ORIGINAL RESEARCH ARTICLE

REVOLUTIONIZING AGRICULTURE THROUGH SPACE SCIENCE AND TECHNOLOGY APPLICATIONS

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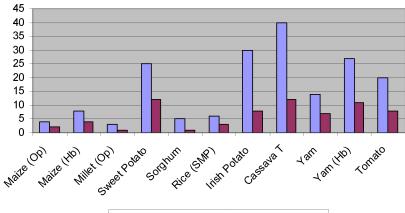*Michael Okpara University of Agriculture Umudike, Nigeria*

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1.0   Introduction

Agriculture is often acknowledged as a key driver of national economies; indeed, it is central to the stabilization of many economies. Nigeria has a land area of 923,767 km^2 with 708,000 km^2 Agricultural land of which 412,938 km^2 is cultivated including 344,577 km^2 arable land and 68,361 km^2 on permanent crops as shown in Figure 1.

Agriculture is practiced largely as a traditional activity and managed as a subsistence cultural activity with the seed stock yields averaging less than one-third of exotic species. For example, cereals yield an average 1.44 kg per ha compared to 8 to 10 tons/ha in USA. On the average, in 2015, Nigeria applied only 8.3kg fertilizer per ha as against 50.2kg in Cote d'Ivoire, 112kg in USA, 246.9kg in United Kingdom, and 1,539.3kg in Malaysia. Nigeria also has only 6.7 tractors per 100 km2 of arable land compared to 30 in Cote d'Ivoire, 52 in South Africa, 271 in USA, 629 in UK and 255 in Malaysia. Nigeria's local poultry matures in over one year, is broody and lays only about 40 eggs a year while a corresponding exotic species of poultry broiler matures in five to eight weeks and the egg poultry lays over 300 eggs a year. Nigerian cattle species weigh about 250kg/head on the average as against 800 – 2000kg/head of exotic cattle; Nigerian goats weigh about 20kg as against 85 kg for female and up to 120kg for male Kalahari goat species. Milk yields of local cattle are less than one kilogram per day as against six to ten kilograms per day for exotic dairy cattle breeds. (Nigeria at a Glance: Food and Agriculture in Nigeria, 2018)

Figure 1: Productivity of Nigerian crops benchmarked on potential for other developing countries (Akimboloba, 2001)
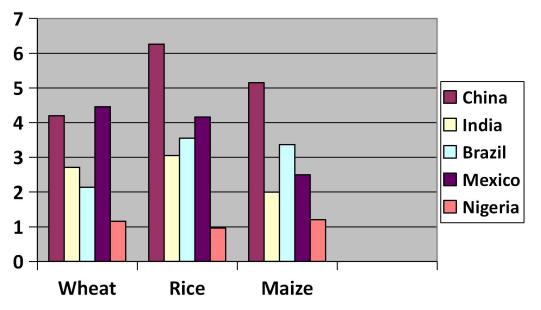

Figure 2: World t op four producers of wheat, rice and maize compared to Nigeria. (Billing, 2017)

Figure 2 shows the comparative level of Nigeria as compared to the world top four countries that produce wheat, rice and maize. Despite this poor profile, Nigeria's Agriculture is expected to feed a population currently indicated in 2016 at 186 million and growing at an average of a 2.68 percent annually (Ogbalubi and Wokocha 2013). Strategic as it is, Ogbalubi and Wokocha (2013), concluded that agriculture basically contributes over 23 percent of gross domestic product (GDP). It provides food for the nation employs over 36.6 percent in regular paid jobs but with over 70 percent engaged in Agriculture in the rural areas; agricultural raw materials stimulate processing for the production of commodities which promote local retail trade and support foreign trade. Agriculture therefore can significantly reduce poverty; create wealth at individual, state and national levels; as well as conserve and earn foreign exchange through import substitution and trade, respectively. The objectives of this paper are to show how Space

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technology applications can significantly influence food production systems and also be key to food security as it can enhance productivity, resilience and profitability.

2. Agriculture and the National Economy

In Nigeria, successive Administrations have through their economic development plans and strategies in Vision 20:2020, and ERGP, 2016 have underscored the need to diversify the Nigerian economy through developing economic sectors other than Oil, which has been the sole source of over 90 percent of the nation's foreign exchange earnings and over two-third of Government funding (Nigeria at a Glance: Food and Agriculture in Nigeria, 2018). It has now become imperative for diversification from oil as a result of the emerging decision by several nations to stop licensing oil and gas fueled cars from 2025, the need to achieve this diversification seems very urgent (Ingrid, 2016).

"With over 90% of export earnings and government revenues dependent on hydrocarbon based primary products, entirely generated from a single region of the country, the pillars of Nigeria's economy are extremely weak, and the continued economic viability of the Nigerian state, as a self-sustaining entity, is perpetually at risk" (Onyenekenwa, 2011)

To diversify the economy, Nigeria identified some sectors including Agriculture, Wholesale and Retail trade, Manufacturing and Telecommunications as key drivers of the economy and therefore conceptually decided to transform their current subsistence and mini-sized management structures into profit-oriented commercial enterprises. For Agriculture, this will involve the modernisation of the process, having regard to value chains, introduction of pertinent mechanization and technologies in order to proficiently increase productivity of crops and livestock and to achieve higher levels of production per unit of farm/ head. In doing this, the nation must also be cognisant of the challenges of climate change and therefore work to transform Agriculture with a conscious focus to enhance climate co-benefits and achieve resilience. www.unoosa.org/oosa

This transformation will mean re-orientation of farmers from their age-old traditional methodologies in subsistent farms to the introduction of modern technologies in intensively managed for-profit farms; abandoning the traditional rain-fed agriculture where farming takes place principally during the rainy season to significantly increasing irrigated land from the current less than one (01) percent to over 40 percent of arable land and therefore reducing idle-times during the dry season; abandoning the "one-size-fits-all" mentality in using one type of fertilizer from the swampy soils of the Niger Delta region in the south to the loose sandy soils of the Sahel region in the north to consciously matching soil nutrition with precise soil characterization and application of nutrients to eliminate any gaps in the nutrient matrix of the soils in each farm to assure the highest yield (Akande, 1998). The transformation must also result in the discard in commercial enterprises of low-yield seeds and young livestock to deliberately improving the genotypic and phenotypic characteristics of our crop and livestock seed stocks through intense selection and other technologies (with preference for artificial insemination and such technologies that may exclude genetic modification); the "retirement" of hoes and machetes while domesticating fit-for-purpose and fit-for-location equipment and machines

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including tractors and other efficient mechanized systems of labour; noting the very high number and the ageing nature of current farmers to "outsourcing" the large number to other sectors while enhancing the technical and management competences of the remaining "agripreneurs" as well as ensuring that programmes (including incentives and professionalization) are available that must attract the youth to study and practice Agriculture. It must also be noted that crops and animals produced in the prevalent subsistent system are sold as primary commodities with hardly any consideration for profit to ensuring that primary products are processed through value-addition systems to ensure higher value-commodities, higher prices and better returns to the farmer. Since units of farm land are very small (less than one-ha in some areas) to organising farmers in collectives/cooperatives to facilitate land consolidation, mechanisation and off-taker partnerships; noting that even with the critical importance of extension to technology transfer, the current extension system has over 20,000 farmers to one low morale, generalist extension worker to ensuring that the succeeding extension system is within accepted ratios of 500 to 1000 farmers to one specialized, well-resourced extension worker (Akande, 1998). The current uncoordinated marketing system where every farmer markets his/her commodity independently whereby livestock are inefficiently transported or farmer trekked hundreds of kilometres to reach market, have negative impact on meat quality. Government need to ensure that there exists special marketing vehicle that ensures crop commodities are ferried to conditioning centres and processing plants in appropriate transport while livestock are hygienically processed and packaged in abattoirs and slaughter slabs close to their areas of production and the meat transported in cold chains to sanitary sales outlets across the country. Ibrahim and Mukhtar (2015) concluded that Nigerian scientists currently struggle to get funding and facilities to conduct research to support innovative Agricultural technology development to well-funded research opportunities producing instructive outcomes for the development of revolutionary technologies that support the highest agricultural yields and most acceptable conformations.

Such a transformation will be incomplete without the application of cutting edge technologies. Today, Nigeria is the number one producer of Cassava in the world. Thirty years ago, Nigeria raised the production of Cassava from 4 to 8 tons per ha, ten years later, production rose to 15 tons per ha and this was celebrated as a great scientific feat. Eight years ago, Nigerian scientists collaborating with their colleagues in the International Institute for Tropical Agriculture (IITA) increased the yield to 45 tons per ha Akinpelu et al. (2011). But is this the highest possible yield for Cassava in Nigeria? Already achievements have been recorded with the production of vitamin A Cassava – which means the limit is yet to be achieved! Cognisant of the variety of activities in the various Agricultural value chains, it is possible to understand the complexity of Agriculture, the several activities leading to the production of commodities and the myriad of facilitating activities that drive the process of commodity production. It also shows the several factors that must operate at full thrust for a production process to be achieved seamlessly. It is fact that any reaction that limits any of these processes will limit or confound commodity production. Production of such agricultural commodities will enhance foreign exchange conservation through import substitution as well as the local retail trade economic sector. Also, such production will promote foreign exchange earnings through foreign trade in the commodities. Both processes will undoubtedly have positive effects on the national economy (Akinpelu et al., 2011).

3. Space Science and Technology for Human Development

In the effort to produce enough food to feed the more than 9 billion global population by 2020, the United Nation projects that global food production must increase by at least 70 percent (Purdy, 2016). This is in the face of an increase in population, expansion of urban and sub-urban settlements with reduction in land available for further expansion for Agricultural production. Invariably, this calls for the development of greater efficiencies in production - efficiencies driven by the most appropriate and most responsive technologies.

Of great interest today is the application of space science and technology to Agriculture. Originally, the objective of space science and technology was to study the origin and evolution of stars and galaxies to help man understand the foundation of the Universe and its changes (United Nations, 2016). Over time, the technology veered into investigating the presence of life in outer space, and now is keenly probing ways of using the science and technology to understand the earth, the circumstances and processes of the Earth. The current drive is to use the technology to bring benefits to man while still exploring the universe for monumental breakthroughs. Consequently, the technology is used today in a wide array of sectors to bring understanding and benefits to our Environment, Agriculture, Education, Global Health, Sustainable Development, Disaster Management, Human Settlements, Research and Development, Transportation, Communication, Humanitarian Assistance, and International Peace and Security (United Nations, 2016). In our great Nation Nigeria, the Minister of Science and Technology, Dr Ogbonnaya Onu, recently identified as quick wins that Space Technology will "positively impact on agriculture, national security, health services, education and manufacturing sector" (The Vanguard 2017).

4. Incursion of Space Science and Technology into Agriculture

It can therefore be concluded that "Revolutionizing Agriculture through Space Science and Technology Applications" evinces the profound sensitivity of the National Space Research and Development Agency (NASRDA) and its subsidiary Centre for Satellite Technology Development (CSTD) to bring due focus to the great benefits that can accrue to Nigerian Agriculture through the application of space science and technology. This is basically in concert with the position their supervising Minister that Nigeria will "continue to utilize space technology to boost vital sectors of the Nigerian Economy".

By accepting Agricultural Revolution as our goal, we are directly raising issues with the use of science, technology and innovation to mitigate inequities, maximize and actualize potentials, and advance environmental and social harmony. We must accept the thesis that Science and technology have progressed from the period of focusing and understanding the Agriculture around us, to a period of trying to control our Agriculture, to a new period of transforming Agriculture. We can therefore appreciate the progression in Cassava yield from 8 tons/ha to 15tons/ha and then to 45 tons/ha and the vision of 100 tons/ha! This will be revolutionary and it can only be achieved by the application of new technologies and innovations. This revolution must take advantage of cutting-edge knowledge, succinct technology and innovation with communal goals.

Space science and technology is one of the emergent technologies of extant considerable interest in the drive to accelerate innovation. Space has been described as "a privileged place

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from which to study large-scale vegetation, ocean currents, water quality, natural resources, air pollutants, greenhouse gases" (Chizea et al 2006). It is indeed a great location for the observation and monitoring of development of events on planet Earth. Major developments have been made by many nations to take advantage of the growing opportunities incident on space science and its derivative technologies. Space technology in agriculture was indeed not in the frame of the main essence of space exploration but rather a spin-off from the primary objective. However, the incursion of space or satellite technology into agriculture and related phenomena, though relatively young in many parts of the world, is already having an important impact on what is currently seen as a shift towards precision control of food production which allows farmers to produce more with less (Ikpaya et al., 2017).

To study and hopefully exploit space, many countries have launched satellites into space with the objective of studying what values may be realizable. The outcome of such explorations has been the development of varied technologies which can be used in several economic sectors including Agriculture. Space science and technology are already being exploited to help in the prediction of factors affecting Agriculture and thus leading to its transformation through the emerging concept of "smart agriculture". Many nations – China, Russia, USA, Denmark, U.K., India - have progressed significantly in utilizing their satellite technologies to advance Agriculture (Ikpaya et al., 2017).

In the United Kingdom (UK), by 2016, about 60 per cent of all farmland in the nation already had farm management tools using the likes of sensor systems, analytics, cameras and drones (Ikpaya et al., 2017). Space technology significantly reduced human agricultural labour with the introduction of more automated mechanical systems. From 2009 to 2016, it injected over 8.2 billion UK pounds into the economy, a 16% growth, while food production became the largest manufacturing sector (Purdy, 2016). Across the nation, the use of satellite technologies is enabling farmers to deal with challenges of low yield and excessive use of fertilizer which often leads to soil and groundwater pollution. With optical satellites, it has been possible to show how well crops are growing by measuring how they absorb solar radiation in the visible and near-infrared spectrum to produce a 'normalised difference vegetation index' (NDVI). The NDVI is proportional to the amount of chlorophyll in the crops (higher chlorophyll reflects more light in green and infrared spectra), which changes as crops grow or their health changes. So, by monitoring chlorophyll levels using the NDVI, farmers are able to determine areas of over-dose and under-application of fertilizer prompting corrective responses. Based on the NDVI, the satellite navigational systems can also be used to remotely control a tractor to differentially apply fertilizer to various areas of the farm depending on the predicted yield level. Consequently, farmers can make significant savings in total fertilizer use as well as in costs while reductions are recorded in nitrate run-off and pollution of soil and groundwater. Furthermore, satellite imaging can monitor soil water level and guide irrigation use (Steven, 2006).

In India, space technology and land-based observations are important in taking informed decisions on agricultural production through the use of regularly generated updates on crop production statistics as well as the provision of inputs to achieve sustainable agriculture. In fact, the Indian National Remote Sensing Centre (Chizea et al., 2006) indicated that the satellite-based optical and radar imagery are used widely in agriculture monitoring. While radar imagery

is especially used during monsoon season, the integrated use of geospatial tools with crop models and in-situ observation system enables timely crop production forecasts, and drought assessment and monitoring. Other achievements of space technology in India include agricultural land-use mapping, the horticultural crop inventory, the agro-meteorological parameter retrieval, and inputs to agro-advisory services as well as methane emission inventory and carbon accounting. With these, India can map its soil, monitor its agricultural land area, soil and its water resources, assess and monitor drought, estimate cropped areas, determine crop stand counts, forecast the weather, annual crop yields as well as incidence of pests and disease detection as shown in Figure 3. In animal agriculture, it can also guide aquaculture/fishery development and probably animal tracking and census (Mody et al, 1987).
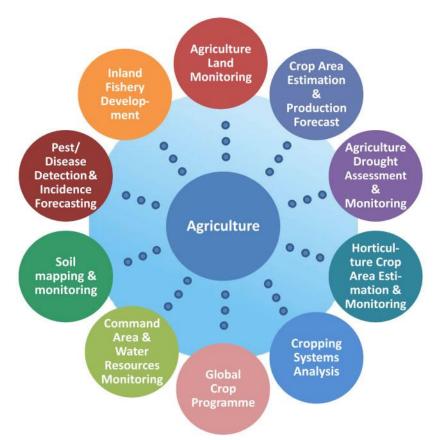

Figure 3: Uses of Space Technology in Agriculture in India. Mody et al. (1987)

In its strides, Nigeria joined the space technology race in 1976 when it planned to launch a satellite but this was not actualized then. To date, Nigeria has launched five satellites:

NigeriaSat-1, the first of Nigeria's satellites launched 27 September, 2003 "to give early warning signals of environmental disaster; to help detect and control desertification in the northern part of Nigeria; to assist in demographic planning; to establish the relationship between vectors and the environment that breeds malaria and to give early warning signals on future outbreaks of meningitis using remote sensing technology; to provide the technology needed to bring education to all parts of the country through distant learning; and to aid in conflict resolution and border disputes by mapping out state and International borders". NigeriaSat-1 is one of the disaster monitoring satellites in the global Disaster Monitoring Constellation networked to share data and information at the threat of a disaster.

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NigComSat-1 – Nigeria's second and Africa's first communication satellite was built in 2004 and launched in May 2007. This satellite, which was designed to provide transponders that would cover most of Africa but was lost in orbit in 2007 and was switched off in November 2008.

NigComSat-1R, launched as a replacement for NigComSat-1, was launched on 19 December, 2011 to continue the objectives of NigComSat-1.

NigeriaSat-2 and NigeriaSat-X, a medium to high-resolution earth satellite launched on 17 August, 2011. NigeriaSat-2 was designed to support food security, agricultural, geological, mapping and security applications as well as to support the national development of GIS application while also continuing the objectives of NigeriaSat-1 but with medium to higher resolution and precision launched to map the city of Lagos as well as take infra-red readings on land use.

NigeriaSat-1 and NigeriaSat-2 are complementary as NigeriaSat-1 is useful in Nigeria to monitor pollution, land use and other medium-scale phenomena, offer satellite data for farmers on where to apply water and fertilizer, keep data on the spread of the desert in Nigeria. The satellites will also provide data on disaster, in an unfortunate event (Ikpaya et al., 2017)

From the above uses indicated for some countries and the extant situation in Nigeria, space science and technology are a most potent technology which can be used to explore and enhance agriculture, environment including drought and desertification, mining, water supply, transportation, communications and indeed most sectors of the economy (Chizea et al., 2006).

5. Scope of use of Space Science and Technology in Agriculture

The United Nations Office for Outer Space Affairs has shown that the use of space technology has continued to expand in scope and breadth. In a publication (United Nations 2016),The Organisation noted the need for a concerted global action on the challenge elucidated by the key sustainable development goal (SDG) of "ending hunger, achieving food security and improved nutrition, and promoting sustainable agriculture". Director, Simonetta Di'Pippo, had surmised that to achieve this goal, 'advanced tools and solutions' must be applied in the concerted global actions. Such tools, he said were available from space science, technology and applications for "the monitoring of crops, livestock, forestry, fisheries, aquaculture, and in supporting farmers, fisherfolk, foresters and policymakers in efforts to employ diverse methods of achieving sustainable food production and to respond to related challenges such as adverse weather conditions, droughts, floods, desertification and land degradation, vegetation fires, and disasters triggered by natural phenomena". The Office specifically identified current uses of space or satellite technology in agriculture and related activities. This included its use in Agricultural Research and development, Biodiversity, Desertification, Drought, Fisheries and aquaculture, Irrigation and water, Landscape mapping, Monitoring agricultural production, Vegetation fires, Weather monitoring and forecasting, and Managing, mitigating and preparing for disasters.

6. Emerging Concepts in Agriculture contingent on Space Technology Development

Smart or Precision Agriculture

Hemlata et al. (2015) has defined Smart Agriculture as "an approach to understand the basic requirements as well as the changes in current environment due to external factors based on the

context information and utilization of collected data to optimize sensors' operation or influence the operations of actuators to change the current environment". They further identified the process to achieve Smart Agriculture as:

"Sensing local agricultural parameters (Observation)

Identification of sensing location and data gathering (Observation)

Transferring data from crop field to control station for decision making (Diagnostics)

Decision making based on local data, domain knowledge and history (Decision)

Actuation and Control based on decision" (Implementation)

Smart or precision agriculture recognizes the complexity of an agriculture system with several different variables/inputs – land, soil, seeds, water, fertilizer, and weather – all interacting concurrently to produce an output. To obtain the best output, cutting-edge technologies, including space technology-powered sensors, are used to collect field data from crops which are fed into different computer and ICT models to determine the precise combination of the variables that will give the best outcomes. Hemlata et al. (2015) also gave some examples whereby, sensors on unmanned aerial vehicles (UAVs) or drones are used to collect the requisite data on several parameters such as plant or animal numbers, plant height, Nitrogen measure, plant health, disease pressure, drought stress and canopy temperature to determine precise levels of inputs to be used on the farm. This precise combination is then applied using electronically controlled farm tractors to deliver determined levels of each input to the crop farm to enable the crop and the far to produce optimally.

Marco et al. (2019) concluded that Smart agriculture ensures that the crop is exposed to the best genetic and environmental conditions which elicit the ideal physiological state to generate optimal crop yields in a location as we drive to achieve sustainable food security. Smart agriculture recognizes the limitations in agricultural value chains and uses the most proficient technologies to correct them so that optimal results are achieved. In effect, precision or smart agriculture eliminates input waste as it enables the farmer to achieve more yield with less input.

Artificial Intelligence

Artificial Intelligence (AI), also called Machine Intelligence is a space technology powered non-natural intelligence application that uses imagery to learn and perceive specific characteristics and is able to reproduce or apply the knowledge. AI is designed with capacity for speech recognition, learning, planning and problem solving which are used to diagnose plant diseases in farms and it also has the capacity to characterize them as individual diseases even among a collection of diseases. In their paper, Ikpaya et al. (2017) it was concluded that AI application has been used, in India to advise farmers on dates to sow their seeds with a resultant 30 percent higher yield. It can also be used to advise farmers on land preparation and application of disease protection measures. This practice is similar to the use of the e-wallet in dispensing agricultural inputs to Nigerian farmers. In either case, all that was required was that the farmer was registered and that they owned basic telephones that can receive text messages.

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Climate Change

One of the most serious challenges of humanity today is Climate Change. Global attention has been drawn to this phenomenon with the convocation of major summits resulting in declarations and memoranda of understanding to which almost all nations subscribed. Though the USA recently reneged by withdrawing its subscription, the world continues to be influenced by the varying changes taking place in the climate across the universe – from the perceptible rise in environmental temperature to increased de-icing of the north pole, increase in ocean heights, flooding resulting in major erosions, increases in incidences of drought, an escalation in the loss of vegetative cover and ultimate desertification and lot more effects. Ikpaya et al. (2017) concluded that a further $4°C$ rise in global core temperature will significantly cause the elimination of most live species as it is known today.

According to Akinyede et al. (2015), Space technology has been useful in identifying the primary cause of climate change which is the depletion of the ozone layer caused by several human induced activities including the production of greenhouse gases and the release of carbon dioxide. Space technology powered applications are currently being used to detect and track temperature changes and the effects, the changes in the seasons - rain and heat, loss of vegetation and advents of drought and desertification. In effect, application of space technologies provides knowledge about the climate and information about its contingent effects and these advise early warning and effective environmental monitoring and assessment of the impact of remedial strategies which can have major effects on Agriculture.

Agricultural Insurance

According to Mody et al. (1987), India, government has developed some insurance policies for farmers which include crop insurance, loss of life, accidental death and disability, student safety, household, agricultural implements and tractors Agricultural insurance is a tool that brings stability to farming. Assurance of compensation for loss of agricultural investment due to untoward events is important in encouraging people to invest in agricultural activities. To be able to properly determine losses, insurance companies must be aware of the state of the farm pre- and post-disaster and this can be done with remote sensing and drones.

7. Conclusion

The United Nation surmises that the global food supply must increase by at least 70% by 2020 for the world to be able to feed its projected population of nearly 9 billion by 2020. For Nigeria, that is currently averagely underfed, food supply must increase by at least 200% for the nation to adequately feed its projected population of 206million by 2020, This may be classically impossible to achieve but it draws attention to the urgent need for Nigeria to raise its game by significantly enhancing its agricultural productivity and production levels if it must achieve food and nutrition security in the near future. To do this, Nigeria must institute a consciously coordinated Agricultural Revolution or Marshal Plan. Cognisant of the current state of Nigeria's Agriculture, it will require a most vigorous programme, a national commitment second to none, and the deployment of most effective and efficient technologies. Space technology is robust, comprehensive and sensitive. It achieves more production for less input, it can drive a sustainable and resilient agricultural system. Indeed, Space technology holds an ace in

crystallizing Nigeria's Agricultural revolution challenge. In that regard, this conference is critical in defining the course to greater satellite technological input in the effort to revolutionize Agriculture in Nigeria. Ladies and Gentlemen, it is dawn, the journey must begin!

8. Recommendations

Space Science and Technology research was primarily intended to study the outer space, the evolution of the stars and galaxies to help man understand the foundation of and changes in the Universe. However, it veered also into Agriculture, among other sectors, in a critically beneficial spin-off with capacity to significantly influence Agriculture and its related events and activities. Cognisant of the global race in the development and consolidation of the use of space science and technology applications in Agriculture as well as Nigeria's low rating the following recommendations are made:

The Government of the Federal Republic of Nigeria should statutorily allocate annually 3percent of the Consolidated Revenue Fund of the Federation to significantly upscale sustained development of space science and technology in Nigeria. Furthermore, Government should expedite the development and launching of NigComSat-2 and NigComSat-3 with a specific target achievement date to enhance Nigeria's communications reach and efficiency and bring enhanced impetus in the national space technology development programme;

The Federal Government of Nigeria should establish a Joint Task Committee comprising the Federal Ministries of Agriculture and Rural Development (FMARD), Water Resources, and Environment as well as the Centre for Satellite Technology Development (CSTD)/NASRDA to identify, develop and promote priority space technology-driven packages needed to i) facilitate Agriculture, particularly among small and medium scale farmers, ii) monitor surface and underground water sources and proper channeling of floods into reservoirs for irrigation purposes, and iii) commence activities for the reversal of desertification, and provide early warning for erosion and healing of existing erosion sites in Nigeria

FMARD should utilize the capacities of CSTD/NASRDA in conducting an automated national agricultural resources census to facilitate national agricultural planning

For a Livestock Census, the exercise should generate comprehensive individual animal characteristics to aid livestock identification and tagging to enhance traceability, eliminate rustling, and facilitate the tracking of trans-boundary diseases;

Cognisant of the serious negative effects of climate change in Nigeria, the NASRDA should intensify research on drought and the encroachment of the desert to enhance its capacity in early warning and advice on remedial programmes.

Specifically, CSTD/NASRDA should promote research in satellite-enabled capacity for

conducting survey of underground aquifers to enhance irrigation in dry land and desert areas

producing more location specific agro-meteorological prescriptions

producing simple farm area estimators and diseases detector

producing simple probes for determining soil water needs and nutrients gaps in the farm to facilitate precision agriculture

farm land mapping for crop intensification;

forecasting of farm yield for planning and insurance purposes

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remote sensing of degraded land for land reclamation purposes

CSTD and NASRDA should make the small and medium scale farmer, the producers of over 80% of Nigeria's agricultural production, as their primary clients of interest and produce simple but powerful satellite technology tools to reduce their drudgery, enhance the efficiency of their production, and increase their profit; and

CSTD and NASRDA should engage in more advocacy on the capacities of and opportunities in satellite technology to attract the buy-in of entrepreneurs, farmers' and Nigerian society.

Space technology applications can significantly influence food production systems and can be key to food security as it can enhance productivity, resilience and profitability. Critical issues of food supply, water availability, soil conditions, climate change and weather conditions can be predicted and monitored with derivatives of space technology.

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