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INTEGRATION OF INDUSTRY 4.0 TO THE NIGERIAN AGRICULTURAL SECTOR

[1,2]Nurudeen Abdulhakeem Hassan, [2]Ishaya Musa Dagwa, [3]Ibrahim Dauda Muhammad
[1]Department of Agricultural Technology, Federal College of Horticulture Gombe, Nigeria.
[2,3]Department of Mechanical Engineering, University of Abuja, Nigeria.
hnuruddeen15@gmail.com

ABSTRACT
As the global population surges, the demand for food increases and meeting these demands requires new approach as traditional practices cannot be sustainable and efficient. Nigeria also faces these challenges, with a population of 180 million people making available and cost effective food is never and easy task. The evolution of digital technologies and their integration to Agriculture will give way for increased economic growth and development to the Agricultural sector in Nigeria. Industry 4.0 is a new approach to digitalization and developing intelligent manufacturing processes over and entire value chain of products with increased customization and individualization. This study reviewed some of the key challenges the Nigerian Agricultural sector faces along the agricultural value/supply chains to pave way for the successful implementation of industry 4.0 to some key areas of the sector.

Keywords:
Agriculture, Nigeria, IoT, Integration,CPS
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INTRODUCTION

As the global population grows and technology advances, the demand for effective, fast, reliable, timely production has been a factor of discussions from academia to industry. The Academia focuses on finding concepts, developing systems, methodologies and business models while the Industry focuses on changing the machine dominant manufacturing to an intelligent machines and processes to effect on productivity and increased customer satisfaction [1].

Agriculture was the leading contributor to the Gross Domestic Product (GDP) of Nigeria prior to the discovery of crude oil with 57% to GDP and 64.5% of export earnings from 1960-1969, between 1970-2000 the sector contribution declined to 23.5% and 5.1% as export earnings [2], in 2017 the production increased to 29.15% of GDP while in the second quarter of 2020 it declined to 24.6% as the result of the global pandemic(COVID-19) [3] Nigeria's agriculture potential is high with a population of around 180 million people, an estimated 82 Million Hectares of arable land of which on 34 million is being cultivated, feeding such population is a huge task indeed for the Government and its farmers. The sector is still underutilized as a result of inability to add value to produced products the Country losses an estimated 9 million USD annually to post harvest losses [4, 3].

Some researchers[5] defined Industry 4.0 as an approach that creates an environment in which elements, devices, functionalities are continuously linked together to have a constant communication with a high degree of coordination [5] while other researchers perceived it as a new level of organization and control over an entire value chain of products, increased customer individualization requirements, creates connection of physical systems, internet, designing and drafting production development, integrated approaches, processes and Information Technology driven solutions [6], the author's see it as a collective approach that integrates machines, work schedule and manufacturing systems through integrated networks and value chain to enable constant communication and high level of coordination between each other.

The advancement of science and technology dynamically improve on industrialization globally, industrial development have evolved over three stages before the commencement of the fourth industrial revolution [7], these industrial achievements developed over two hundred years ago; the first industrial revolution paved way for steam and water powered facilities, the second gave birth to mass production and assembly systems while the third came with the integration of electronics and information technology (IT) to further automate and simplify manufacturing systems [8] [9].

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This development has influenced industry through smart factories, products and services with integrated internet of things (IoT) and industrial internet [10] to achieve sustainable manufacturing of products and services using present information and communication technology (ICT) infrastructure.
The slogan of industry 4.0 as it relates to Agriculture is termed Agriculture 4.0 or Farming 4.0 [11] the view is to increase the use of ICT technology with agricultural practices to enable for past, present and future challenges be addressed using intelligent networks that constitutes the incorporation of several data from different sources to increase productivity, efficiency and transparency across the agricultural value/supply chain [12]. There is an intensive investigation going on in areas of precision agriculture, autonomous machinery, new measurement tools and agricultural production planning and control.
This study analyses some of the key challenges the Nigerian Agricultural sector faces along the agricultural value/supply chains to pave way for the successful implementation of industry 4.0 to some key areas of the sector.

BACKGROUND

Nigerian Agricultural Sector Challenges

Nigeria has a land mass of 92.4 million hectares (ha) of land of which 91.1 million ha of land, 1.3 million ha of water bodies, out of the 91.1 million ha land 84 million ha is arable but only 34 million ha is utilized for agricultural productivity. Despite these huge land mass, Nigeria spends and estimated 5.8 Billion USD for importation of fish, wheat, dairy products and other food commodities [2, 13, 14].
[14] some of the challenges identified are: uncontrolled demographics, stressed natural resources, climate change, land degradation, insecurity and food wastes. To tackle these challenges, The Government has made so many policies and reforms for the agricultural sector to thrive such as National Agriculture Policy, Agricultural Transformation Agenda and recently the Economic Recovery and Growth Plan. However, agriculture is still largely subsistence and the focus has been on production rather than value addition [15, 2]
Uncontrolled Demographics: demographics can be classified as rural-urban migration, over population. The absence of basic and social infrastructures caused an imbalance in the rural areas of Nigeria resulting in people migration to urban areas in search of better life and standards [16]. According to Knoema Nigeria's population is estimate to be 200 million people as at 2019 a clear indication of an overpopulated country where natural resources will be stretched [17], global population stands at 7.6 billion people in the next 3 decades the population is estimated to increase by 30% to a staggering 10 billion global citizens, this means by the year 2050 farmers need to produce 70% more food to meet with the food demand [18, 19].
Stressed Natural Resources: Human impact on land has caused several negative effects on the environment from over grazing, land clearing, bush burning, deforestation, poor land fallow system, fertilizer misuse and other negative factors with the intent of either agricultural purposes, source of fuel and raw materials, food for livestock of which the resultant effect has reduced the quality of soil for agriculture, increased desertification and soil erosion [19, 20, 21].
The increasing demand for food to feed such a huge population as stated by Knoema[17] is never an easy task, the rural population that are largely farmers and nomads with an unbalance between the urban and rural areas, the act of sustainable agriculture has been traditionally active as such little use of technology, science and innovative means of cultivation.
Food wastes:Global food wastes stands at a staggering 1 trillion USD with around 50% of global production food production being wasted because of inefficiencies in handling, access to markets and inadequate industries. With over 800 million malnourished people, these wasted foods account to around 25% global water consumption and other resources such as land, labor, capital, manufacturing, packaging and time; these are left to decay in landfills without oxygen given out methane which increases greenhouse gas emissions [19].

Nigeria losses an estimated 5.3 billion USD to food imports ranging from dairy, fish, cereals, sugar and molasses, fruits and vegetables [13]. The production of fruits and vegetables annually is around 16.4 million metric tons, making Nigeria the 2nd largest producer of tomatoes in Africa, 13th in the World and sadly 3rd largest importer of processed tomatoes commodities in Africa, over 50% of these produced fruits and vegetables are lost due poor infrastructures, lack of access to markets, poor postharvest handling costing Nigeria around 9 million USD annually [4]. With the global food consumption at 3.4% and a predicted population growth of around 400 million people by year 2050, an estimated 4% annual food consumption increment[2, 13], to feed these number of people will indeed be a great challenge as such an integrated approach that requires "Smart farming" practices, "smart Industries" for processing of raw materials to finished goods is urgently needed.

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Need for Integrating Industry 4.0 To Nigerian Agricultural Sector

The concept of industry 4.0 lies mainly in creating an arena that connects all elements and functionalities in a hitch free manner to achieve maximum outputs. This connection ranges from the agricultural value chain to the supply chain in a holistic system approach that entails digitalization of agricultural processes using sensors, devices, communication technology and the internet to monitor, track changes and make timely decisions and recommendations to change the way traditional farming practices are done [22, 23], a cost effective automation, efficient operation conditions for farmers and other stakeholders and to improve on cross-industry cooperation [24, 25].

TECHNOLOGIES OF INDUSTRY 4.0

These technologies are the enabling components of industry 4.0, they include; Systems Integration, Big Data Analytics, Cloud Computing, Cyber Physical Systems (CPS), Internet of Things (IoT), Artificial Intelligence/Machine Learning, Autonomous Machines and Simulation. All these components enable the integration of production facilities, supply chain service systems for full synthesis of value added networks that can coordinate a real time decision making processes [23, 26].

Cyber-physical systems

CPS is a system that integrates information and physical dynamics to secure critical industry ecosystem using sensing, computation and communication to safeguard industrial systems using intelligence to achieve common task [27]. The integration of these systems increases the flexibility and efficiency of industrial systems to increase the level of interaction between people to people, machines to people, machine to machine in real-life solutions and virtually [28]. Due to this integration of CPS, several smart devices are connected to the internet at a greater efficiency and scalability to improve on the Internet of Things network [29]. It processes these data generated from by sensors using powerful computing software and other resources to effect these data into useful real-life solutions [30].

CPSS architecture modules: these modules enable control of CPSS applications it comprises of Application-as-a-service (AAAS), Network-as-a-service (NAAS), infrastructure-as-a-service (IAAS). These modules detect how CPSS application respond to input and execution of output [31].

Internet of Things (IoT)

Internet of Things is an electronic concept that connects the internet to objects to convert them into connected devises, to enable for smart objects for sensing, transmission of data, processing and feedback to the sensing environment for increased safety, sustainability and efficiency [32].

STATE OF THE ART

For implementation of Industry 4.0 to agriculture, three key factors need to be adhered to [26];

I. Horizontal integration,
II. Vertical integration and networking of systems,
III. End-to-end engineering of overall value chains.

Horizontal integration: this enables the acquisition of data on products produced between organizations to optimize product qualities using information systems, efficient financial management and flow of materials [26]to meet customer needs and improvement on the entire supply chain through situation analysis and environmental studies to develop models and strategies for sustainability of manufacturing or service operations, company's level of integration and technological adoption level to identify change elements within the organization [33].

Vertical integration: offers a digitalized cross-linking of business units in different hierarchical levels of the organization, it involves creation, development, manufacturing of products and administration [26]. It assesses the system to identify the social technical systems, value creation modules to provide support to operations and transformation into smart factories with high flexibility and profitability [33], to meet customer needs with maximum utilization of resources [34].

End to end Engineering integration: this facilitates the automation, flexible, digitalized and efficient production systems as products and services are key components of industry 4.0 [34, 35] to check for the compatibility of this union and bring about smart products to meet customer needs and give way for the production of cyber-enabled products and optimization along the entire value chain of the product [36, 34]. This integration of CPS, physical production system and products will

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allow monitoring, improved resources utilization, self-regulation, autonomous production and seamless flow of materials across production lines for faster production in real time within or outside the organization [37], [38].

AGRICULTURAL PRODUCTION PROCESSES

Traditional cultivation, processing practices are being transformed into smart practices to boost productivity, reduced wastes, increased profit, customer satisfaction and new business models. The digitalization of agricultural processes will improve on traditional machines to bring in new tools and machines for production such as autonomous tractors and equipment, connected machines and tools, will reduce the need for highly skilled operators, Global Positioning System (GPS) will give a real time data for precise tracking of farm operations to pave way for enhanced billing and profit [39, 40], sensors for detecting weather conditions, soil conditions such as nutrient content, moisture content, irrigation requirements, drone technology for detection of insects and pest infestation and recording these data for present and future utilization and optimization of production practices [11].

AGRICULTURAL SUPPLY CHAINS

Nigerian agricultural supply chain has its own challenges from poor inputs, subsistence farming, low adoption of mechanization, poor postharvest handling, lack of adequate rural infrastructures and access to markets, unfavorable credit facilities, government policies, low funding of Agricultural Research Institutions, poor adoption of modern agricultural practices across the value chain [14] [13], [2].

Connecting industry 4.0 components to the supply chain via cloud and internet of thing to provide for more value added services to close the gap between virtual and physical world, the more the connectivity with farms and machines the more increased the transparency and security in production, processing and increased customer satisfaction [11], [40]. Increasing the chances of modernization of farmers production practices and the rural infrastructures to obtain and share real-time market and production information [41].

AGRICULTURAL BUSINESS MODELS (ABM)

Business modeling is an approach that seeks to minimize the current cost of processes in a system at a more efficient, increased profit, less production time and a satisfactory product [42]. It is a comprehensive tool that understand how business is done, conduct performance analysis, identify and implement competitive strategies in product design or services offered to the market and customer engagements. In the case of agriculture, it is the digital transformation of agricultural supply chain to enable innovative business approaches that combines economic, humans, Animals and environment for sustainable productivity to improve on the existing practices for more profit, reduced wastes and increased customer satisfaction [11].

The components of ABM are value proposition, value creation, delivery and value capture. Value proposition deals with what the company or farmer has to offer as a product or service. These smart products or services will provide cost reductions, new income streams and new innovations integrating IoT application and platforms that allow connectivity between devices at different location to gather data, analyze, optimize processes and production at the lowest possible cost, reduced wastages, faster transactions and transparency which will increase customer satisfaction and loyalty [42]. Tracking and analyzing customer-buying behavior using smart channels, utilization of data on soil and environmental conditions to provide adequate information for timely decision making and recommendations for increased growth and innovative farming [5], [11].

CONCLUSIONS

Agriculture 4.0 revolution can offer several advantages to the Nigerian Agricultural sector, not just the Government and stakeholders but also technological sophistication in simplifying production processes. These technological advancements will go a long way in transforming the sector challenges by adopting new technologies to replace traditional practices of agriculture, incorporating cross-industry methodologies for solving agricultural challenges and customer focused goods and services with high efficiency and effectiveness. New technologies and software alone cannot address all the problems ravaging the agricultural sector in Nigeria. Necessary infrastructure, funding, favorable regulations and adequate investment in Agricultural Research and Education are needed to ensure implementation of Industry 4.0.

RECOMMENDATIONS

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Traditionally in Nigeria, Government plays the role of promoter/facilitator allowing other stakeholders to play the remaining part, for Industry 4.0 to thrive the Government needs to take the primary role with full engagement to ensure that food security is guaranteed to its teeming population with the following also taken into cognizance.

- adopt a goal-oriented problem solving mentality
- upgrade the rural telecommunication infrastructures
- seek for cross-industry collaboration
- develop a holistic research and development solutions
- create educational programs and awareness initiatives
- friendly regulations

REFERENCES

[1] O. Ercan and G. Samet, "Literature review of Industry 4.0 and related technologies," *Journal of Intelligent Manufacturing,* p. 56, 2018.

[2] PwC, "Transforming Nigeria's Agricultural Value Chain," PwC, 2017.

[3] NBS, "GDP Report," National Bureau of Statistics, Abuja, 2020.

[4] N. Abdulhakeem, I. Muhammad and I. Dagwa, "Simulation and Optimization of a Process Layout for Dehdyrated Fruit and Vegetables Processing Plant," *Bayero journal of Engineering Technology (BJET),* vol. 15, no. 1, pp. 99-106, January 2020.

[5] Z. Ilaria, C. Massimo, E. Gianluca, S. Maria Grazia and C. Andrea, "Revolution 4.0: Industry vs. Agriculture in a Future Development for SMEs," *Processess,* vol. 7, no. 36, p. 16, 2019.

[6] V. Saurabh, A. Prashant and B. Santosh, "Industry 4.0 – A Glimpse," in *2nd International Conference on Materials Manufacturing and Design Engineering*, 2018.

[7] L. Yongxin, D. Fernando, E. d. F. R. Loures and P. R. Luiz Felipe, "Past, present and future of Industry 4.0 - a systematic literature review and research agenda proposal," *International Journal of Production Research,* 2017.

[8] R. Drath and A. Horch, "Industrie 4.0: Hit or Hype?," *IEEE Industrial Electronics Magazine,* vol. 8, no. 2, pp. 58-56, 2014.

[9] W. Stephan, S. Mathias, O. Moritz and G. Dominic, "Towards Industry 4.0 - Standardization as the crucial challenge for highly modular, multi-vendor production systems," in *International Federation of Automatic Control IFAC*, 2015.

[10] T. Stock and G. Seliger, "Opportunities of Sustainable Manufacturing in Industry 4.0," in *13th Global Conference on Sustainable Manufacturing - Decoupling Growth from Resource Use*, 2016.

[11] B. Anja-Tatjana, C. Eduardo and S. Thilo, "Farming in the Era of Industrie 4.0," in *51st CIRP Conference on Manufacturing Systems*, 2018.

[12] G. P. Tejas and P. S. Sanjay, "Industry 4.0 implications on Agriculture Sector: An Overview," *International Journal of Management, Technology And Engineering,* vol. 9, no. 1, 2019.

[13] FMARD, "The Agriculture Promotion Policy," Federal Ministry of Agriculture and Rural Development, Abuja, 2016.

[14] P. Dayo, N. Ephraim, P. John and A. O. Omobowale, "Constraints to Increasing Agricultural Productivity in Nigeria:," IFPRI, 2009.

[15] J. U. Ata-Agboni and N. Beluchi, "Economic Recovery Programmes of Buhari's Administration as a Developmental Stage Paradigm," *International Journal of Public Administration and Management Research (IJPAMR),* vol. 5, no. 1, pp. 39-47, 2019.

[16] I. Tunde Charles, "Rural-Urban Migration And Agricultural Development In Nigeria," *International Research Journal*, vol. 1, 2009.

[17] Knoema, "Knoema," 2019. [Online]. Available: www.knoema.com/atlas/Nigeria/Population. [Accessed 17 September 2020].

iJETRM
International Journal of Engineering Technology Research & Management

[18] UNPP, "United Nations, Population Division," 2019. [Online]. Available: population.un.org/wpp/download/Standard/Population. [Accessed 23 September 2020].

[19] D. C. Matthieu, V. Anshu and B. Alavaro, "Agriculture 4.0: Future of Faming Technology," Oliver Wymann, 2018.

[20] B. Macaulay, "Land Degradation in Northern Nigeria: The impacts and implications of human-related and climatic factors," *African Journal of Environmental Science and Technology,* vol. 8, no. 5, pp. 267-273, 2014.

[21] C. T. Isife, "Environmental Problems in Nigeria- A Review," *Sustainable Human Development Review,* vol. 4, no. 1&2, pp. 21-37, 2012.

[22] J. Lee, H. Kao and S. Yang, "Service innovation and smart analytics for Industry 4.0 and big data environment, Product Services Systems and Value Creation," in *Proceedings of the 6th CIRP Conference on Industrial Product-Service Systems*, 2014.

[23] B. Mohd Aiman Kamarul, O. Mohd Fauzi, N. A. Nor Hayati and T. Muhamad Farihin, "Industry 4.0: a review on industrial robotics," *Journal Technology Sciences and Engineering,* pp. 137-143, 2016.

[24] V. Bonneau, B. Copigneaux, L. Probst and B. Pedersen, "Industry 4.0 in Agriculture: Focus on IoT," European Commission, 2017.

[25] S. Eleni, A. Konstantinos and P. Dimitrios, "A Context-Aware Middleware Cloud Approach for Integrating Precision Farming Facilities into the IoT toward Agriculture 4.0," *Journal of Applied sciences*, vol. 10, January 2020.

[26] U. Alp and C. Emre, "Understanding Industry 4.0," in *Industry 4.0: Managing digital transformation* , Springer, 2017, p. 293.

[27] W. Jun, L. Shibo, W. Seng and W. Hongkai, "NLES: A Novel Lifetime Extension Scheme for Sefety-Critical Cyber-physical Systems Using SDN and NFV," *IEEE Internet of Things Journal*, vol. 6, no. 2, pp. 2463-2475, 2019.

[28] H. Yu, H. Qi and K. Li, "A Powerful software defined cyber-physical system to expand CPS adoption," *software: Practice and Experience* , pp. 1-13, 2019.

[29] Y. Heisheng, Q. Heng and L. Keqiun, "CPSS: A study of cyber-physical system as a software defined service," *Procedia Computer Science* , vol. 147, pp. 528-532, 2019.

[30] N. Hirofumi and S. Sugano, "Ephemeral-Cyber-Physical System: A Cloud-Like CPS Using Shared Devices in Open IoT," *IEEE Systems Journal*, vol. 14, no. 4, pp. 5176-5186, 2020.

[31] Y. Haisheng, Q. Heng and L. Keqiu, "CPSS: A study of Cyber Physical System as a Software-defined Service," in *2018 International Conference on Identification, Information and Knowledge in the Internet of Things*, 2019.

[32] S. Emiliano, S. Abusayeed, H. Song, J. Ulf and G. Mikael, "Industrial Internet of Things: Challenges, Opportunities, and Directions," *IEEE*, vol. 14, no. 11, pp. 4724-4734, 2018.

[33] P.-L. Magdiel, A. S.-M. Jania, M.-S. Jose´ Antonio, S.-F. Toma´s Eloy and V. Pandian, "Vertical and horizontal integration systems in Industry 4.0," *Wireless Networks,* 2018.

[34] S. Michael, "Industry 4.0 and lean management: a proposed integration model and research propositions," *Journal of Production & Manufacturing Research,* Vols. 6,, no. 1, pp. 416-432, 2018.

[35] C. Leyh, S. Martin and T. Schäffer, "Industry 4.0 and lean production—A matching relationship? An analysis of selected Industry 4.0 models," in *Computer Science and Information Systems (FedCSIS)*, 2017.

[36] H. Kagermann, J. Helbig, A. Hellinger and W. Wahlster, "Recommendations for implementing the strategic initiative INDUSTRIE 4.0: Securing the future of German manufacturing industry; final report of the Industrie 4.0 Working Group," Forschungsunion, 2013.

[37] L. Bassi, "Industry 4.0: Hope, hype or revolution?," in *3rd International Forum on Research and Technologies for Society and Industry (RTSI)*, Italy, 2017.

[38] J. Axelsson, J. Fröberg and P. Eriksson, "Towards a system-of-systems for improved road construction efficiency using lean and Industry 4.0.," in *13th Annual Conference on System of Systems Engineering (SoSE)*, 2018.

[39] E. Harold, J. Woodard, M. Glos and L. Verteramo, "Digital Agriculture in New York State: Report and

iJETRM
International Journal of Engineering Technology Research & Management

Recommendations," Cornell University, New York, 2016.

[40] I. Kovács and I. Husti, "The Role of Digitalisation in Agricultural 4.0- How to Connect the Industry 4.0 to Agriculture," *HUNGARIAN AGRICULTURAL ENGINEERING*, pp. 38-42, 2018.

[41] A. Lorenzo, M. P. Antonio, P. Umberto and C. G. Achille, "Towards Industry 4.0 Mapping digital technologies for supply chain management-marketing integration," *Business Process Management Journal*, vol. 25, no. 2, pp. 323-346, 2019.

[42] C. O. Sezi and U. Alp, "Smart and Connected Product Business Model," in *Industry 4.0: Managing Digital Transformation*, Switzerland, Springer International Publishing , 2018, pp. 20-40.

[43] P. Torres-Carrion, C. Gonzalez-Gonzalez, S. Aciar and G. Rodriguez-Morales, "Methodology for Systematic Literature Review applied to Engineering Education," in *IEEE Global Engineering Education Conference*, Canary Islands, 2018.