

# **APPLICATIONS OF MECHATRONICS IN AGRICULTURE: A CASE STUDY OF COCOA NURSERY FARMING IN NIGERIA**

## **ABSTRACT**

Agriculture is one of the foundations of the Nigerian economy and Cocoa is on the list of those contributing greatly to the overall GDP (Gross Domestic Product) of the country's economy. As a result of this, with increasing attention to food reliability and security across the globe, there is a need to create awareness of the importance of the use of advanced machinery in the activities of this sector. Research on agricultural robotics is scarce in the country, therefore, forcing farmers to still use some primitive farming methods and tools that have been in existence for hundreds of years and this has stopped us from attaining our full potential.

The problems faced with cocoa farming currently in Nigeria include aging trees/farms, inconsistent production patterns, disease incidences and pest attacks, and very minimal mechanization of the agricultural sector. The application of mechatronics has been seen to solve most of these problems in agriculture generally across the globe. This paper is aimed at bringing to our attention the importance or advantages of mechatronics application in agriculture in the country, areas of application which include precision agriculture (PA), Animal production, Autonomous Tractors, Nursery Automation, Crop fertilization, seeding, weeding Irrigation, etc. It also shows how adopting these systems would solve a lot of problems faced with cocoa farming and agriculture generally in the country.

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### **INTRODUCTION**

Until recently, agriculture has always been about doing more with more, more horsepower, more inputs, and more acres, but the new digital era is changing all of that. In the last decade, it has been about doing more with less and providing farmers with tools to make informed decisions (Jahmy Hindman, CTO at John Deere speaking at CES in 2021). Automation and Robots are beginning to proliferate within agriculture and there is a need for the Nigerian agricultural sector to also meet up with this trend to be able to maintain relevance in the industry.

Robots in agriculture have been conceptualized since the early 80's but were first developed in agriculture in the early 1900's. Megatrends like Artificial Intelligence (AI), Machine learning and other cutting-edge technologies will unleash opportunities for the development of new machines and processes that will help sustainability in the long run. Developments like these are critical, considering speculations that by 2050, the world population would have exploded to reach about 10 billion people and all these people will need food to survive, which is the basic essence of agriculture.

Cocoa production started in Nigeria around 1879. A local chief established a plantation at Bonny in defunct Eastern Nigeria (Amos, 2007) and despite the huge potential farming cocoa has in stimulating agricultural growth in Nigeria, it is surprising that the trend of cocoa production is not on a steady accent in recent times it has declined in economic importance at aggregate national level (Adeogun and Oluyide, 2006). Such signals call for realizing sustainable potentials of the sector and is expected that a lot of research efforts should be directed towards finding solutions faced with practicing farming cocoa in Nigeria.

Farmers in Nigeria are faced with problems of pest damage, weed control, crop health management, resource waste, and environmental damage due to heavy machinery like other farmers around the world. What makes the difference in solving these problems is the adoption of robotic innovations which is not common in the country. According to Abhisesh Silwal, a project scientist at the Carnegie Mellon University of Robotics Institute; similar to the autonomous car industry, full autonomy of farm vehicles and equipment can also be considered as important, if not the ultimate goal in the agricultural industry. Automating

delicate, time-sensitive tasks like pruning and harvesting which typically require skilled workers could help sustainability in the long run.

Applying Mechatronics in Agriculture is no longer a new thing as day by day, breakthroughs are being discovered in the Agricultural Robotics world.

## **THEORETICAL ANALYSIS**

### **HISTORY OF MECHATRONICS**

Mechatronics as the word implies is a fusion of mechanics and electronics. The word was created by Japanese named Tetsura Mori an employee at Yaskawa electric cooperation, Japan in 1969. This is an essential term for Advanced Automated Industry. The development of mechatronics engineering intends to produce a design solution that is aimed at unifying various subfields in engineering. It is focused on the integration of Mechanical, Electronic, and Electrical Engineering systems and is a combination of robotics, computer science, telecommunications, systems control and product engineering.

### **MECHATRONICS APPLICATION IN AGRICULTURE**

1. Precision Agriculture: precision agriculture as the name implies, is an approach to farm management that uses Information Communication Technology (ICT) to ensure that crops and soil receive exactly what is needed for optimal health and productivity. It is more of a systematic way of farming that uses different kinds of Information Communication Technologies such as satellites, Global Positioning systems (GPS), Geographic Information systems (GIS), sensors, electronic systems, computers and cameras in observing, measuring and analyzing variations within agricultural fields to increase long term output with minimum inputs or exact inputs.

According to the National Research Council (NRC) 1997; Precision agriculture was defined as the application of modern information technology to provide, analyze, and process multi-source data of high spatial and temporal resolutions for decision making and operations in crop production management.

The objective of precision agriculture is to define a Decision Support System (D.S.S) for managing farm operations to optimize input returns and preserve resources. The precision agricultural practice has been enabled by the advent of the Global Positioning System (GPS)

and Global Navigation Satellite System (GNSS). With these technologies, farmers can locate precise positions in the field. This gives room for creating maps of spatial variability of as many variables that can be measured e.g. Crop yield, terrain features/topography, organic matter components, moisture levels, PH (potential hydrogen), Magnesium (Mg), Potassium (K) and others. Similar data is collected by real-time sensor arrays that can measure everything from chlorophyll levels to plant water status along with multi-spectral imagery. The data is used to optimally distribute resources and in recent technological advances, the sensors go directly into the soil and wirelessly transmit data without the human in the loop presence.

2. Animal production: In the aspect of animal production, Biosensor technology has been seen to have great potential in improving animal welfare, health and production efficiency. The widespread use of antibiotics and chemotherapeutics to control disease in animals and improve animal performance has led to finding residues of veterinary drugs in food of animal origin. Biosensor technology offers an alternative drug screening method that is highly sensitive, does not require sample preparations and can be rapidly done online at low costs. Biosensors are also used in metabolic level detection in veterinary testing and animal husbandry. For example, Estrus detection by monitoring progesterone levels in milk.

Another technology adopted in this field of agriculture is the use of transponders for animal identification and traceability process. The availability of devices for animal identification since the 1970's has made this possible and also facilitated the implementation of sophisticated livestock management schemes which has progressed advancements in animal farming.

2. Autonomous Tractors: An autonomous tractor also known as a driverless tractor is a vehicle used on farms that is automatically operated with an intelligent system that guides it for proper functioning. It runs on a field intelligence basis and has sensors that fetch the farm's information for real-time analysis. The John Deere Company famous for producing tractors recently launched its first successful autonomous tractor called the 8R. The tractor is equipped with six stereo cameras that capture a 360degree view to be able to detect obstacles, and has real-time data sharing capabilities, machine learning and remote monitoring/management features. This data shared is used for algorithm adjustments, enhancing performance and also suggests

how some operations on the farm can be improved. All the farmer needs to do is to control the entire process from the Smartphone app.

4. Nursery Automation: The demand for labor in the nursery and horticulture industry continues to climb year after year. Finding people to perform repetitive and labor-intensive tasks is almost impossible, therefore making the industry not being able to meet demands as a result of inadequate workers and causing many seasonally dependent fruits and vegetables to go to waste. This has called for the need for automation in the industry to solve labor shortage problems.

Adopting mechatronic techniques in the nursery farming of cocoa beans in Nigeria would go a long way in solving problems posed by farming the beans in the country together with other innovations of smart agriculture.

The AIS mobile robot named BigTop (fig.6) developed by AIS(Artificial Intelligence System) uses a set of sensors to observe its surrounding environment. The sensors enable the robot to either autonomously make decisions or pass the information to an operator on the farm about the farm. When the robot operates independently, its autonomous decision-making ability is based on preprogrammed algorithms. These algorithms are designed to enable the robot autonomously do the required job using instructions provided by the nursery. The artificial intelligence of the robot is built flexibly enabling it to operate independently or be controlled by an operator. The robot can identify, lift and move plants. It uses two robotic arms to pick up to six plants at a time and places on its rotating robotic platform base. It can space plants in a preprogrammed pattern and can navigate and operate in both indoor and outdoor environments.

## ILLUSTRATIONS



Farmer monitoring farm through the network. (fig.1).



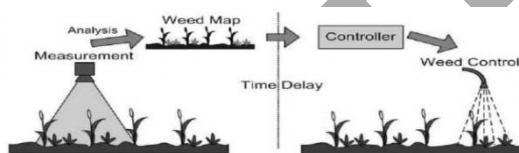
Nursing cocoa seedlings in polythene bags. (fig.2).



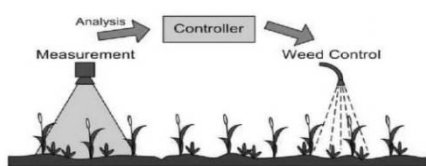
Farmer irrigating manually. (fig. 3)



Automatic irrigation system in a Nursery. (fig.4)



(a) Mapping approach in weed control



(b) Real-time approach in weed control.

Mapping and Real-time approaches in weed control  
(Reproduced from Vrindts [29])

Automatic weed control approaches (fig. 5).



The AIS nursery mobile robot (fig.6)

## **METHOD**

### **Factors considered when starting a cocoa nursery farm in Nigeria.**

A cocoa nursery is where cocoa seedlings are raised before transplanting to the field. Some factors need to be considered before starting a cocoa nursery. These factors include Water, soil properties, nursery site, transplant site/farm location, shady trees close to the nursery which could pose threats to the health of seedlings through infection, etc.

1. Water: water is an important factor when considering establishing any nursery in general as seedling needs water for survival. Different technologies are in existence today which take care of different areas pertaining to water supply for crops. Technologies like drip irrigation systems and even smart agricultural technologies can determine the exact amount of water the cocoa seedling needs for survival.
2. Soil property: soil to be used to grow seedlings must have good aeration (to avoid water logging), water retention and high organic matter content. Loamy soil containing matters with appropriate nutrients required for the growth of the seedlings is best used to achieve the best results and minimize the application of fertilizer to seedlings which can cause damage to it.
3. Nursery site: the site should be about 10 meters away from the cocoa farm to avoid pest attacks or the spread of disease to the seedlings as the case may be.

### **NURSING THE COCOA SEEDLINGS.**

Nursing the cocoa seeds can be done in two (2) ways

1. In pots or polythene bags (fig.2)
2. On Seedbeds

## **MAINTAINANCE OF THE COCOA NURSERY USING MECHATRONIC TECHNIQUES.**

1. Irrigation.
2. Weed control.
3. Fertilizer Application.
4. Pest and Disease Control.

1. Irrigation: irrigation (fig.6 and fig.14) is the process of applying artificial water (which is not natural watering like rainfall, or dew) to the cocoa seedlings. Cocoa is usually vulnerable to water at this early stage of development. Four cocoa genotypes (Fb amazon, T1, T7 and Amelonado) have been tested in Nigeria under four irrigation regimes which are daily, 3, 5 and 7 days to study the effect of water stress during the critical early stage. Researchers collected data on the physiological effects the different regimes had on the cocoa and found that the physiological characteristics of the cocoa were directly related to their sensitivity to water stress.

Water stress has continually been seen as a critical factor to consider in the early developmental stage of cocoa and thereby the need for the introduction of irrigation systems. These systems provide room for precise application of water to the cocoa (precision irrigation) where the cocoa seedlings get exactly the amount of water needed to survive. According to some studies, these systems have been seen to increase cocoa resilience and limit the yield-reducing changes induced by water stress.

Raspberry Pi 3 Model B is a smart cocoa monitoring system where a farmer monitors the soil moisture in the nursery and the irrigation machine of the nursery through the network (Fig 1). The system collects the soil moisture information of the nursery and any changes that are



detected by the inbuilt sensors of the system that can cause harm to the cocoa seedling will be managed. The system also provides information on soil moisture that can be monitored through the system's application for further actions to be taken. These aids the farmer practice irrigation correctly, thereby increasing productivity and adaptation of the cocoa seedlings.

2 Weed control; this can begin before planting by recognizing and removing weed seeds before planting takes place. Weed control is very important in young cocoa to avoid the cocoa competing for soil nutrients and water. Weed control can be done mechanically by the farmer by uprooting weeds in the pots of the cocoa seedlings but this can be tasking in very large farms where automated machines will be required to perform such tasks e.g. a weeding robot. Automatic detection systems of weeds were influenced by the need to create systems that would allow reductions in herbicide application. Autonomous mobile robots can detect and control weeds autonomously. It can navigate, detect, and control weeds on the farm.

There are two automatic weed control approaches (fig.5) which are mapping (fig.5a) and online methods (fig.5b). In mapping, the location of the weed in the nursery will be mapped before removal, while in the online method; the control method is applied almost instantly after detection. Automatic and efficient control of weeds in a real environment requires robust detection of crops and weeds. There are several ways of gathering this information, ranging from manual human input to automatic recognition systems.

3. Fertilizer application; Research has shown that the application of modest amounts of fertilizer to cocoa seedlings has increased the growth of seedlings and nutrient concentration. However, to achieve the best result, well-timed supplies of fertilizer in the nursery will improve agronomic performance in fields. The application of fertilizers has been seen to give the seedlings a more visually attractive look and offer more agronomic advantages for the

seedlings (faster establishment, earlier fruiting and higher yield potential when they are eventually planted.)

4. Pest and disease control; This can be controlled by avoiding and removing tree species that can be hosts to any pest or disease that affects cocoa in and around the nursery and species that are hosts to natural enemies of cocoa pests should be favored. The spacing of pots in the nursery also has an impact on disease control in the nursery. Regular monitoring should be done for early detection of diseases to avoid disease spread and pest attacks. Biopesticides can also be applied for prevention and treatment and should be used in planting in the nursery.

## **DISCUSSION**

In agriculture today, technologies such as robots, temperature and moisture sensors, aerial images and Global Positioning System technology are regularly used. These advanced devices and precision agriculture and robotic systems allow profitability, efficiency, safer, less laborious, and more environmental system of farming.

Introducing robots in cocoa nursery farming to perform some operations in the nursery will do a lot in solving some problems faced with growing the beans in recent years that have affected the GDP percentage of the agricultural economy of Nigeria. Problems faced with cocoa farming include aging trees and farms, low yields, inconsistent production patterns, disease incidence, pest attacks, weather conditions, etc. can all be solved by introducing Mechatronics and systems technologies in the farming of the beans and agriculture generally in the country. Mechanization of tasks and availability of vital information in the nursery will improve productivity and sustainability. Maintaining the nursery can be done by the mechatronic techniques mentioned in this paper and provide solutions to most problems faced.

## **CONCLUSION**

Mechatronics engineering and its application to agriculture have positively impacted the sector and other aspects of engineering and life. Agriculture is one of the largest non-oil export earners and a key contributor to the creation of wealth and poverty reduction in the country and the largest employer of labor (Central Bank of Nigeria, 2005), hence the need for the mechanization and automation of this sector.

The Federal Ministry of Agriculture and Rural Development (FMRD) includes cocoa farming and production, tomato farming, aquaculture, rice, maize, cassava, ginger, poultry, etc. Among the appeals project priority chain, therefore the importance and need for more research to be carried out in this field.

Programs like Africa Agric Machines Equipment and Technology Expo (AAMETEX) held in Abuja in June 2022 bring both private and government organizations to share innovations and new technology advancements in agriculture in the country and around Africa will influence farmers' approach to using smart technologies for farming and the availability of these advancements. Organizations like the National Centre for Agricultural Mechanization (NCAM), and International Institute for Tropical Agriculture (IITA), amongst others all came together to display different inventions in technology for agriculture they have innovated. Programs like this create awareness and expose some technological advances to farmers from different parts of Africa.

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