, %	97
6	Output capacity, kg/h	18.12
7	Hulling capacity, kg/h	10.86
8	Capacity utilization (CU) , %	97
9	Air velocity	9.8m/s
10	Air volume	0.25m³/s

A large amount of air was blown from cleaner blower unit which separates dehulled samples into three items viz. chaff, hulled rice and stones which comes from three different outlets. Figure 12 shows the final prototype dehuller/destoner. Table 5 shows the critical operating parameters with coefficient of dehulling of 0.77, coefficient of wholeness of 0.88, cleaning efficiency of 97% and capacity utilization of 97% which was found to be far better than any known rice processing traditional nor hand tools for paddy rice dehusking.

This research work shows that the milling efficiency was affected by the machine adjustment due to excessive breakage recorded when the machine was operated with single adjustment for all the paddy varieties. The optimum moisture content on wet basis for all the paddy varieties was in group A (12 %). The dehulling efficiency of the rubber roller dehusker was 63.75 %, Coefficient of hulling was from 0.44 to 0.77, coefficient of wholeness was from 0.55 to 0.88 and the cleaning efficiency obtained for the rice varieties was 82 to 97 %. The terminal velocity of the rice grain was 7.5 m/s while the air velocity of blower was 9.8 m/s. The rubber rollers maximum coefficient of dehulling, coefficient of wholeness, dehulling efficiency and cleaning efficiency for the rubber roller dehusking machine were of higher values than using *Teflon* rollers on the same machine. Out of locally available materials searched and tested, industrial rubber roller material performed best, (Adisa *et al*., 2017) with coefficient of dehulling, coefficient of wholeness, dehulling efficiency and cleaning efficiency of values 66.00%, 0.77, 0.88 and 97.00% respectively. In Countries where majority of rice processing is done with pestle and mortar this developed machine will go a long way to contribute and sustain and improve rice production.

2.1.5 Aerodynamic mechanism for grain cleaning and destoning equipment development

Provision of a well processed, dirt and stone free clean grains results in good quality and attracts high demand and good price value. Most of the locally grains produced with traditional processing methods in Nigeria, results in rushing for well processed imported grains from developed nations. There was a need to carry out a research work in providing mechanical cleaner/destoner to add value to our locally produced grain crops.

Adisa in Mamah *et al.* (2016) determined some physical properties such as drag coefficient, terminal velocity and Reynolds number which were considered in design grains cleaner/destoner. In aerodynamic principle of grain and foreign materials separation, fluid flow occurs around the solids and the problem involves the action of the forces exerted by the fluid on these solids that brings about the separation. The air velocity, air volume and relative humidity were measured by digital air flow meter. Moreover, a number of parameters were identified to influence the separation of particles in fluid medium. Such parameters are: (i) fluid velocity (ii) particle direction in air flow (iii) particle feed rate (iv) loading ratio (v) direction at which particle is injected (vi) resilience time of particle in the separation chamber, the ratio of grain to material other than grain (MOG) and air turbulence intensity (Hamilton and Butson, 1979), see Figures 13 and 14.

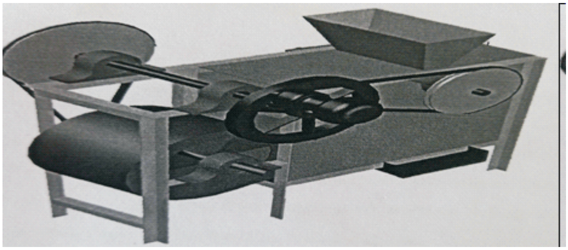


Fig. 13: Isometric view of grain cleaning/destoning machine.

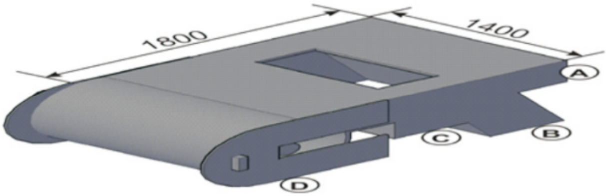


Fig. 14: Newly constructed cleaning unit housing with air volume adjuster

KEY:
A = Outlet for materials lighter than dehusked grain
B = outlet for dehusked grain
C = outlet for stones and materials heavier than dehusked grain
D = air volume adjuster

In free fall, the object attains a constant terminal velocity at which the net gravitational acceleration force, equal the resisting upward force. Under steady state condition, where terminal velocity has been achieved, if the particle density is greater than the fluid density, the particle motion will be downward. If the particle density is smaller than the fluid density, the particle will rise. When air stream is used in separation of rice from associated foreign materials such as chaff, stone, dust, etc., knowledge of terminal velocity of all the particles involved would define the range of air velocities affecting good separation of the grain from

Table 6: Values for volume shape factor, grain density and geometric mean diameter for some common grains

Grain	Density, $Pp(\text{kg}/\text{m}^3)$	Volume shape factor, Z	Geometric mean diameter(m)
Maize	1260	0.29	6.22
Wheat	1320	0.27	3.36
Barley	1020	0.23	3.70
Soya bean	1340	0.46	6.22
Rice	1370	0.27	2.75
Rape seed	1000	0.41	2.05
sorghum	1250	0.38	3.61

Source: Glorial and O' Callaghan, 1990.

foreign materials, see Table 6 for some grains density. The terminal velocity is derived by setting the gravitational force equal to the resisting drag force and velocity equal to terminal velocity as reported by Joshi et al, 1993 on equation 20 as:

$$Fg = Fr \text{ when } V = V_t^2,\ \frac{M_P\ g\{\rho_P - \rho_f\}}{\rho_f} = \frac{C A_P \rho_f V_t^2}{2},\ V_t = \sqrt{\{\frac{2W(\rho_P - \rho_f)}{\rho_P \rho_f A_P C}\}} \qquad 2$$

Also, the overall drag coefficient C, was given on equation 2 by Glorial and o'Callaghan, 1990 as:
Where: C = overall drag coefficient
g = acceleration due to gravity,
Mp= mass of particle,
Pp=mass density of particle,
Pf = mass density of fluid,
Ap = projected area of particle normal to the motion,
W = weight of particle.
The results in adding good value to the processed grain crops for healthy consumption.

2.1 Agricultural Instrumentation and Mechatronics Equipment Development

In modern agricultural, biological, and biomedical instrumentation, they all make use of electronic sensors, analog and digital circuits, computers and microcontrollers for scientific measurements and process control. Instrumentation is used for commercial product development, testing, and basic research for measuring parameters like force, power, pressure, voltage, speed, just to mention few. Here, a power measuring instrument was developed which was very useful in developing some agricultural machines.

2.2.1 Development of an epicyclic gear transmission laboratory dynamometer

Measuring power transmission for machines with low power consumption require accurate measuring device where its speed can be varied from low to high and very little power is allowed to be absorbed by the dynamometer (torquemeter). This can be achieved in a situation when local production of power measuring device is required.

Adisa and Inns (2012) at Silsoe Campus of Cranfield Institute of Technology, England in 1987 developed an epicyclic gear transmission laboratory dynamometer which was designed, fabricated and tested with prony brake on a small capacity rice dehusking machine with source of power from an electric motor. The dynamometer was produced using a bicycle epicyclic gear of sturmey Archer hub type. This gear was chosen because of the advantages of free running (under the designed condition, the power loss should be small), appropriate load capacity for this application, availability, easy adaptation and other conventional epicyclic advantages (Compact, Colinear input and Output shafts, etc.). The sturmey Archer hub has four gear ratios out of which 1:1.3, 1:1 and 1:3 was selected for this study. The variable gear selection made it possible to use the torquemeter for power measurement of other machines with variable speeds (see Figures 15 and 16). This was reproduced here by A. F. Adisa and V. Adepoju as an undergraduate final year project in 2011 at Federal University of Agriculture, Abeokuta for it use here.

The results obtained from this power demand analysis, Table 7 and Figure 17 easily confirmed that the new epicyclic gear dynamometer developed measured the power and the transmission at 92% efficiency. Also, the power supplied by the electric motor which was calculated from

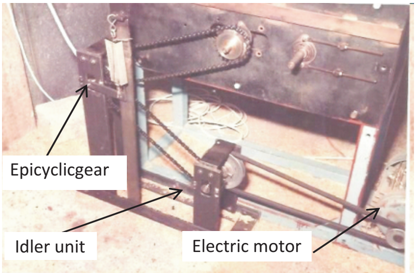


Figure 15: Epicyclic Torquemeter on the first huller.

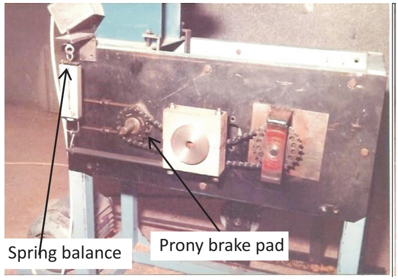


Figure 16: Prony brake assembly on the first machine huller machine.

the speed drop directly was in good relationship with that of the dynamometer and Prony brake results. With the aid of the dynamometer, the power required to drive the transmission (chains, sprockets and bearings) and machine rollers when not dehusking were found to be 69 watts out of which 65 watts was transmitted to carry out the rice dehusking operation and 4 watts absorbed by the dynamometer driving system.

In summary, transmission efficiency between the epicyclic dynamometer and prony brake was found to be 92% while that from electric motor to prony brake was found to be 83%. The dynamometer absorbed 4 watts (6%) out of 69 watts required to drive the rice dehusker. This showed a marked improvement when compared with other power measuring devices that can be constructed locally.

Table 7: Torquemeter Test Result

	No Load on the machine	loaded by the prony brake							Loaded by grain alone
Electric motor speed (rev/min)	1495	1494	1490	1486	1482	1480	1470	1456	1492
Torquemeter Output sprocket speed (rev/min)	652	651	650	648	646	645	641	635	650
Torquemeter output sprocket speed (rev/min)	883	882	878	867	859	858	852	845	879
Brake drum (fastroll) speed (rev/min)	1009	1008	1003	991	982	981	974	965	1004
Torquemeter spring balance force (N)	2.5	3	5	7	9	10	15	20	4
Prony brake spring balance (N)	0	2	4	6	7	8	13	17	0
Prony brake power (w)	0	60	118	175	203	232	374	484	0
Torquemeter power (w)	65	78	131	189	246	273	408	537	105
Electric motor power (w)	69	83	138	193	248	275	413	605	110

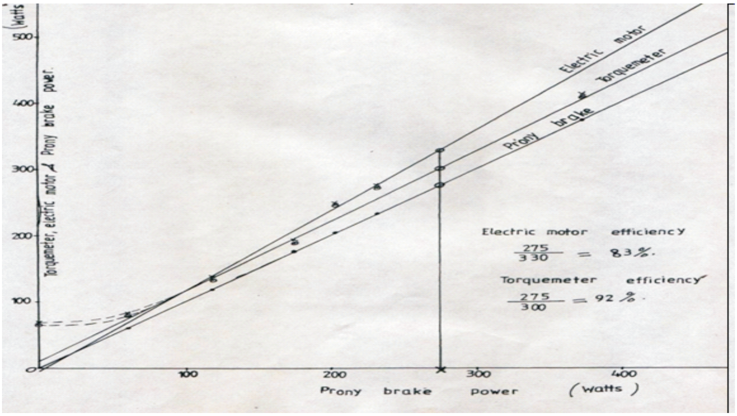


Figure 17: Power transmission efficiencies for the electric motor, torquemeter and prony break

2.3 Water Supply Equipment Development for Rural Use

Water is an essential input for for agriculture and food production, as well as a vital component for functioning ecosystems. Adequate access to water can support productivity and food security, improve public health, and contribute to economic growth and poverty reduction in rural areas. A research work of developing a water drilling was carried out.

2.3.1 Design of an agricultural tractor mounted Prototype of a pater drilling rig

Water drilling rigs are essential for an all-year- round water supply and is either human powered or internal combustion engine driven. Manually powered rigs are simple to assemble but slow, laborious, and ineffective in drilling through rocky basement formations while engines powered rigs which are mostly imported, require highly skilled personnel to operate, with an array of expensive consumables and spares for maintenance which takes its cost beyond the reach of many, particularly the rural dwellers.

Adisa with the team of researchers in this University carried a study that designed a low power prototype drilling rig that can obtain its drilling power from the Power Take off (PTO) shaft of an agricultural tractor and capable of getting to a depth of 30 metres in a rocky formation (Babalola et al., 2018). The design was subdivided into structural, hydraulic, and mechanical components respectively. A low sophistication rig, with ease of operation, capable of drilling to the depth of 30 metres and a hole diameter of 152.4 mm by overcoming the resistance posed by any rock/soil formation was developed. Hence, power obtained from the PTO shaft of the agricultural tractor, will be used to power the drilling effort using the mud rotary drilling technique with locally available materials. Figure 18 shows the schematic diagram of the machine as expected to function while Table 8 is the design values parameter and Figure 18 is fabricated rigs at different stages and being tested.
Figure 19: Hydraulic Pump speed and rotary head speed obtained from the preliminary run.
From Figure 20, the R square value of almost 1 shows a strong correlation between the two variables recorded. At the peak hydraulic pump input speed of 539.9 rpm, a maximum value

Table 8: Design values of parameters

Parameters	Calculated Value	Final design values
Drilling Power Required	14.7 kW	28 kW
Weight on Bit	3430 N	3430 N
Drilling Torque Required	3.6 Nm	21 Nm
Minimum rotary head speed	28 rpm	28 rpm
Rotary Head Weight	-	40 kg
Drill bit diameter	-	152.4 mm
Column material and Length	-	U-Channel , 3.962 mm
Drum strength		91.5 kN
Rope Length	12 m	38 m
Hydraulic pump power	14.7 kW	46 kW
Hydraulic Cylinder:	487 N/m^2	250 kN/m^2
Reservoir Size	0.12 m^3	0.15 m^3

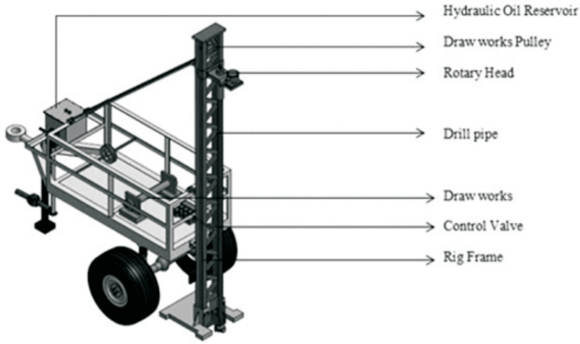


Figure 18: Isometric view of the drill rig.

Figure 19: The drill rig at various stages of completion

of 84 rpm was recorded as the speed of the rotary head. Maximum power obtainable from the tractor PTO is 80% of the rated engine power which is 41.8 kW at 21 Nm torque. This is sufficient to drive the rotary head and safely power a drilling operation to the required depth. This is greater than the minimum required torque of 3.4 Nm.

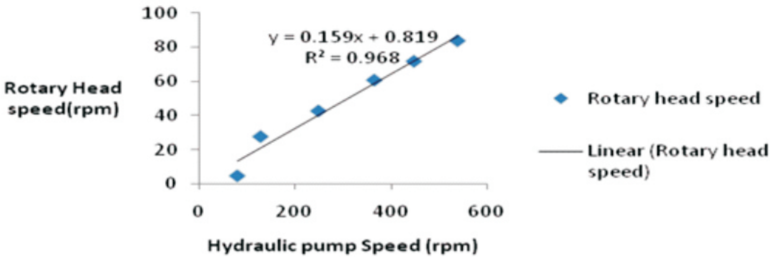


Figure 20: Hydraulic Pump speed and rotary head speed obtained from the preliminary run.

of 84 rpm was recorded as the speed of the rotary head. Maximum power obtainable from the tractor PTO is 80% of the rated engine power which is 41.8 kW at 21 Nm torque. This is sufficient to drive the rotary head and safely power a drilling operation to the required depth. This is greater than the minimum required torque of 3.4 Nm.
The total cost of fabrication of the project was ₦841,000 *($4,500)* as of 2018 which favourably compares well with motorized rigs (1.5 to 10 million Naira) in the open market. The study also favourably compared to who spent a total of ₦10,240, 000 on a truck mounted drilling rig as well as Jibrin *et al.,* (2013) who utilized a 16 kw energy source to power the drilling operation of their drilling rig. None of these studies also gave information on their engine performance in their literature like what this work gave.

A prototype of drilling rig was designed, fabricated and tested which was found to be capable of reaching a drill depth of 30 metres in a basement formation. The agricultural 50 Hp tractor PTO shaft was able to power and drive the drilling rig. A 50 hp (37.28 kW) tractor or above can then be used to power the drilling procedure using specifications of this design. From this study, the drum and rope mechanism had a design factor of 10. Maximum weight on bit at the expected depth is 3.430 kN while total drilling power calculated was 14.7 kW *which was lower from the Tractor supply of 41.8 kW*. The construction of the machine was carried out using locally sourced materials as this has an advantage of easily replaceable spares than imported drilling rigs whose spares might have to be imported for repairs to be done which would even cost more. Comprehensive water drilling procedure was carried out which was found to be satisfactory.

2.4 Tillage and Tera Mechanic Equipment Development

Soil tillage is an essential land preparation operation to provide good and conducive environment for crop planting, and positioning in the soil of some necessary plant foods for good crop establishment. There are various types of tillage equipment, and their selection must be based on proper knowledge of some soil conditions and parameters. Measurement of these parameters is being carried out in this research study by developing a testing rig.

2.4.1 Development of an instrumented system for off-road vehicle performance in southwest of Nigeria

Tera mechanics is the study of mechanics of vehicle/terrain interaction which is terrain behaviors, off-road vehicle performance and design under different soil conditions and vegetations for field operations. The data of parameters from this study are very useful in designing and modelling of off-road vehicles like SUV vehicles, tractors and agricultural vehicles, military vehicles, and construction equipment. Development of these vehicles is done by employing computer-aid methods for high-mobility of off-road vehicles (Wong, 2009).

The use of off-road vehicles in agriculture, earth moving, cross-country transport and logging industry has grown rapidly in recent years because of the increased demand for machines with a higher power, better production capacities and improved energy conversion efficiency (**Zeljko, 1997)**. As vehicles of traction and transport, they generate drawbar power from the deformation of their wheels/tracks and the soil on which they operate. Hence, the most distinct visual distinctions between an on-road and off-road vehicle are: the mechanisms used to provide vertical support and stability, means of propulsion, and steering method for the vehicle. On-road vehicles use simple threaded pneumatic tires of a relatively narrow size range, the off-road vehicles use a wide variety of traction devices like much larger and multiple pneumatic tires, steel tracks, special purpose wheels and, recently, rubber track (Goering *et al*., 2003; Yu, 2005).

There was need for further studies into the usefulness of the off-road vehicle in ensuring the sustainable development of agriculture and enhancing the livelihoods of many farming generations which is essential in securing the future of human in this modern time. Matching implements correctly to effectively utilize tractor power had been a continuing research pursuit with the advancements in machinery technology (Roeber, *et al*, 2017). There is no doubt, this has created an immense opportunity for researchers to probe further the possibilities of maximizing tractor power in location-specific applications in various regions to various field operations.

Adisa and a team of researcher are (A. A. Babalola on-going PhD work) currently engaged on development of unique instrumented system and measurement methods for the evaluation of different types of soil engaging machinery working under different field conditions in the Department of Agricultural and Bioresources Engineering of Federal University of Agriculture, Abeokuta. The developed instrumented system rig will be utilized to measure four major parameters which are tractor performance, tillage quality, soil failure and environmental conditions for optimum agricultural machinery selection for tillage operations under different soil conditions:

Tractor performance determination: - measurement of draft and power for field operations, fuel consumption, energy utilization determination, drawbar pull-drawbar, torque in PTO, wheel speed/travel velocity, vibration level/comfort level of tractor operator with various mounted sensors on the rig.

Tillage evaluation: - measurement of tillage depth, width of cut, tool orientation, soil tilth (pulverating level), furrow slice height, furrow width, surface roughness with attached sensors on the rig and other instruments for tillage variable parameters determination.

Soil characteristics determination: - this is soil characteristics or behaviours in traffic and mobility. Parameters like sinkage, shear stress, normal stress, soil penetration resistance measurement with mounted various instruments/sensors on the rig.

Environmental factors determination: - determination/measurement of parameters like emission, humidity, noise, and temperature.

Figure 21 is free body diagram of the kinematic links of the three-point hitch system showing forces that are acting on both the tractor and the implement when in operation.

Where: AC = lower link,

DF = distance of the lift arm pivot point to the hydraulic cylinder pivot point on the lift arm respectively, GE = hydraulic cylinder, FB = lift rod , HI= upper link , L_{G}- Lift cylinder length,

L_{Top}- Top link length, L_{AB} is the length of the lower link fixed point to the lift rod fixed point

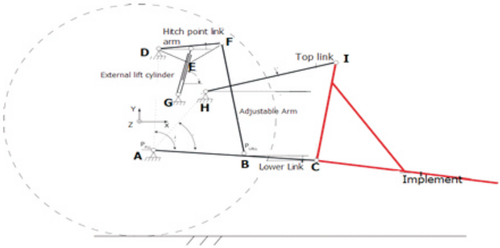


Figure 21: Free body diagram of the kinematic links of the three-point hitch system
Source (Karakoç 2019).

on the lower link, L_R is the lift rod length, L_{LOWER} is the lower link length.

CI is the mast height (all in mm), α_1- Angular orientation of the lower link with tractor body of the hitch system along the horizontal axis, degrees.

α_2- Angle between the lower link and the hitch body, degrees.

α_3- Lift cylinder angle with the horizontal axis, degrees.

α_4- Upper arm angle with the horizontal, degrees.

α_5- Lower link deflection when coupled with implement, degrees.

α_6- Lift arm angle with the lower link, degrees.

α_{7-} Top link angle with the horizontal, degrees.

α_{8-} Angle between top link and implement along the vertical axis, degrees.

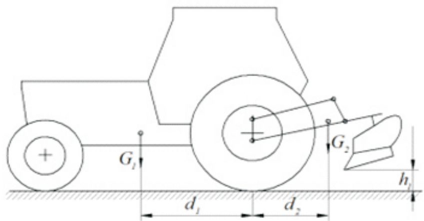


Figure 22: Schematic drawing of tractor during tillage operation.
Source: Scheaua (2014).

Where: G_1- Centre of gravity of the Weight where all the weight is acting, kN.

G_2- Implement attachment weight, kN

d_1- Distance of the wheelbase to the centre of gravity of tractor, m.

d_2- Distance of wheelbase to the implement, m.

h_1- depth of implement working, m.

Figure 22, during ploughing, the tractor should be able to overcome the implement weight, parasitic and frictional forces of the soil, rolling resistance of the wheels, and wheels slip. This relationship is represented by the unit draft which is given by Scheaua (2014) in equation 3.

$$F_t = R_w hln \quad (3)$$

Where:

R_w- Soil resistance during ploughing, N/m^2.

h- working depth, m.

l-working width, m.

n- number of working bodies.

Figures 23 are the designed and fabricated three-point hitch dynamometer rig which is ready for testing. Presently dry season field tillage operation testing and subsequently data collection is going on at CEADESE farm.

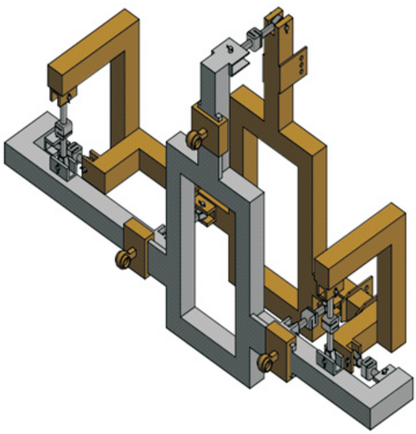


Figure 23: The isometric view of the three-point hitch dynamometer rig

2.4.2 Technical and socio-economic relevance in technical adoption: case study on rotatory tillage equipment in southwest of Nigeria

The present and future shortage of farm labour for agriculture requires consideration in developing countries including Nigeria where there is drifting of working-class citizens from rural to urban cities where they are making more money, for an example motorcycle transport business than farming labour operation services. As much as 80% of farm power is provided for by human beings, which now call for need to develop and possibly engage simple and avoidable equipment to replace some manual tools for farming operations. Such type of equipment for small holder farming must be easily repairable and maintainable, inexpensive and environmentally friendly. Also, it must be suitable for small farms, simple in design and technology and versatile for use in different farm operations. The report of Okurut and Odogola (1999) was that apart from land, farm power is the second most important input to agricultural production. Also, Barton (1999) stated in his report that farm power determines the scale and intensity of farm operation. The report of Sarker (1999) was that adoption of power tillers for tilling has brought some significant changes on overall production and sustainability of small farm systems. The present and future shortage of farm labour for agriculture requires consideration in developing countries including Nigeria.

Adisa *et al*. (2015) began the technical and social- economic assessment and recommendation for adoption of a newly purchased Husqvarna T560 RS rotary cultivator by IFSERAR which took place at Federal University of Agriculture, Abeokuta, Southwest of Nigeria based on performance efficiency, affordability, durability, acceptability and ease of operation for the smallholders. Adoption of power tillers for tilling has brought some significant changes on overall production and sustainability of small farm systems. Addressing this requires acquisition of appropriate mechanized farm tillage tools. Figure 24 is a 6 hp (4.48 kw) Husqvarna T560 RS rotary cultivator of 0.78 m width was acquired for field performance test for appraisal and adoption for small scale farming as part of the front-end concern in the procurement- adoption chain.

Going by the results obtained from this experiment Tables 9, 10, 11, 12, and 13 the effective field capacity of the machine on a land that was already under cultivation was found to be 0.033 ha/hr (i.e. 5 working days/ hectare) and about 12 hours to till one acre in well cleared stone-free soil type where it was tested. The soil tillage of this equipment was found suitable

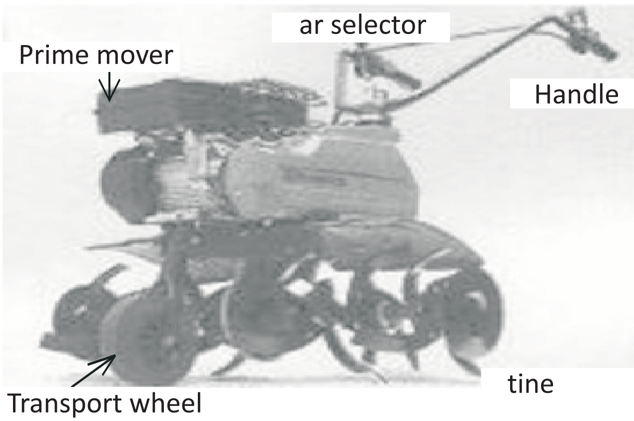


Fig. 24: Husqvarna T560RS rotary cultivator.

for crops that can tolerate zero to shallow tillage depth of 0.21 m which this equipment was able to provide in the sandy loam under friable soil moisture condition. The awareness of the machine was 39% among the farmers, 67% rated the machine useful for tillage but the machine price range was above what their individual income can sustain in the study area. The machine was hereby recommended only for introduction to research institutions, private horticulturalists and vegetable cooperative farmers in the

rural and urban farming communities of one-to-two-hectare farm holding capacity. The experience on the TREFAD farm where the land was newly cleared, had stumps and gravel type of soil was not encouraging.
The equipment was recommended to be used for both secondary tillage operation but can work effectively and efficiently better on land that had been cleared of trash already, void of stones and not weedy as in gardens, vegetable farms and horticultural fields. Though the machine capacity is small, if well handled, it will perform well in soil loosening and pulverization for good seed bed under friable soil moisture condition. The soil tillage performance of this equipment will be suitable for crop seeds that can tolerate zero to shallow tillage plowing depth of 0.21 m which this equipment was able to provide. Husqvarna T560RS rotary cultivator was recommended based on its performance efficiency, affordability, durability, and ease of operation for smallholder farms. The machine was not operationally gender- friendly, just 39% farmers awareness, not simple to operate as advertised and target training is required in the study area.

To this extent, this equipment was recommended to be introduced to all relevant Colleges, Departments, Institutes and Centres of the University for patronage. Also, it was recommended to be introduced to private horticulturalists and vegetable cooperative farmers in the rural and urban farming communities. The price was ₦200,000.0 as of 2015 which was within what some farming groups could afford to improve and increase their size of holdings, output and incomes.

Table 9: Field performance test for T560RS rotary cultivator.

Parameter	Plots I	Plots II	Plots III	Average
Length of plot (m)	10	10	10	10
Machine rated width (m)	0.78	0.78	0.78	0.78
Machine rated speed (km/h)	0.55	0.55	0.55	0.55
Working width of cut (m)	0.62	0.63	0.65	0.63
Depth of cut (plow depth) (m)	0.19	0.21	0.22	0.21
Average time taken per plot (min/plot)	1.18	1.20	1.13	1.18
Fuel consumption (L/ha)	49.25	47.50	46.50	47.75
Working speed (km/hr)	0.51	0.50	0.53	0.51
Theoretical field capacity (ha/h)	0.043	0.043	0.043	0.043
Effective field capacity (ha/h)	0.032	0.032	0.034	0.033
Machine field efficiency (%)	74.42	74.42	79.07	75.97
Soil moisture content before plow (%) (w.b.)	14.11	15.02	12.87	14.00
Soil moisture content after plow (%) (w.b.)	13.64	12.81	15.13	13.86

Table 10: Soil properties before tillage operation.

Depth (cm)	Bulk density (g/cm^3)			Average (g/cm^3)
	Plots I	Plots II	Plots III	
0-10	1.44	1.38	1.34	1.39
10-20	1.45	1.38	1.36	1.40

Table 11: Soil properties after tillage operation.

Depth (cm)	Bulk density (g/cm^3)			Average (g/cm^3)
	Plots I	Plots II	Plots III	
	1.31	1.24	1.30	1.39
1.35				
1.29	1.27	1.25	1.27	1.40

Table 12: Cone index before tillage.

Depth (cm)	Cone index kN/m^2			Average
	Plots I	Plots II	Plots III	
2.5	316	566	566	483
5.0	937	786	528	750
7.5	1,748	1,051	331	1,043
10.0	930	861	854	882
12.5	1,536	823	1,794	1,384
15.0	1,513	1,551	2,605	1,890
17.5	1,847	2,286	2,552	2,228
20.0	2,082	1,986	3,560	2,544
22.5	2,112	1,945	2,855	2,304

Table 13: Cone index after tillage.

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15.0	1,513	1,551	2,605	1,890
17.5	1,847	2,286	2,552	2,228
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22.5	2,112	1,945	2,855	2,304

2.5 Fishery and Aquaculture Production Equipment

Pond aeration and encaged floating systems were developed to sustain large quantities of fish and biomass materials. In these studies, prototype paddle wheel aerator and floating fish cages were developed from local materials.

2.5.1 Development of a paddle wheel aerator for small and medium fish farmers in Nigeria

During the past decade, pond aeration systems have been developed which will sustain large quantities of fish and invertebrate biomass. These aeration systems are modifications of standard wastewater aeration equipment. Paddlewheel aerator is surface aeration system which can be vertical shaft or horizontal shaft that is producing a large air-water interface for the transfer of oxygen from which atmosphere is enhanced. The importance and functions of aeration process is hereby highlighted by some investigators like Boyd (2003); Omofunmi, 2014; and Tucker (2005) include: it reduces the concentrations of ammonia, nitrites and carbon (iv) oxide, it increases pH level of pond water, it increases the carrying capacity of an aquaculture system, reduces fish mortality, it enhances fish reproduction systems, it reduces level of salinity especially during time of low rainfall, it increases pond productivity. It also it increases fish growth, it regulates water temperature especially as this can affect dissolved oxygen (DO) of aquatic, it is used to control thermal strati- fixation, and it prevents eutrophication in fishponds.

Adisa with a team of researchers in the Department of Agricultural and Bioresources Engineering, Federal University of Agriculture, Abeokuta, carried out the study of the importance and functions of aeration in fish production, and developed a prototype paddle wheel aerator with local materials Figures 25, and 26 (Omofunmi *et al.*, 2017). The main features of the paddle wheel aerator were electric motor used as prime mover which was of one horsepower capacity, and paddle hubs with six paddles all mounted on a shaft made of stainless steel and brass materials. Aeration experiment was conducted in water basin made up of plastic. Paddle-wheel aerator performance evaluation was conducted using unsteady state test. Physico-chemical properties of water sampled from the tested ponds were determined in accordance with the American Public Health Association standards (APHA, 2005),

Table 14. The machine was operated in circle and there was dissolved oxygen gradient in basin. Required paddle wheel aerator power was calculated by using equation 4.

$P = P_r b 2\pi r n$ .... (4) (John, 1995).

Where: P is power, kW.

P_r is resistance force to drive the paddle wheel, N

b is paddle wheel width, m.

Performance test carried out showed from Table 15 that the overall oxygen transfer co-efficient (K_La) was observed to be as high as 8.19 hr^{-1} and standard oxygen transfer rate (SOTR) and

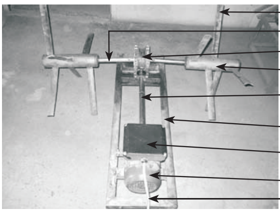

Fig. 25: Paddle-Wheel aerator.

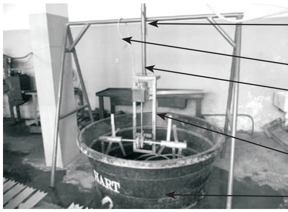

Fig.26: Mounted Paddle Wheel Aerator for Operation

Table 14**:** The quantity of Cobalt Chloride and Sodium Sulphite used per cubic metres for the deoxygenated volume of water

Volume (m^3)	Mass of Cobalt Chloride (g)	Mass of Sodium sulphate (g)
1	20	2,000
2	40	4,000
3	60	6,000
4	80	8,000
5	100	10,000
6	120	12,000
7	140	14,000
8	160	16,00

Table 15**:** Summary of Oxygen transfer coefficient, Standard Oxygen Transfer Rate (SOTR) and Standard Aeration Efficiency (SAE) for the Paddle wheel aerator

Volume of water (m^3)	Gradient	Oxygen transfer coefficient K_{La} (hr^{-1})	SOTR (kgO^2hr^{-1})	SAE ($kgO^2kw^{-1}hr^{-1}$)
1	0.16	8.19	1.30	1.34
2	0.14	7.20	1.29	1.30
3	0.13	6.65	1.25	1.27
4	0.11	5.56	1.21	1.23
5	0.09	4.65	1.19	1.19
6	0.08	4.18	1.11	1.17
7	0.07	3.52	1.10	1.15
8	0.06	3.08	1.09	1.13

Standard aerator efficiency (SAE) ranged from 1.1- 1.2 kg O^2 hr^{-1} and 1.1-1.3 kg O^2 kW^{-1} hr^{-1} respectively. The paddle wheel aerator improved the water quality by addition of oxygen leading to appreciable increase in the fish stock density which has been a major setback of low-income fish farmer in Nigeria. From Table 16, the machine was found effective and efficient at water volume equal to or less than 2 m^3 pond water. This device is recommended for modification to optimize its functions and for scaling up for the benefit of the large-scale fish industry.

Table 16: The effectiveness level, range and restrictive feature of the paddle wheel aerator

Effectiveness level	Range (m^3)	Restrictive feature
High	≤2	adequate supplied, equal distribution and mixing of dissolved oxygen with the system
Medium	2-5	supplied and provide mixing of dissolved Oxygen at nonuniformity in the system
Low	> 5	Dead zone and oxygen stratification occurred

2.5.2 Development and performance evaluation of a low-cost floating fish cages for aquaculture using locally available materials in Nigeria

The production of fish protein in aquacultural industry in Nigeria is limited due to problem of infrastructural development, crop farming, thereby hindering it from meeting the increasing demand of fish in this sector. Raising fishes in an existing water body using cage culture has been proven to be the best approach to meet this demand. Fish farming and farming of other sea animals started in many countries in the world not too long ago, taking Nigeria as example, it started about 50 years ago according to **Olagunju *et al.* (2007*)***, of which it is yet to meet its domestic fish production need for the masses.

Figure 27: Picture of imported fish cage system

Source:https://www.shutterstock.com/image-photo/fish-farm-sea-view-mountain-floating-414753016#

The development of a cage system made from local readily available materials is inevitable if the productions of fisheries would meet the demand in the nation with low income. Most of these fish farmers are of limited economical resources to acquire the big and costly imported cage system. This work developed a novel fish cage system, made from local and cheap sourced material of reasonable durability which was designed, fabricated, and evaluated.

Adisa et al. (2019) developed a low-cost floating fish cages using locally available materials. The developed cages were tested at Oyan dam situated in Abeokuta, Ogun State. Two cages were designed and constructed using bamboo stems and plastic drums as floating materials. The design considerations, assumptions and calculations catered for the frame, netting system, floating system, mooring system and anchor system. Physical and mechanical strength, durability, availability, affordability, and accessibility of the materials used were considered too. The dimension of the floating cage each was 2.0 x 1.1 x 2.0 m with two interlaced nets of mesh sizes 0.01875 m, to serve as protection and 0.00625 m of blue and white colour, to house the fishes. The data required to develop a low-cost floating fish cage for aquaculture are majorly the

environmental data as shown in Table 17.
In this research, various locally affordable materials were used for different sections of the cage. These materials include bamboo, high density polyethylene (HDPE) plastic drum, plastic gallons, fishing nets, marine ropes, dead weight, and twine. The criterion for selection was majorly based on their physical properties.

Frame is the structural skeleton of the cage. It helps to maintain the shape of the cage bag and also serves as a working platform. Bamboo stem was used for the framework in this design as shown in Figures 28, and 29 based on the characteristics for selection. The fish cage is rectangular in shape, the dimensions of the rectangle are length of 2.6 m by width of 1.7 m.

Table 17: Some Environmental Data for fish cage design

Items	Values
Water depth, (m)	4.0
Wind velocity, (m/s)	3.6
Current velocity, (m/s)	0.3
Horizontal component of wave particle, (m/s)	2.0

Source: Cardia and Lovatelli (2015), and FUNAAB Metrological Centre.

Calculated and designed are the following critical components:

- *Cages frames design calculations.*
- *The netting system and sinker*
- *The floating system:*
  - *Design of plastic as float*
  - *Design of bamboo stem as float*
  - *Design of mooring system*
  - *Static and dynamic forces acting on the cages.*
  - *Design of anchor system.*
- *Performance test of the cages carried out with two species of fishes, Tilapia and Catfish.*

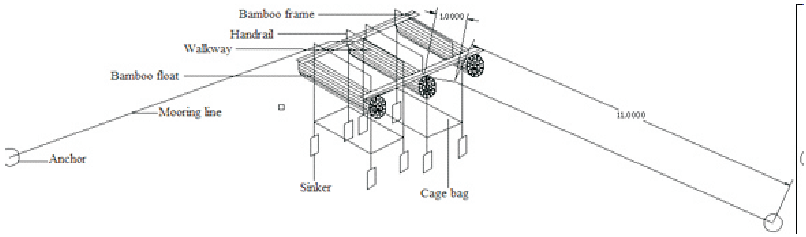

Figure 28: Isometric view of the designed bamboo float fish cage

Figure 29: The three types of net on the installed cage

Fig. 30: Plastic drum floating fish cages installed and anchored on Oyam dam, Abeokuta, Nigeria

Fig. 31: Bamboo floating fish cages installed and anchored on Oyam dam, Abeokuta,

Fig. 32: Team of researchers from FUNAAB inspecting installed floating fish cages on Oyan dam.

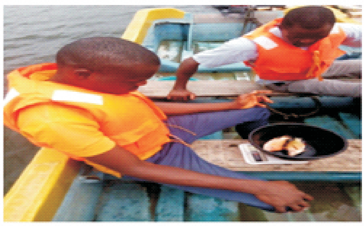

Fig. 33: Checking the average weight of stocked *O. niloticus* at the site.

This is the bedrock and core area in floating cage system. Buoyancy and stability of the cage is majorly determined by the floating material used. According to Vikash and Gunjan (2014), one of the major roles of the float is that it prevents the side of the cage exposed to the current from becoming submerged by the thrust of excessive current. Two floating materials namely, bamboo stems and plastic drums were selected for this research work. For an object to float on water according to Archimedes' principle, the total weight of that object at maximum load (TW_b) will be less than buoyant force (F_b).

Figures 30, 31, 32, and 33 show the assembling, installation and, anchored fish floating plastic and bamboo cages on Oyan dam at Abeokuta, Nigeria. Four hundred sample fish, each of ***Clarias gariepinus (Catfish)*** and *Oreochromis niloticus* (hybrid Tilapia), were cultured for 70 days from fingerlings of 5 and 1 g to an average of 259.19 and 131.70 g to test the functionality and performance of the cages after a no-load test of the cages for 30 days. The variations in the growth rate of fish species in both cages were monitored using a sensitive weighing balance. Plastic drum and bamboo stems used as floating materials that has a buoyancy of 0.184 kg and 800 kg respectively on water. It was observed that plastic drums impact more *buoyancy than bamboo stem, though it deteriorates faster due to direct heat of the sun, while bamboo stem as an organic plant absorbs water from its environment with time.*
Tables 18 and 19 show that more weight was gained in white nets than in blue nets. For the two breeds, a different gain of weight of 52.0 g was observed between white and blue net for *C. gariepinus* while for *O. niloticus,* 54.5 g difference within the period of breeding investigation which was analyzed statically using a t-test.

Table 18. Growth rate of *C. gariepinus*

No of weeks	No of hrs	No of minutes	No of seconds	White net (g)	Blue net (g)
1st	0	0	0	5	5
*2nd	168	10080	604800	No reading	No reading
3rd	336	20160	1209600	65	60.5
4th	504	30240	1814400	98.7	81.7
5th	672	40320	2419200	134.2	101.1
6th	840	50400	3024000	170.7	139.9
7th	1008	60480	3628800	211.3	168.1
8th	1176	70560	4233600	259.19	207.2

Table 19. Growth rate of *O. niloticus*

No of weeks	No of hrs	No of minutes	No of seconds	White net (g)	Blue net (g)
1st	0	0	0	1	1
*2nd	168	10080	604800	No reading	No reading
3rd	336	20160	1209600	15.2	11.4
4th	504	30240	1814400	37.7	23.6
5th	672	40320	2419200	53.2	35.1
6th	840	50400	3024000	79.1	47.5
7th	1008	60480	3628800	102.7	61.3
8th	1176	70560	4233600	131.7	77.17

A new indigenous fish floating cages system were developed from locally sourced materials; plastic and bamboo, were evaluated on full load condition of two fish species namely, *C. gariepinus and O. niloticus*. These cages were used successfully in raising the fishes in three months with no failure of the structure, the mortality rates showed that *O. niloticus* were found to have a better and adaptability rate over *C. gariepinus* and hence average farmer could conveniently and economically adopt this fish production. High mortality rates of 68.5 and 62% were recorded for *C. gariepinus* in white and blue nets respectively after about 24-120 hrs of stocking while *O. niloticus* had high adaptability rate with low mortality rate of 2.5% and 3.5% respectively from the white and blue net cages within same period. When compared with imported cage, the locally designed cage is estimated to be 70% cost effective. This study established that affordable floating cage can be achieved using locally sourced materials.

2.6 Agricultural Machinery Field Operation Performance Evaluation and Engineering Production Economics

Having a large fleet of farm equipment that are purchased and brought to use at various times (years) for various farm operations, they don't wear out at the same rate even though being maintained under the same workshop management system. Hence, there is need from time to time to carry out technical assessment of the equipment field operations performance to determine their overall effectiveness levels for the purpose of their optimum usage.

2.6.1 Technical assessment of agricultural equipment condition for sustainability

Zero hunger/No hunger is Sustainable Development Goal 2 (SDG2) of the United Nations General Assembly agenda to be achieved by 2030, (UN-GA, 2015). This study captured aspects of the SDG2 target of agricultural productivity for food production systems through monitoring and controlling the operating conditions of agricultural equipment. In general term, agricultural equipment productivity can be determined by ratio of outputs to inputs in the system, Dharmasiri (2013). This can also be measured by total factor productivity (TFP), whose changes are usually attributed to improvements in technology, such as the equipment management system.

Equipment utilization, availability, reliability, and maintenance are all factors that serves as performance indicators of sustainability for agricultural equipment for a functional and sustained agricultural mechanization system for sustained food production. The goal of sustainable agricultural business is to maximize output and minimize production downtime, (MaxGrip, 2022) by tracking equipment successes and failures from which the organization can develop informed recommendations on when equipment should be replaced, upgraded, or brought in for maintenance (Severino, 2019).

Equipment breakdowns exist in different degrees like partial or total breakdown which is the system, component, or device can no longer produce/perform desired operations in terms of quantity and quality even when the equipment is still running and producing, Limbecmms (2018). Machinery operational scheduling is determining the time periods during the year when each operation can be performed from the point where the required capacity can be calculated. An obsolete machine is one that is out of production and repair parts are no longer available and it can be replaced by another machine or method that will produce at a higher profit (Srivastava *et al*., 2006).

Adisa (2024) carried out a study at Sunti Golden Sugar Company (A subsidiary company of Nigeria Flour Company Plc), Niger State, Nigeria's 1,300 ha farm out of about total 15,000 ha land acquired for future expansion (a major source of the nation's sugar production/supply). It treated 120 equipment to obtain information to monitor and control data needed to reduce equipment maintenance costs, optimize expenditure on maintenance and minimize the total cost of the system, (Dunn, 2002) for 2017and 2018 cropping seasons. Figures 34 is a field fuel depot to ease field fuel supply while Figure 35 is a prepared field awaiting sugarcane planting and Figures 36 and 37 are the central workshop where major repair work is conducted.

Figure 34: Fuel depot at field workshop to ease fuel Supply to machines right on the field.

Figure 35: A field fully prepared for sugarcane planting.

Figure 36: Central workshop where several engines are being overhauled.

Figure 37: Some earthmoving equipment in central workshop awaiting repair.

It is possible for equipment to fail/breakdown in different degrees such as partial or total. To effectively monitor and control these failures/breakdowns, there are failure metrics to guide the process of determining equipment failures which are MTBF (mean time between failure), MTTR (mean time to repair), and MTTF (mean time to failure), Limblecmms (2018). Total operational time is expected equipment operating hours minus equipment downtime to calculate MTTR and MTBF, Limblecmms (2018). Calculations of equipment utilization, availability, reliability, and maintainability were based on labour hours spent on maintenance (time spent), number of breakdowns and repairs (downtime), operational time, equipment uptime data recorded for the period of field operation in question (2017 and 2018 cropping seasons).

Equipment utilization is referred to as the measurement of the use and performance of site machinery which assists businesses to improve jobsite productivity and reduce the cost of equipment rental and project delays. Equipment utilization was calculated using equation 5:

$$E_u\ (\%) = \frac{\text{equipment effective (operation)}\mathit{time}}{\text{total obtainable time}}\ x100 \quad (5)$$

Failure rate was calculated using equation 6 (ASAE EP456, 2015):

$$\gamma = \frac{\mathit{number\ of\ failures}}{\text{unit cumulative time}} = \frac{\mathit{total\ failures}}{\text{total time}} \quad (6)$$

Mean time between failures (MTBF) was calculated using equations 7 and 8 (Abernethy, 1996):

$$\text{MTBF} = \frac{\mathit{units\ of\ cumulative\ time}}{\mathit{number\ of\ failures}} \quad (7)$$

$$= \frac{\text{total operating } \mathit{time}}{\mathit{number\ of\ frequency}} = \frac{1}{\gamma} \quad (8)$$

Where: γ – failure rate

Mean time to repair (MTTR) was calculated using equation 9 (Abernethy, 1996):

$$\text{MTTR} = \frac{\mathit{total\ failure\ time}}{\mathit{number\ of\ failures}} = \frac{1}{\tau} \quad (9)$$

Repair rate was calculated by using equation 10 (Nkakini *et al*., 2008):

$$\tau = \frac{\mathit{restoration\ time}}{\mathit{duration\ of\ failures}} = \frac{1}{MTTR} \quad (10)$$

Where: τ – restoration time to duration of failures, i. e. repair rate.
An operational reliability value is equal to one minus the probability of downtime when both probabilities are expressed as decimals. Equipment reliability is the probability that the equipment will perform its intended function satisfactorily for a specified period under specified operating conditions (De Carlo, 2013). Two reliability figures of merit are the failure rate, and mean time between failures (MTBF), which is the inverse of the failure rate. Reliability of the equipment was calculated using equation 11 (ASAE EP456, 2015):

$$R(t) = e^{-\gamma t} \quad (11)$$

Where: e – base of the natural logarithm (2.7182)

γ – failure rate.

t – mission time, hr (Equipment operational time plus failure time)

Maintainability is the ease with which maintenance activities can be performed on an asset or equipment which is to measure the probability that a piece of equipment in a failed state can be restored to normal operating condition after undergoing maintenance. Maintainability of equipment was calculated using equation 12 (Nakajima, 1988):

$$M(t) = 1 - exp.^{-\tau t} \quad (12)$$

The availability of equipment and machinery is defined as the percentage of time it is operable and committable when needed which is the actual time that the machine or system is capable of production as a percent of the total planned production time. Equipment availability was calculated using equation 13 (Nkakini *et al*., 2008):

$$A = \frac{1}{1+\gamma\tau} \quad (13)$$

A total of 120 fleets of agricultural production equipment were analysed over the 2017 and 2018 cropping seasons for 1,300 ha farmland for their failure rate, repair rate, mission time, mean time between failure (MTBF), and mean time to repair (MTTR). The results of this were used to obtain Table 20, which provides clear indicators of each equipment operational state condition: utilization, reliability, maintainability, and availability, so that the management and ownership decisions of the system can assess their technical soundness and operational cost effectiveness.

Table 20: Crop cultivation equipment performance evaluation for the 2017 and 2018 cropping.
seasons

S/No	Equipment type / Model	Power rating, Kw	MTBF, hr	MTTR, hr	Equipment utilization, %	Equipment Reliability, %	Equip. Maintainability	Equipment Availabilitylaity, %
1	John Deer-01- 3050	67.6	92.59	8.00	28.2520	3.8427	1	92.0530
2	John Deer-02-2850S	64.0	0.73	8.00	8.2446	0	1	8.35580
3	John Deer-03-3050	67.6	151.52	8.00	33.4558	4.2500	1	94.9896
4	John Deer-04-4960	149.0	38.17	8.00	27.9220	0.0019	1	82.6923
5	John Deer-05-3050	67.6	48.31	8.00	27.7960	0.0286	1	85.7868
6	John Deer-06-3650	85.3	0.00	8.00	0	0	1	0
7	John Deer-08-2650	58.2	36.36	8.00	18.3467	0.2245	1	81.9820
8	John Deer-09-3350	74.6	232.56	8.00	31.8681	35.5410	1	96.6667
9	John Deer-10-3650A	85.3	0.32	8.00	1.6447	0	1	3.8760
10	John Deer-11-4960	149.0	1.83	8.00	8.4183	1.63E-124	1	18.6441
11	John Deer-13-8960	275.0	0.00	8.00	0	0	1	0
12	John Deer-14-8960	275.0	7.51	8.13	36.0537	6.415E-83	1	47.9725
13	John Deer-29-8970	298.4	6.68	6.62	38.7640	4.84E-106	1	50.1818
14	John Deer-30-8970	298.4	59.17	9.43	67.1296	8.511E-10	1	86.3095
15	John Deer-31-8970	298.4	12.33	8.00	18.2086	1.82E-09	1	60.6557
16	John Deer-36-8970	298.4	92.59	10.64	62.0989	0.0015	1	89.7585
17	John Deer-44-7225J	168.0	212.77	9.17	73.7599	0.0675	1	95.8736
18	John Deer-45-7225J	168.0	7.94	8.06	38.3928	3.962E-79	1	49.6941
19	John Deer-46-7225J	168.0	7.80	8.00	32.6675	6.575E-56	1	49.3671
20	Bell Tract- 47-1734AF	224.0	1.00	0.00	61.8783	100.00	1	100.00000
21	Valtra Tract-15-T171	134.0	3.49	8.00	15.1098	9.097E-89	1	30.3867
22	Valtra Tract-16-T171	134.0	42.19	9.01	67.5925	9.833E-19	1	82.4859
23	Vatra Tract-17-T171	134.0	0.00	8.00	0	0	0	0
24	Valtra Tract-18-T171	134.0	151.52	8.00	52.6724	1.4854	1	95.0233
25	Valtra TracT-19-T191	141.0	15.72	8.00	39.9088	2.766E-24	1	66.2703
26	Valtra Tract-20-T191	141.0	0.00	0.00	41.3065	100.0000	0	100.00
27	Vatra Tract-21-T191	141.0	3.02	8.00	12.7840	7.64E-105	1	27.4205
28	Valtra Tract-22-T191	141.0	0.00	0.00	38.3445	100.0000	1	100.000
29	Valtra Tract-23-T191	141.0	6.41	8.00	13.9880	6.012E-31	1	44.4795
30	Valtra Tract-24-T191	141.0	0.00	0.00	36.4297	100.0000	0	100.00
31	Valtra Tract-25-A950	71.0	0.00	8.00	0	0	1	0
32	Valtra Tract-26-A950	71.0	526.32	8.00	38.4943	36.2489	1	98.5455

33	Valtra Tract-27-A950	71.0	0.00	0.00	40.0390	100.000	0	100.000
34	Valtra Tract-28-A950	71.0	454.55	8.00	29.7872	36.1369	1	98.2456
35	Valtra Tract-31-T191	141.0	0.00	0.00	0	0	0	0
36	Valtra Tract-32-T191	141.0	769.23	5.99	46.7289	36.5131	1	99.2556
37	Valtra Tract-33-T191	141.0	33.11	8.00	40.3571	8.191E-07	1	80.5574
38	Valtra Tract-34-BM125i	98.4	2.58	8.00	22.8346	4.08E-159	1	24.3698
39	Valtra Tract-35-BM125i	98.4	270.27	8.00	39.2241	12.7632	1	97.1530
40	Valtra Tract-37-T191	141.0	208.33	9.26	44.0148	1.5328	1	95.7373
41	Valtra Tract-38-T191	141.0	0.00	0.00	62.8780	100.0000	0	100.0000
42	Valtra Tract-39-T191	141.0	0.00	0.00	39.375	100.0000	1	100.000
43	Valtra Tract-40-T191	141.0	0.00	0.00	75.5	100.0000	1	100.000
44	Valtra Tract-41-T191	141.0	833.33	9.00	50.7138	36.3951	1	98.9378
45	Valtra Tract-42-T191	141.0	714.29	8.00	45.4189	36.3663	1	98.8604
46	Valtra Tract-43-T191	141.0	0.00	0.00	48.5665	100.00	0	100.000
47	Valtra Tract48- T194H	298.0	0.00	0.00	72.8078	100.00	0	100.000
48	Bulldozer-01-D7G	164.0	10.78	8.00	23.6816	8.921E-33	1	57.3965
49	Bulldozer-02-D7G	164.0	12.69	8.00	44.7704	1.546E-57	1	61.2922
50	Bulldozer-03-D7G	164.0	81.97	8.06	45.3125	0.0002	1	91.0434
51	Bulldozer-04-D7G	164.0	87.72	8.20	70.05	2.521E-06	1	91.4491
52	Bulldozer-05-D7G	161.0	84.75	8.00	65.4494	0.0006	1	91.3726
53	Bulldozer-06-D8R	245.0	13.11	8.06	32.0652	1.219E-17	1	61.9965
54	Bulldozer-07-D8R	245.0	0.00	8.00	0	0	0	0
55	Bulldozer-08-D8R	245.0	5.83	8.00	17.6005	5.55E-42	1	42.1687
56	Bulldozer-09-D8R	245.0	0.67	8.70	6.70872	0	1	7.1691
57	Bulldozer-10-D8R	245.0	0.12	8.47	1.3816	0	1	1.4132
58	JD Cane loader-01-BELL	49.0	238.10	8.00	24.3853	35.5719	1	96.7480
59	JD Cane loader-02-BM100	74.6	0.89	8.00	9.2634	0	1	10.0363
60	JD Cane loader-03-BM100	74.6	92.59	11.76	36.3281	0.3573	1	88.7405
61	JD Cane loader-04-BM100	74.6	22.08	8.00	8.125	1.6807	1	73.4219
62	JD Cane loader-05-1850	78.0	0.00	0.00	47.2994	100.00	0	100.00
63	JD Cane loader-06-1850	78.0	0.00	0.00	67.5336	100.00	0	100.00
64	JD Cane loader-07-EU6	164.0`	0.00	0.00	76.6542	100.00	0	100.00
65	Crane truck-03-JIAN HUAN		0.00	10.31	0	0	1	0
66	Cane truck-04-BEDFORD		0.00	10.31	0	0	1	0
67	Cane truck-05-IVECO	307.0	0.00	8.00	0	0	1	0
68	Cane truck-06-HOWO	251.0	0.15	8.00	0.5769	0	1	1.8405
69	Crane liebher-60T-LIEBHER	270.0	33.56	8.00	73.5825	7.22E-08	1	80.7638
70	Crane liebher-70T	330.0	103.09	8.00	81.4474	0.1557	1	92.8036
71	Motor grader-01-140H	138.0	0.00	8.00	0	0	1	0
72	Motor grader-02-140H	138.0	10.25	8.47	42.0982	1.205E-71	1	54.7937
73	Motor grader-03-140H	138.0	0.00	8.00	0	0	1	0
74	Motor grader-04-140H	138.0	78.13	10.20	66.6382	1.513E-08	1	88.4485
75	DP-03	45.0	0.00	8.00	0	0	1	0
76	Tipper lorry-01-MP380E38H EURTRAKKER	283.0	35.84	8.00	59.4406	8.016E-09	1	81.7308
77	Tipper lorry-02- MP380E38H EUROTRAKKER	283.0	344.83	8.00	62.3188	12.918476	1	97.7273
78	MP380E38H Tipper lorry-03	283.0	0.00	8.00	0	0	0.8	0
	Tipper lorry-04- MP380E38H							

79	EUROTRAKKER Tipper lorry-05-MP380E38H	283.0	2.93	8.00	8.3970	2.741E-47	1	26.8293
80	EUROTRAKKER Tipper lorry-06-MP380E38H	283.0	6.30	8.00	34.8993	9.038E-64	1	44.0678
81	EUROTRAKKER Tipper lorry-07-MP380E38H	283.0	2.34	8.00	19.5489	1.09E-169	1	22.6087
82	EUROTRAKKER	283.0	3.95	8.00	11.1281	2.255E-47	1	33.0317
83	Roller compac. -01-CP563E	108.0	0.00	8.00	0	0	1	0
84	Roller compac. -02- CP563E	108.0	0.00	8.00	0	0	1	0
85	Roller compac. -04-CS563E	108.0	2.57	8,26	21.6634	2.44E-308	1	23.7057
86	Roller compac. -05-CS563E	108.0	0.02	8.00	0.2577	0	1	0.2755
87	Roller compac. -06-CS563E	108.0	8.91	9.80	27.7237	3.052E-57	1	47.5
88	Excavator-01-325C	141.0	34.60	8.00	41.5240	3.28E-06	1	81.2395
89	Excavator-02-320DL	97.0	68.97	8.55	63.4868	1.458E-05	1	88.9401
90	Excavator-03-320DL	97.0	0.32	8.00	3.8961	0	1	3.8961
91	Excavator-04-325C	141.0	8.62	8.00	27.5	1.049E-29	1	51.8699
92	Excavator-05-325C	141.0	62.11	8.62	58.5481	1.299E-09	1	87.7656
93	Excavator-06-325C	141.0	0.00	8.00	0	0	0	0
94	Excavator-07-325D	141.0	0.00	8.00	0		1	0
95	JCB Backhoe-01-3CX	55.0	5.18	7.14	18.1429	2.49E-49	1	42.0530
96	JCB Backhoe-02-3DX	68.0	23.26	9.09	36.3281	4.448E-18	1	71.8147
97	JCB Backhoe-03-3DX	68.0	1000	8.00	66.9837	36.4907	1	99.1952
98	JCB Backhoe-04-4CX	74.6	14.37	8.20	46.3294	4.917E-43	1	63.7108
99	Ditch witch-01	45.0	0.00	8.00	0	0	1	0
100	Ditch witch-02	45.0	6.00	8.00	9.375	7.13E-10	1	42.8571
101	Ditch witch-03	45.0	5.00	8.00	7.8125	3.795E-11	1	38.4615
102	DP-02	45.0	0.00	8.00	0	0	1	0
103	TelehandlerTH-01-TH460bB	55.0	8.94	8.00	42.4051	4.047E-48	1	52.7559
104	ST-01	65.0	0.00	0.00	42.6073	0	0	0
105	Hydra Crane-01-15XW	80.9	666.67	8.00	56.3758	36.3526	1	98.8235
106	Hydra Crane-02-15XW	80.9	2.29	8.00	19.5565	1.88E-246	1	22.2647
107	Forklift-02	40.0	0.00	0.00	100.00	100.00	0	100.00
108	Forklift-03-7FDU30, 3 tons	40.0	19.16	8.00	70.5263	5.726E-16	1	70.5263
109	Forklift-04-DP35N,3.5 tons	40.0	9.60	8.00	30.6122	1.244E-18	1	54.5455
110	Forklift 05 DP30N, 3 tons	40.0	3.78	8.00	26.5777	2.769E 77	1	32.0644
111	Forklift-06-DP30N, 3 tons	40.0	31.75	8.00	68.0556	5.677E-08	1	79.8519
112	Forklift-32T-SVE TRUCK	40.0	21.28	8.00	54.4034	1.752E-09	1	72.6755
113	Wheel loader-01-938G	134.0	0.07	8.00	0.7143	0	1	0.9174
114	Wheel loader-02-938G	134.0	0.02	8.00	0.2737	0	1	0.2750
115	Wheel loader-03-950H	162.0	14.35	8.00	44.8171	1.825E-26	1	64.1921
116	Wheel loader-04-950H	162.0	68.97	8.00	62.7016	0.0044	1	89.6254
117	Wheel loader-05-928G	116.0	9.97	8.00	50.3989	1.817E-28	1	55.4905
118	Wheel loader-06-928G	116.0	37.45	8.00	77.9167	0.0005	1	82.3789
119	Fuel Bowser-05	52.2	0.00	0.00	0	100.00	0	100.00
120	Fuel Bowser-06	52.2	0.00	0.00	0	100.00	0	100.00

The data in Table 20 column 6 shows the calculated values of fleet utilization, which ranged from zero to 81%. This gives the knowledge of how equipment utilization helps to:

(i) Minimize equipment hoarding and get it to the job site as needed.

(ii) Prevent machines sitting unused on sites, eating up maintenance costs while contributing nothing to the project.

(iii) Enhance uptime with an effective maintenance schedule and identify machine underutilization for manager's management planning.

The evaluation of mixed fleets of equipment was found to be useful for evaluating the operational level of individual equipment and machine fleets.

Table 20 column 7 shows the results from the reliability calculation for equipment which were as low as 36.50% and even in some cases as low as zero. This is the percentage of what was okay for the period in question. The inverse of this is the percentage of its failure at the given time. Equipment with a zero-reliability level is not dependable for operational work in the field. Differentiating availability from reliability, reliability differs from availability by quantifying the probability that equipment will work as intended without any failures. This is in contrast with just measuring the time it is in operation.

The equipment being evaluated here are repairable types, hence there was need to determine the state of the technical soundness condition of each equipment or maintainability level of each of them at the time in question which varied between being in functioning state (1) or at failure state (0) as shown in Table 20 column 8 (INFRALERT, 2016). Most of the equipment maintainability values were 1, indicating that the equipment was functioning at the time of evaluation. Very few equipment maintainability value was 0, an indication that some equipment was in failure state at the time of evaluation. By interpretation, a lower mean time to repair would correspond to a higher level of maintainability and conversely, maintainable equipment takes less time to repair. Maintainability picks up where reliability might fall short. While reliability characterizes how long an asset can operate without issues, maintainability describes the likelihood that the same asset can be restored once a failure occurs.

Table 20 column 9 shows the calculated equipment availability during the 2017 and 2018 cropping seasons' operation. It showed, good values of 100% except for a few cases where equipment was down throughout the seasons. As a result, it helps monitor and control equipment availability, as well as reduce downtime to a minimum. However, planned downtime must be used to take initiative-taking measures to keep equipment in efficient working order.

Generally, it can be said of the fleets of these 120-equipment assessed, that maintainability was easier to improve because of proper documentation of repair procedures (historic repair records) and availability of repair tools and materials which could significantly reduce the time it takes to restore broken down equipment. All these factors will improve availability and reliability and decrease downtime of equipment and help determine which ones to be retained, replaced, or traded off. In Table 19, the combined values of reliability and maintainability shows a clear level of availability, which is in accordance with De Carlo (2013).
For crop cultivation, establishment, weed control up to harvesting and transporting to the post-harvest processing store, tractor power and machinery size must match in terms of row spacing and tramline width to reduce soil compaction over time (Adisa, 2012). The headland or trace size for appropriate connected tractor and implement length to reduce turning time must be determined in-place for each block of field.

The use of a cropping field operations calendar is essential for crop and operational sequencing and should be put in place since crop and operational periods overlap. Resources like fuel and oil, equipment spare parts, fertilizer, insecticides, herbicides, and their availability are limiting factors to be considered as well (Kepner et al., 2005).

During planned equipment downtime, major repairs and maintenance are to be conducted before critical field operation periods to improve pre-field and in-field efficiency (Deere, 1984). Proper breakdown communication reporting and daily record of every equipment operation will improve machinery performance efficiency (Adisa, 2012).

This unit is overly critical for releasing and allocating equipment periodically to various sections. A range of operations will be allocated based on the equipment budget, machinery costs/hour, and the size of the field section's jobs. Now it will be left for Sectional Manager to effectively use, monitor to minimize equipment time lost to the barest minimum and proper reporting and recording of the equipment uptime and downtime.

A central laboratory was needed for the following reasons. The soil is the major component of crop cultivation and because there is always a long-term effect of mechanical tillage, chemical application and equipment continuous traffic on soil texture and structure, adequate technical precautions must be put in-place from the start. Hence, a soil map and periodic soil survey and analysis are needed to determine soil texture and structure condition, soil nutrient level, soil tilth condition and chemical component level. The outcome of this information includes, aside from normal soil preparation practices, special soil preparation, the amounts and types of additional nutrient supplementary and soil treatment required, disease control and a few others. Also crop breeding for improved, adaptable, higher yielding, drought, disease resistance

varieties must be developed for commercial production.
It can be summarized, that among the calculated values, equipment utilization ranged from 81% to 0%, availability from 100% to 0%, and reliability from 36% to 0%. Additionally, there were maintainability values of 1 (functioning state) and 0 (failure state) for 120 equipment fleets assessed for the cropping seasons. Most of the equipment was well utilized, readily available, reliable, and easy to maintain, while few were underutilized, unavailable, unreliable, and difficult to maintain. All these factors help to improve availability and reliability and decrease equipment downtime for higher agricultural operational productivity. This technical soundness and operational overall effectiveness assessment was crucial to decide what equipment to retain, replace, or trade off.

2.6.2 Crop - machinery management system for field operations and adopted planning techniques for plantation sugar cane production

Agricultural mechanization must be seen in the context of a broad agricultural development strategy whose objectives are likely to be agricultural productivity to increase the sector's contribution to economic growth and security; increase rural welfare, income, employment, living standards and poverty alleviating; achieving social modernization, attitudes and behaviour. Agricultural operation maximum profitability is possible with good knowledge of agricultural machinery management to eliminate costly mistakes for optimum system cost, Deere (1984).
Farm mechanization major objectives are to maximize production at minimum risks by good management planning and operation of machines to carryout sequence crop production operations for the whole farming system (Yousif *et al*., 2013). This requires study of relationship and identification of crop to be cultivated, operations, machines and weather which can control machine capacity in-term of width, speed, field efficiency, and selecting appropriate

implement within time availability (Yousif *et al*., 2013). The goal of good crop-machinery management is to have a system that is flexible enough to adapt broad range of weather, soil and crop conditions at minimal long-run costs and production risks, Edward (2017).

Adisa and Eberendu (2021) carried this study on what were needed at Sunti Golden Sugar Company, Nigeria to determine cost of equipment use and select appropriate tractor power and machinery for the crop cultivation, crop establishment, weed control, cane harvesting and transporting to the store for post- harvest processing for a farm target size of 4,770 ha of sugar cane. Factors considered are machinery performance to carryout operations, running/operational costs, size selection, operational timeliness like tillage, planting and harvesting dates effect on production, field capacity, matching tractor power and implement size, operational scheduling for optimum output, Edward (2017).

This section dealt with farm equipment requirement determination for implements and source of power, tractor, (Srivastava *et al.*, 2006; ASAE, EP493, 2006; ASAE, EP496.2, 1999 and ASAE, D4977, 2011). This was determined by using operations required, area to be covered per unit time and implement type specified for the crop production procedure which consist of machinery selection, power requirement and machinery costs (Yousif *et al*., 2013). The available period for land preparation at Sunti Golden Sugar was from October to April of the following year with December as break (6 months). The daily field day work starts from 8:00 am to 3:00 pm with one hour break (6 hours) from Monday to Saturday (6 days) and operates four weeks in a month at peak period of operations. The target area to be covered is 4,770 ha out of 15,070 ha for future expansion of the total land acquired for the sugar cane plantation. The equipment selection was based on yearly ratoon/newly developed replanting of 1,000 ha for ripping, deep plow and row marking of fields.

The tractor power and machinery size for the crop cultivation, crop establishment, weed control up to harvesting and transporting for the post- harvest processing store were determined to match each other in terms of row spacing and established tramline to reduce long time soil compaction problem, Adisa, (2010). The headland or trace size for appropriate connected tractor and implement length to reduce turning time must be put in-place for each block of field. A well- drawn cropping field operations calendar was very important for crop and operational sequencing and be put in-place since the operations are overlapping with multi-periods. Resources like fuel and oil, equipment spare parts, fertilizer, insecticides, herbicides and their availability are limiting factors to be considered (Kepner *et al*, 2005). Figures 38, 39, 40, and 41 are various activities and equipment on the farm site.

Fig. 38: Field being manually planted by both female and male labourers.

Fig. 39: An earth canal for surface irrigation

Fig. 40: A pivot irrigation system

Fig. 41: Pump station for surface irrigation station.

Based on agricultural field operational planning factors like soil, weather and environmental conditions, appropriate implement matched with tractor calculations were carried out to obtain Tables

21, 22, 23, and 24. Determined are the values of each implement field capacity within allotted time available, actual number of implement/tractor power required, fuel and oil consumption per unit time for the sugar cane cultivation, harvesting and transporting operations at the sugar cane farm. Also, appropriate earthmoving and earthwork equipment for road, irrigation and drainage structural works were also selected.

Table 21. Recommended Machinery and Capacity Operation Requirement for Sunti Sugar cane 4,770 ha

	Implement/Operation											
	Implement Specifications							Owners Costs	Operating / Timeliness Costs			Total Costs
S/ No	Implement/ Equipment Operation/power required, kW	Time avai. mont	Field capacit yare, ha/h	Field capacit materia t/h	Total implem. capacity required width, m or ton.	Num of imp. req.	Estimated Purchase price, (N)	Total annual owners. cost, N/ha	Cost of oil cons. med, N/h	Repair and mainten.c ost, N/ha	Time liness penalty cost, N/ha	Total operating costs N/ha
1	Ripping, Subsoiler/165.56	3	2.31		4.40/3.00	2	6,360,000	1,399.20	51.41	4,699.56	29,739.2 5	34,490.22
2	Deep plow/293.87	4	1.74		3.31/2.50	2	20,400,000	4,488.00	95.62	11,934.0	23,791.4	40,309.02
3	Rome harrow,28'' Dia./5.6m/123.00	4	3.48		6.62/5.60	2	11,200,000	2,464.00	54.14	6,552.00	28,371.2	37,441.39
4	Row marking/38.98	4	1.74		2.84/3.00	1	2,708,500	595.87	32.26	1,644.06	23,791.4	26,063.59
5	Selfpropelled cane planter-ACME 2AZ-2/131.13	4	8.28		23.01/3.0	8	22,250,000	4,895.00	60.48	16,682.9	31,438.6	53,076.98
6	Valtra Mould former-BT MP2/145.83	4	8.28		11.83/3	4	2,504,110	115.49	6.29	318.66	23,791.4	24,231.84
7	Fertilizer Spreader/74.60	2	16.57		33.83/4.5	8	7,500,000	345.91	9.69	1,255.51	31,438.6	33,049.74
8	Row crop cultivator, weeder/67.14	2	16.57		22.09/4.5	5	2,848,500	131.38	7.38	362.47	28,371.2	28,872.48
9	Boom sprayer ALFA 1000/106.81	2	16.57		36.40/18	2	2,970,000	136.98	12.22	432.46	37,490.5	38,072.24
10	JD. Cane Harvester 3520/251.00	4	8.28	578.08	13.77/3	5	80,465,000	3,508.75	25.77	6,778.03	149,962.	160,274.87
1	JD Cane loader 6068T/138.00	4	8.89	578.08	333,000/40 ton/h	13	51,198,000	10,649.1	62.21	4,636.80	69,864.3	85,212.53
12	Cane wagon transporter/72.76	4	8.89	578.08	333,000/15 ton/load	33	5,775,000	251.82	7.99	959.50	69,864.3	71,083.65
13	Cane stubble shaver/ratoon manager/86.27	As req.	1.50			As req	2,298,407	1,011.30	45.50	6,870.14	35,491.1	43,418.04
14	Sugar cane sett cutter/ chopper/65.52	As req.	5.55			As req	44,787,727	18,631.7	35.14	52,934.5	12,065.6	83,667.03
15	Bowser- FKWT 3000L/52.20	As req.	3000L/ load		3000L/ load	As req	2,385,000	524.70	30.53	1,030.32		1,585.55
16	Cane loader BM100/74.60	As req.	8.89	578.08		As req	25,000,000	5,200.00	38.02	10,800.0	69,864.3	85,902.36
17	Cane loader Bell/49.00	As req.	5.39	350.33		As req	24,000,000	4,992.00	29.38	10,368.0	115,230.	130,620.17
18	Cane loader 1850/78.00	As req.	8.89	578.08		As req.	40,000,000	8,320.00	39.17	17,280.0	69,864.3	95,503.51

Note please: Nigeria Naira to USD at time of study was N385 to $1.

Table 22: Recommended Machinery Cost of Field Equipment for Sunti Sugar cane 4,770 ha

		Tractor/Prime mover						
		Power Ratings		Owner ship Costs	Operating Costs			Total Costs
S/No	Implement/ Equipment Operation/power required, kW	Equipment/ power, kW	Estimated Purchase price, (N)	Total annual ownership cost, N/ha	Cost of fuel cons., N/ha	Cost of oil cons. N/ha	Repair and maintena. cost, N/h	Total operating costs N/ha
1.	Ripping, Subsoiler/165.56	J. D. tract. 7225J/168.00	48,000,000	10,416.00	2,807.14	52.27	20,736.00	33,959.14
2.	Deep plow/293.87	J.D.Tract, 8970/298.00	88,000,000	19,096.00	7,456.32	114.05	38,016.00	64,682.37
3.	Rome harrow, 28'' Dia./5.6m/123.00	Valtra med. tractor, T171/134.00	30,000,000	6,517.50	3,359.23	58.18	12,960.00	22,894.91
4.	Row marking/38.98	J.D. tract. 2650/58.20	13,000,000	2,886.00	724.03	32.26	5,616.00	9,258.29
5.	Selfpropelled cane planter ACME-2AZ2/131.13	Valtra Tract. T191/141.00	35,000,000	7,603.75	3,162.24	60.48	15,120.00	25,946.47
6.	Valtra Mould former BT-MP2/145.83	J. D.Tract. 4960/149.00	45,000,000	1,962.26	922.75	13.31	4,075.47	6,973.79
7.	Fertilizer Spreader/74.60	Valtra Tract. BM- 125i/98.40	23,480,000	1,026.25	420.72	9.69	2,126.49	3,583.15
8.	Row crop cultivator, weeder/67.14	J.D.Tractor 3350/74.60	17,000,000	791.19	1,025.11	432.78	1,539.62	3,788.70
9.	Boom sprayer ALFA 1000/106.81	Valtra Tract. T171/134.00	30,000,000	1,366.35	412.73	12.22	2,716.98	4,508.28
10.	JD. Cane Harvester 3520/251.00	Self prop./ 251.00	80,465,000	3,508.75	2,048.41	25.77	6,778.03	12,360.96
11.	JD Cane loader6068T/138.00	JD Cane loader6068T/138.00	51,198,000	10,649.18	1,931.93	62.21	22,117.54	34,760.86
12.	Cane wagon transporter/72.76	J.D. Tract. 3350/74.60	17,000,000	791.19	366.27	7.99	1,539.62	2,705.07
13.	Cane stubble shaver/ratoon manager/86.27	Valtra Tract. BM 125i/98.40	23,480,000	9,790.38	2,108.16	46.08	20,286.72	32,231.34
14.	Sugar cane sett cutter/ chopper/65.52	J.D. Tract. 3050/67.60	44,787,727	18,631.70	1,546.56	35.14	52,934.55	73,147.95
15.	Bowser- FKWT 3000L/52.20	John Deere tractor, 2650/58.20	13,000,000	2,886.00	1,594.94	30.53	5,616.00	10,127.47
16.	Cane loader. BM100/74.60	Cane loader BM100/74.60	25,000,000	5,200.00	2,083.97	38.02	10,800.00	18,121.99
17.	Cane loader. Bell/49.00	Cane loader Bell/49.00	24,000,000	4,992.00	824.26	29.38	10,368.00	16,213.64
18.	Cane loader. 1850/78.00	Cane loader 1850/78.00	40,000,000	8,320.00	2,139.26	39.17	17,280.00	27,778.43

Note please: Nigeria Naira to USD at time of study was N385 to $1.

Table 23: Sunti Sugar cane 4,770 ha Recommended Machinery Capacity and Cost of Self-propelled Field Equipment Operation Requirement for Earthworks

	I Implements								
	Implement Specifications				Ownership Costs	Operating /Timeliness Costs			Total Costs
S/No	Implement/Equipment/ power required, kW	Eq. cap., area. ha/h	Number of imp. req.	Estimated Purchase price, (N)	Total annual ownership cost, 1000 , N	Cost of fuel consumed, N/h	Cost of oil cons., N/h	Repair and maint. cost, N	Total cost, N/h
1.	Cat. Bulldozer D7G/164.00		As required	150,000,000	31,200.00	7,773.00	119.00	115,200.00	154,292.00
2.	Cat. Bulldozer D8R/245.00		As required	200,000,000	41,600.00	11,694.00	166.00	153,600.00	207,060.00
3.	Amphibious excavator SWEA220/69.60	0.10	As required (50 ha/yr)	48,147,500	10,014.68	2,820.00	63.00	36,977.28	49,874.96
4.	Ditch witch implement RT55/42.00	0.07	As required (25 ha/yr)	25,600,000	5,324.80	1,491.00	47.00	11,059.20	17,922.20
5.	Excavator 325C/141.00	0.08	As required (25 ha/yr)	60,000,000	12,480.00	6,093.00	105.00	46,080.00	64,758.00
6.	Excavator 320L/97.00	0.06	As required (25 ha/yr)	65,000,000	13,520.00	4,617.00	79.00	49,920.00	68,136.00
7.	Excavator JS2052C/106.00	0.07	As required (25 ha/yr)	55,000,000	11,440.00	4,542.00	84.00	42,240.00	58,306.00
8.	Motor grader 140H/138.00		As required	103,846,000	21,599.97	6,567.00	103.00	79,753.73	108,023.70
9.	Compactor VM116drum/85.00	1.47	As require (10 ha/yr)	29,500,000	6,136.00	4,047.00	72.00	12,744.00	22,999.00
10.	Paywheel loader 432ZX/112.00	1.81	As required	49,000,000	10,192.00	5,289.00	88.00	21,168.00	36,737.00
11.	Backhoe loader JCB 3DX/68.60	1.76	As required	45,000,000	9,360.00	3,264.00	62.00	19,440.00	32,126.00
12.	Backhoe loader JCB 3CX/55.00	1.70	As required	40,000,000	8,320.00	2,619.00	54.00	17,280.00	28,273.00
13.	Backhoe loader JCB 4CX/74.60	1.74	As required	48,000,000	9,984.00	3,060.00	66.00	20,736.00	33,846.00

Note please: Nigeria Naira to USD at time of study was N385 to $1

Table 24: Cropping Calendar for 4,770 ha Sugar cane Cultivation

S/No	Operation	Cover. area, ha	Oct., h	Nov., h	Dec., h	Jan., h	Feb., h	Mar .h	Apr., h	May, h	June h	July, h	Aug., h	Sept., h
1.	Ripping	1,000	72	144	72	144								
2.	Deep plow	1,000	36	144	72	144	144	36						
3.	Harrow	1,000		144	72	144	144	72						
4.	Row marking	1,000		144	72	144	144	72						
5.	Cane planting	1,000		144	72	144	144	72						
6.	Bedforming/ earth-up	4,770		72	72	144	144	144						
7.	Ratoon cane stubble shaver/manager	500		72	72	72	72							
8.	Fertilizer broadcasting	4,770		36	36	36	36	36	36	36	36			
9.	Herbicide spraying	4,770			36	36	36	36	36	36	36	36		
10.	Row crop cultivating/ weeding	4,770				72	72	72	72					
11.	Irrigation/drainage	4,770		As req.	As req.	As req.	As req.	As req.	As req.	As req.	As req.	As req.	As req.	As req.
12.	Cane harvesting	4,770		144	72	144	144	72						
13.	Cane loading	4,770		144	72	144	144	72						
14.	Cane transporting	4,770		144	72	144	144	72						
			108	1,332	792	1,512	1,368	756	144	72	**72**	36		

This study was able to determine appropriate tractor power matched with machinery for the crop cultivation, crop establishment, weed control up to harvesting and transporting for the post- harvest processing store for 4,770 ha of sugar cane production. This was made possible based on agricultural field operational planning factors like soil, weather, and environmental condition, implement and appropriate matching tractor calculations. As part of the recommendation, during the planned equipment downtime, major repairs and maintenance were also to be carried out before critical field operations' period to improve pre-field and in-field efficiency for effective equipment and field operational planning and management.

3.0 CONCLUSIONS

Mr. Vice Chancellor, agricultural machinery engineering is a key to accomplishing sustainable national food security and industrial development in a nation like ours, Nigeria. Mechanized farm operations are means of encouraging youth participation in crop and livestock production, thereby increase income earnings from agricultural production, improves living standard of rural dwellers, increase technical skills of farming operators, better healthy condition just to mention a few. The range of research work carried out span from development of equipment for tillage, planting (which indeed offer numerous benefits) including increased output efficiency, reduced labour costs, and potentially higher yields. Crop harvesting by machine plays a crucial role in modern agriculture by improving efficiency, reducing labour requirements, and optimizing yield and quality. Post-harvest processing in order to add value to harvested crops, instrumentation development, fishery and aquaculture production, water supply, and agricultural machinery field operation performance evaluation and engineering production economics. From the foregoing, the conclusions from this lecture are the followings:

The adoption of precision row crop planters in Nigeria has the potential to transform the planting process, making it more efficient, cost-effective, and productive. As agricultural technology continues to advance, integrating precision planting equipment into farming practices can help Nigerian farmers overcome challenges and achieve sustainable agricultural growth.

The development of a "stripper rotor" in a harvester machine is a fascinating example of agricultural machinery innovation. This mechanism indeed integrates multiple functions into one operation, streamlining the harvesting process, increasing efficiency, saving time and cost of labour for farmers. Additionally, it can contribute to reducing losses and preserving the quality of the harvested crop.

Designing a small capacity roller rice dehusking machine involves several considerations, especially when aiming to minimize power requirements, incorporate additional units like destoning and grain metering, and accommodate alternative power sources such as petrol engines and electricity. By carefully considering these aspects during the design process, you can develop a small capacity roller rice dehusking machine that meets performance requirements while minimizing power consumption and incorporating additional features for improved functionality.

Designing a dynamometer using a bicycle epicyclic gear from locally available resources, an instrumentation, particularly the Sturmey Archer hub type, presents a practical and resourceful approach. By leveraging the advantages of bicycle epicyclic gears, particularly those from Sturmey Archer, in the design of the dynamometer, engineers can create a reliable, cost-effective, and locally sourced solution for measuring power output in various applications. This approach demonstrates resourcefulness and innovation in utilizing readily available components to meet specific engineering requirements.

Development of a low-power and low-sophistication prototype drilling rig capable of reaching a significant depth of 30 meters in rocky formations and powered by the Power Take Off (PTO) shaft of an agricultural tractor which as engineers, was achieved by focusing on simplicity, durability, and efficiency at Federal University of Agriculture, Abeokuta. This practical solution addresses the need for cost-effective drilling equipment in agricultural and rural development contexts, where access to water and geological exploration are essential for sustainable growth and development.

Presently, a PhD student is working on the development of an instrumented system for evaluating soil-engaging machinery under various field conditions. It will be a significant contribution in the field of agricultural engineering when completed. It involves development of an instrumented system capable of accurately measuring key parameters related to the performance of soil-engaging machinery. In addition, the instrumentation designed and developed will be able to assess tractor performance, tillage quality, soil failure characteristics, and environmental conditions during field operations.

The adoption of power tillers and mechanized tillage tools through technical and socio-economic assessments introduced in this research is recommended for adoption by government and farmers particularly by the ongoing monitoring and evaluation on smallholder farmers to improve agricultural productivity, livelihoods, and sustainability in their farming systems.

The development of a prototype paddle wheel aerator for fish production using local materials demonstrates a proactive approach to addressing the aeration needs of aquaculture systems. By improving oxygenation and water quality, paddle wheel aerators contribute to the success and sustainability of fish farming operations, ultimately enhancing food security and livelihoods in the aquaculture sector.

The development of a novel floating fish cage system made from local, cheap, and durable materials represents a practical and impactful solution for expanding fisheries production and meeting the demand for fish in low-income areas of the world. These initiatives have the potential to drive positive socio-economic change and foster sustainable development in the fisheries sector.

Conducting technical assessments of farm equipment performance based on key performance indicators is essential for ensuring the sustainability and efficiency of agricultural mechanization systems. By systematically monitoring and analysing equipment utilization, availability, reliability, and maintenance, farmers and equipment managers can optimize resource allocation, reduce costs, and enhance overall farm productivity and sustainability.

The study conducted at Sunti Golden Sugar Company, Nigeria, was aimed to determine the cost of equipment use and select appropriate tractor power and machinery for various operations involved in sugar cane cultivation and post-harvest processing. By considering factors such as machinery performance, operational costs, size selection, operational timeliness, field capacity, and operational scheduling, the study provided valuable insights and recommendations for optimizing sugar cane cultivation of 4,700 ha and processing operations at Sunti Golden Sugar Company, Nigeria.

4.0 RECOMMENDATIONS

I hereby recommend the Followings:
Mr. Vice Chancellor, Sir, by virtue of the old Agricultural Engineering curriculum which was of wider scope, this career field and research practices were made possible. The present day curriculum has turned many core courses into elective courses, I will recommend that some of these elective courses should be reversed as core courses for agricultural engineering students.
The College of Engineering can make a good head way with introduction of bringing together staff in various research areas to begin to fine tune some projects that have been successfully completed and can be patented and go into commercial production. This will be of great benefits to the immediate communities we are to serve and the nation at large.

With great appreciation to the University Management concerning provision of essential tools, equipment, and other facilities in the College of Engineering and at Agricultural and Bio-resources Engineering Department, we wish that more up- to-date equipment can be provided for commercial production of some of these finished works.

Any nation that cannot provide enough food for its citizens is in grave danger. The nation should tap more into the usage of abundant skilled human resources and cut edge successful research work outcomes of the nation's research institutions to sustain our food security and industrial development. This will definitely and drastically reduce unemployment, usefully engaging the nation's working class and youth in the society which will ultimately leads to zero hunger and reduction in crime rate hence insecurity which is presently a daily occurrence in Nigeria consequently. These will also result into boosting of the Nation's IGR and hence the GDP as there will be very little need for importing what we eat and feed upon

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