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Updates on Modern Agricultural Technologies Adoption and Its Impacts on the Improvement of Agricultural Activities in Rwanda: A Review

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Abstract:- Rwanda's agriculture sector is undergoing a great change from subsistence towards modern commercial agriculture. The adoption of modern agricultural technologies is an indispensable strategy for Rwanda to reach a sustainable economy by boosting agricultural productivity and obviously cutting off food shortage. In this context, the current review aimed at providing the updates about the mostly adopted modern agricultural technologies and their impacts in the improvement of agricultural productivity in Rwanda. The combination of working strategies like ICT in agriculture (ICT4Ag) Strategy; policies such as Crop intensification program (CIP) implementation, and modern agricultural technologies: plant biotechnology mainly micro propagation through modern tissue culture; in vitro production of free-diseases and free-virus crops; microbial biotechnology; drones technology in precision agriculture; IoT (Iinternets of Things); Unmanned aerial System (UAS); Smartphones and mobiles phones; greenhouse, and along with Modern irrigation like water pumping systems, as well as agricultural mechanization have brought an important contributions to the agricultural activities in Rwanda: cutting off environmental obstructions, a tremendous mass production of crops resistant to environmental harsh conditions; propagation of shelf life crops, short-time and accessible crops over the time. Furthermore, agricultural mechanization is considered as a robust approach to boost agricultural production and relenting human workloads. However, adoption of modern agricultural technologies in Rwanda is relatively low; owned by a limited number of smallholder farmers, and still confront with the challenges related to climate change, insufficient of knowledge on the utilization of modern technologies and unaffordability. To ensure a sustainable food production and socio-economic development, and sustainable adoption of these technologies, it requires a serious discourse not only the government concerned, but all stakeholders' contributions as well.

Keywords:- *Modern Irrigation; Agricultural Mechanization; Crop Intensification Program (CIP); Green Revolution; Modern Biotechnoloyg; Precision Agriculture*.

I. INTRODUCTION

In general, in the coming 30 years, agro-food chain will face the challenges of food perishability, meaning that accessibility to food as well as environmental sustainability will be in question, despite the adoption of Green Revolution as a powerful force for increasing food security and agricultural yield [1]. Agriculture sector reportedly accounts around 2 billion of population found livelihoods from agricultural activity [2]. However, the farming productivity is relatively low in order to keep the food availability against the world population which is speculated to increase over 11.2 billion by the year 2100 [3]. It is in this way, modern agricultural technologies adoption is foreseen as a sustainable response. Contemporary agriculture is prominently dominated by adoption of modern agricultural technologies, which profitably have boosted agricultural production, and reduced the food perishability, as well as creating environmental friendly. This has been achieved when new technologies have been discovered, and farmers have been insighted to involve and utilize the advanced technologies, including modern agricultural biotechnology includes, Genetic Engineering (GE). For instance, genetically modified organisms (GMOs) and CRISPR-cas9 (Clustered Regularly Interspaced Short palindromic repeats) technology [59,35]; hybridization in plant breeding, for example, selecting high quality breeds that resistant against diseases and environmental harsh conditions (i.e. abiotic and biotic factors); Small and large scale agricultural mechanization, such as machinery and power tractors in easing farmers' agricultural operations, including land preparation, crop treatment, agro-processing, harvesting, storage and products transportation [6]; modern Irrigation practices [29]; precision agriculture, such as Drone technology; green housing practices; Robotics and Automated system (RAS); Artificial Intelligence (AI) [53]; Mobiles and smartphones in farming; shelves vertical farming [4,7]; Internets of things (IoT), and so much more [9,8,10]. Furthermore, the concern on the use of modern technology has been expanded, as an example is the usage of blockchain technology, which plays a key role in food supply chains by detecting food safety and authenticity, resulting in creation of the customer–providers relationship [11]. However, Adoption of these technologies in Africa, particularly in Rwanda is still limited, unaffordable, and owned by smallholder farmers. Furthermore, the African agriculture is still relying on either

the use of primitive or mixed agriculture practices [12]. Consequently, either the improved agricultural outputs or inputs are significantly low [11]. Alongside, African depends on the international food aids, and still requires technical assistance [13, 12].

In particular, agriculture holds an indispensable economic sector in Rwanda with an estimated account approximately 91.1% of active population depending on this sector, and its country products' export contributes nearly 70% [14]. About 91% food requirement is produced from agricultural activities, as well as it is considered as a source of revenue [15, 47], and 72% accounts people waged from agriculture sector. This sector accounts 33% of the country's gross domestic product (GDP) [16]. Among food crops grown in Rwanda those highly produced include beans, but also cash crops that are exportable such as tea, coffee, pyrethrum, as well as new introduced crops that should be exported like vegetables, flowers, and spices/pepper. In addition, Rwanda's agricultural regional trading consists of beans, potatoes, maize, rice, cassava flour, and maize flour with Eastern Africa [5, 53]. In Rwanda, numerous projects have been initiated and funded under the aim of achieving economic transformation and strongly curtailing poverty, as well as eradicating hunger [5, 17]. Among these initiatives is Green Revolution. Historically, Green Revolution has been considered as agricultural revolution originally developed in Asia and less expanded in Latin American with the intention merely based on the production of high-quality wheat and rice [18]. Also, Allocations and prioritization of funding in agriculture is the important strategy not only to maintain social-economic development, but increase food security as well.

Since 2007, Ministry of agriculture and animal resources (MINAGRI) has embarked on crop intensification program (CIP) policy as a strategy to catch up Green Revolution. CIP has been regarded as the major approach to boost agricultural productivity and combat food insecurity and ensuring smallholder income efficiency by improving agriculture inputs use [19, 13, 16-17]. In the context of accessing modern agriculture technology, Government of Rwanda has implemented various plans and projects such as irrigation Master plan 2015-2020 [47]; SMART agriculture, which concerns of having a low carbon emission, adopting to the use of agro-ecological strategy, and utterly restoring climate change [48], and SMART ICT, especially in agriculture, as the approach to make modern agriculture digitalization [45]. Furthermore, the projects under the World Bank funding such as Rural Sector support project (RSSP), Land Husbandry, Water Harvesting and hillside Irrigation (LWH) facilitated the government of Rwanda to raise commercialized marshland and hillside agriculture of target area, resulting in increase of the productivity at the markets place. Whereas, Sustainable Agriculture Intensification and Food Security project seeks to bring the nutrition improved food and climate reconstitution. All have been contributed together as a durable and effective solution for improving agricultural productivity, reduction of food costs [20], boosting livestock production, and building a sustainable economy [21]. In the same way, through Rwanda Agriculture Board and Animal resources development board (RAB), Government of Rwanda has also admitted various projects in irrigation "Small scale irrigation technology' (SSIT) dealing with the large scale hillside irrigation including pivots, sprinklers and drip system, and mechanization technology to accelerate the rate of agricultural productivity [24]. Currently, Rwanda is using mainly Tissue culture and micropopagation, but also adoption of modern biotechnology is in trial [22]. On the other hand, Drones technology usability in precision agriculture has been contributed in spraying pesticides, in irrigation and distribution of fertilizers effectively [23]; IoT (internet of things) has brought the great advantages in irrigation of rice [42]. Despite the efforts that Rwanda has made in boosting agricultural productivity and curtailing poverty, there still a strong imbalance linked between agriculture and poverty, and the smallholder farmers still face several challenges such as incomprehension on the use of fertilizers, limited fertilizers accessibility and expensiveness of available modern agriculture technologies [5]. This research review aimed to give the updates about the mostly adopted modern agricultural technologies and their impacts on the improvement of agricultural activities of Rwanda.

II. MODERN AGRICULTURAL TECHNOLOGIES AND THEIR IMPACTS IN RWANDA

A. Crop Intensification program (CIP)

In Rwanda, specific programs and policies have been initiated in order to handle agriculture-faced challenges. Among including the Strategic Plan of Agricultural Transformation (PSTA) I, II III and IV, the National agriculture policy and Crop intensification program (CIP) so as to respond to the low agricultural productivity and inputs use. Crop intensification program (CIP) adoption has been foreseen as a crucial approach to reach agricultural intensification, where its application might curtail the problem related with shortage of land accessibility; Curtailing low agricultural productivity caused by low inputs; ensuring smallholder income efficiency and handling the food insecurity issues [25]. CIP program is mainly focused on 4 essential parts: Land use consolidation, submissiveness of chemical fertilizers (DAP and UREA NPK), utilization of improved seeds, the provision of propinquity extension services, ensuring post-harvest management and improved storability [16, 13]. Considering proximity of extended service, Rwanda has made decentralization of service at district and sector level. Thus, Implementation of national policy is assured by an agronomist who connects national policy and local farmers. Also, agronomists play a key role to provide all necessary guidances, information, and training to the local farmers, and farmers was found to be satisfied up to 65% for all 4 CIP policy components, 84 % for inputs use, 93.7% access to chemical fertilizers, 64.3% land use consolidation, 77.4% proximity and extension services, as well as 64.3% post-harvest management and storability [16]. Even though land consolidation can facilitate the management of utilizing small land, and help access to the inputs use, the increase of income is low, and farmers satisfaction about its outputs is moderate [16]. Therefore, there is a need of the improvement. CIP implementation has significantly brought about the 2-fold increase of productivity

of the targeted crops such as maize, wheat and cassava; 30% increase of Irish potato and rice, whereas 3-fold increasing of beans crops [26, 17]. In CIP, the usage of fertilizers and application of improved seeds varieties, besides the pesticides have been considered as a driving force for Rwanda in achieving a high agricultural yield, eradication of poverty and hunger, and satisfactorily make food available [27]. For boosting agricultural productivity, Rwanda has gradually imported improved hybrids seeds: maize and wheat, cassava and potato from Kenya and Tanzania, and also fertilizers distribution have been increased approximately 83% among smallholder farmers [28, 29]. A part from hybrids, Rwanda agricultural Board (RAB) has initiated multiplication of the pollinated and self-pollinated maize, rice and beans, in collaboration of private sector [29]. As a result, Rwanda has been classified among the country with improved food security, and it has been taken an account as a bridge towards MDG1 finalization [17]. However, as reported by the same author [13], CIP has presented some drawbacks: some are disproportional adoption between farmers, meaning that participation is unequally distributed, that is unaffordability to access to the improved seeds for smallholder farmers; others are linked to the environmental degradation. For instance, the intensive utilization of chemicals fertilizers and pesticides prompt the soil and water retaining high salinity, so far might result in soil infertility. Furthermore, as reported by author [58], CIP policy adaptability failed to maintain the food security and risk management.

*B. **Irrigation technology***

The government of Rwanda through the Ministry of Agriculture and Animal resources (MINAGRI) has embarked on the application of irrigation strategy in PSTAII strategy plan, and government has had incentives to allocate 2% of public funds for enhancing irrigation system [34]. Also, establishment of Irrigation Master Plan (IMP) has been thought as a transformative channel to adapt to modern irrigation and reach efficiently to food security. This Irrigation Master plan (IMP) has established in order to exploit efficiently and sustainably whichever types of water resources either underground or surface ones. Considering irrigation water resources, they should be divided into: Runoff for small reservoirs, runoff for dams, direct river and flood water, Lake water resources, ground water resources, as well as marshlands, which have brought Rwanda to have a national irrigation accounts approximately 600000ha [56]. Irrigation is indispensable because it allows massive cropping and curbs climate vulnerability. Hence, contributing a sustainable agricultural production and eradicating problems linked to the food perishability [34].

Based on that Rwanda is a landlocked and thousands hills, thus, mostly agriculture is the hillside-based-agriculture. Also, due to climate challenges, including prolonged droughts and insufficient rainfall, all these factors have prompted the government of Rwanda facilitating the farmers to easily obtain water through the practices of hillside irrigation, especially to the most vulnerable area, as an example sprinkler irrigation in Gashora for cassava production and coffee farms in Ngugu Kirehe District; Gravity fed-irrigation in Rubengera in Karongi District, and much rainwater harvesting systems in differents area of Rwanda has been envisaged. Furthermore, Drainage and marshland Irrigation for the production of rice and soya in Eastern region of country, such as Mutara, Bugesera, have been initiated [49]. Rwandan's farmers do still use motorized diesel to pump water in irrigation practices, but this is not environmental friendly and is expensive. On the other hand, Rwanda has commenced the usage of high modern technology systems like water pumping systems (i.e. solar photovoltaic (PV) and Diesel pumping systems: Hybrid PV-diesel and diesel-generators) at the first hand, it has been started at most vulnerable area, such as the case of Bugesera District, and gravity strategy (Using the water from lake and rivers). However, Diesel pumping systems have brought numerous drawbacks: fuel dependency, carbon emission, and expensiveness. However, iimportantly, Photovoltaic water pumping systems (PVWPS) immediately linked to irrigation systems compared with Diesel Water pumping systems (DWP systems) is more beneficial due to the environmental carbon dioxide emission mitigation, independent to fuel consumption, and helps income saving [30].

C. Modern biotechnology

The progress in biotechnology has tremendously changed the world, either in agricultural area, medical, environmental, or in animal and so much more. Especially, in modern agricultural fields as the focus of this review, modern biotechnology is nowadays dedicated as a driving force for the development of improved foods stuffs and livestock through the production of improved seeds, diseases resistance crops; production of qualitatively and quantitatively desired seeds and fruits; enhanced nutrional value crops and storability; production of adaptive crops against the environmental harsh conditions (abiotic and biotic factors); generating short-time growing and quick productive crops [32]. Due to a high demand of food and food insecurity issues, Rwanda needs strongly to access sufficiently and qualitatively food production. Even though Rwanda has adapted " the "CIP "[19,17], this could not satisfactorily meet with agricultural faced-constrains: sudden climate change, shortage of rain, high salinity soil, crops diseases, fluctuations in pH, scarcity in water and geographical structure that generates erosion unless Rwanda carefully seeks alternative technologies.

Through its ongoing strategic plan for agriculture transformation 2018-24, PST4 and Under Ministry of Agriculture and Animal Resources (MINAGRI), Government of Rwanda has an insight to enhance research and innovations development in almost all sectors. But particularly in biotechnology, there is eagerness to improve agriculture research by spreading improved crops varieties and breeds .Also, Rwanda seeks to strengthen agriculture research technology, where it is focusing on the development of genetically modified organisms (GMOs) in which MINAGRI has targeted that by 2020, its research will have been able to detect GMOs, whereas by 2022 GMOs products will be available [43]

Currently, Rwanda has admitted the program concerning about plant and microbial biotechnology to access modern agricultural technology as reported in MINAGRI annual report 2018-2019 [45]. This program is prominently based on two objectives: (1) the plant tissue culture and micropropagation of disease free-crops, and (2) plant epidemiology and breeding research. For instance, a tremendous development of biofertilizers through microbiol biotechnology application [22, 45]. Among adopted crops including Banana, sweet potatoes, and cassava. Biotechnology application, for example *in vitro* production crops like Banana, sweet potatoes, passion fruit and Tamarillo have been developed in Rwanda [22]. Crop production through tissue culture has additional advantages like producing virus free- resistant crops and propagation in short period of time, increasing of crops fitness; hence, plant remains accessible throughout the time [22, 33].

Rwanda has also attempted to admit institutions in accordance with the policy that researching and implementing agricultural biotechnology to introduce genetically modified hybrids, plant breeding, and tissue culture. Such institutions among reported are: University of Rwanda (UR), Rwanda Agricultural Board (RAB), INES-Ruhengeri and FAIM.CO [32]. As reported by [22], Rwanda has strongly embarked in Tissue culture as one way to produce plant diseases free-resistant and quick propagation, and this has pushed establishing laboratories that concern on the multiplication of potatoes, coffee banana, and pineapple plantlets. Among other modern agricultural technologies that Rwanda has experienced up-to-date including Marker assisted selection (MAS) [32]. Generally, this technique is commonly used in plant molecular breeding to determine the phenotype encoded by a specific gene on the chromosome with the help of DNA markers [35, 36]. DNA markers have been used for the characterization of the behavior of a specific gene, and greatly applied in gene mapping. MAS have helped the researchers or breeders to determine genes of interest that might be linked with diseases resistance in attempts to improve the quality of crops and increase crops production [35]. Through adoptation of plant breeding and microbiol biotechnology, Rwanda has attempted the Marker assisted selection MAS) in so-called "common bean". Through Rwanda Agricultural Board (RAB), as an example, is the introgression of *Pythium root rot* resistance genes and *Mosaic Necrotic virus* along with a trial to produce virus resistant cassava, and sweet potatoes [32, 36].

Precision modern agricultural technologies and others types of technologies

Precision agriculture technology is a novel-third wave-technology revolution, apart from Green revolution and agricultural mechanization. Precision agriculture is a satellite based farming management, for example usage of GPS, in which internal and external-field crop variability is maintained, such as monitoring crops-related environmental stress (i.e. water scarcity ,soils, weeds control, and diseases and pests control, field humidity control, pH, field topography, mapping, nitrogen monitoring, crop yield, etc. [23,39, 54]. Also, it is based on the practice of information technology (IT), geographical information (GIS), as well as remote-sensors to improve services delivery and increasing agricultural production [8]. For instance, in irrigation practices and fertilizers monitoring [39, 23]. Up-To-date, precision agriculture predominantly utilizes mobiles phones and smart phones technology; drones technology, where for i.e. , the latter finds application in crops-pesticides spraying, in irrigation and distribution of fertilizers, along with Internet of Things (IoT) [9, 10, 23]. Innovations in modern agriculture have tremendously emerged. For instance, Blockchain, which plays a great role in food supply chains in detecting food safety and authenticity resulting in creating the customer – providers relationship [11]. Besides, robotics and Automation system (RAS) has been introduced as the one way to replace farming machinery inefficiency, just to mean 'making human work easier' suh an example is carrying heavyloads, and it's autonomously operating. RAS has been substantially used in various agricultural activities such as weeds control, providing guidance for the farmers, irrigation, and increasing precision, as well as monitoring that environmental conditions do not have adverse impacts on the crops productivity [57]. Other types of technologies like modern green housing, vertical farming, sensors and artificial intelligence (AI) have been working together to make agriculture more smarter and cherishable. As an example, Artificial intelligence uses computer operations in monitoring weeds, crops and crops quality; automated soil sensing in moisture and temperature monitoring [53].

Nowadays, the government of Rwanda (GoR) is much concerning about what could help smallholders farmers improve their life-standard by generating more incomes, and how reaching a transformative agriculture. Through this initiative, Rwanda has effortly embarked on the project of using "Unmanned Aerial Systems (UAS) [40], and Drones technology.These technologies are largely applied to large landscaping in farm boundaries 'mapping and determining biomass development as well as in crop inventory procedure Among these two projects, but specifically drone, works importantly with the aim of nitrogen-monitoring fertilizer in wheat crops, and they are financially supported by the Centre for Agricultural and Rural cooperation (CTA) and Airinov; and under management of Charis Unmanned Aerial Solutions (Charis UAS) and the Regional Research Center for Integrated Development (RCID) [41]. Concerning about drone, after information is being gathered by drone about the soil properties, the farmers would use it to predict the quality and quantity of the fertilizers that are appropriately needed. As long as farmers rightfully choose the fertilizers, this provokes the increase in crops yield and solidifies the economy of the country as well as food security. For instance, a trial started in Northern Province of Rwanda, Gataraga sector, Musanze Disrict, farmers benefited from the usage of Drone in spraying pesticides to improve productivity of Irish potatoes and wheat monitoring. Due to these technologies, Farmers have become able to select right seeds suitable for the soil [42, 56].

By establishing The SMART Rwanda Master Plan 2015 ~ 2020 [46]; the Smart Rwanda Mater Plan (SRMP); SMART agriculture [48], Government of Rwanda has prioritized ICT with the intention of providing quick and better services

delivery and achieving a transformative social-economic growth [43]. Rwanda has, on the other hand, embarked upon the so- stipulated the short-coming five years strategy (the ICT4RAg strategy plan 2016-2020) that seeks to achieve a modernized agriculture through the enhancement of agriculture sector and rural development in which ICT becomes a crucial tool ensuring that communication and sharing information runs smoothly and productively, therefore, responding to the farmers needs [21]. As a consequence "ICT and internet" have been pervasive and entrenched in Rwandan society [45]. Furthermore, Population who accesses mobiles and smart phones has been dramatically increased, and both mobiles and smartphones have been drastically multiplied at the market places [43]. ICT, alongside with smart mobile technology in Agriculture have helped farmers to purchase and receive subsidized inputs use, seeds, and fertilizers vouchers on their mobiles phones, which they use to buy inputs from agro-dealers. Such as example is the use of Smart Nkunganire system (SNS). Also, in Rwanda, ICT has been perceived as the strategy to increase agriculture business through which farmer are able to access, share, process information easily; ICT has increased service delivery, increased the number of the skilled and knowledgeable farmers, and it has allowed existence of systems that are importantly used in Agriculture data analysis and management. Among adequate introduced systems are: Agriculture management system (MIS), Satellite crop monitoring, Agriculture data warehouse, Smart Nkunganire system (SNS), National agricultural insurance scheme (NAIS), as well as Agriculture Land Information system (ELIS), etc.[45]. On the other hand, there is Internets of things (IoT) as networking systems, which operates via connectivity between computers system and WiFi-incorpotated devices. Such the examples are Wireless Sensors network (WSN), WiFi-based long distance (WiLD), etc. Through these technologies, agriculture activities such as irrigation, farm monitoring, fertilizer usability control, and soil monitoring, etc. have been enhanced. As a result, the outputs have been incredibly increased, and by cutting off farmers 'workloads [56, 43]. Indeed, availability of internet-networking devices has the advantages of facilitating the manipulation of the digital tools, which help smallholder farmers to delivery services successfully. Among these services, especially in agriculture, include controlling environmental conditions in greenhouses (i.e. weather surveillance), monitoring soil, and plant and water quality. Typical example is when the (IoT) internets of things under a digital support system (DDS), along with weather data can alarm the farmers when to apply pesticides, and also (IoT) internets of things is evolvingly applied in aquaponics and hydroponics for monitoring water behavior, temperature and pH [10,53]. In Rwanda, Internet of things (IoT) merely in irrigation system has been used to improve rice (*Oryza sativa*) productivity at Muvumba valley Rice irrigation in Nyagatare district, Eastern province of Rwanda [42]. By the author [10], IoT Irrigation system uses algorithms for it to work autonomously. It encompasses field sensors that send data to the connected cloud network, and then to the smart phones to report the status of the field conditions. For instance, about water threshold variation, water scarcity, flooded field, temperature, moisture, etc. [53]. At this time information might be sent to the farmers to participate in case the system fails.

By the intention of promoting agricultural productivity and eradicating poverty, and through its on-going Strategic Plan for Agriculture Transformation 2018-2023 (PSTA4), Government of Rwanda (GoR) would seek to harvest much crops through the adaptation of Greenhouse and hydroponics technologies, and 8.22 billion have been allocated [43]. Hydroponics technology consists of growing a root-containing plant in a container-containing water solution that harboring necessary nutrients for the growth of cultivar. The greenhousing is advantageous in boosting agricultural productivity, due to that it allows the drip irrigation practices, better use of oxygen and nutrient; better crops grow in a controllable environment. Therefore climate impediments, for examples weeds, soil born-pests, and toxic pesticides are undermined. However, smallholder farmers complain saying that these modern technologies are expensive and sophisticated, which require effective follow up and skilled farmers [51]

D. Agricultural Mechanization

Rwanda has initiated the agricultural mechanization strategy (AMS) [44], and along with other technologies could improve significantly agricultural productivity. Through these initiatives, two strategies have been stipulated: the first strategy was stipulated that, by 2017 farm mechanization would reach 25%, providing the opportunity for farmers at least 4 Rwandan farmers access or utilize and employ mechanization services. In the Second, the stipulation was that 50% agricultural activities may be mechanized by 2020, and the aim was to achieve a productive-transformed farming, high yield, improved livelihoods of the population and enriching exportation, etc. [52]. By Government of Rwanda putting agricultural mechanization at high agenda both public and stakeholders might promote farmer accessing the farm machinery in different farming operations, including ploughing stage, crop treatment, agro-processing, post-harvesting processing and products transportation. However, mostly concerned crops include the rice, maize, and wheat [34]. Machinery utilization, along with other technologies has been complemented to highly raise agricultural productivity. Among this machinery used including tractors, power tillers, animal tractions, and haversters. For instance, animal tractions have been applied mostly in Eastern province, Nyagatre district. Nonetheless Mechanization is largely owned by the government with an account of 80%, while 20% is undertaken by private sectors [44]. In a-MINAGRI annual report 2018-2019 showed an increase of land mechanization from 41,010 ha to 47,060 ha, and mechanized farm operations accounts 26% [45]. Furthermore, under MINAGRI surveillance, there are 7 private companies, however, 3 of them ensuring on tractors and tillers operations and supplying. Among these companies: Way-Invest Ltd dealing with distribution of tractors and tillers; Yanmar-Japan (operates under Akagera Motor) that supplies power tillers for rice mechanization; Mahindra-Indian (operates under ETC agro); BrazAfric, which distribute agricultural machinery, basically post-harvesting machines. On the other hand, Rwanda is engaged to use locally manufactured machineries

through the Rwandese Association for Sustainable Development (ARDI), where 50 Rice threshers have been locally manufactured, and offered for helping the cooperatives [44]. It is advantageous for utilization of mechanization due to that it enhances human capacity; relenting manpower exhausts, brings efficiency in the field operations, and also works is accomplished in short time. By Rwanda adopting mechanization properly and efficiently will bring out benefits, such as cutting off the emigration of young Rwandan from rural area due to that they are disappointed with the drudgery agriculture labor [34]. However, Mechanization is disproportionately adopted in Rwanda meaning that prioritization is based on the area where land is considerably flat that facilitates machinery operations, and adoption of machinery and mechanized land, and animal traction is relatively low.

III. CONCLUSION

Agriculture sector holds the great contribution in the development of Rwanda's economy. However, it needs to be more commercial than subsistence production, and this requires effortly adoption of new modern technologies. In this review, we identified the adoption of CIP policy even though it is associated with some drawbacks [13] and failed to satisfy to farmers needs [58]; tissue culture through micro propagation, *in vitro* production or propagation, Marker assisted selection (MAS) which have contributed to the production of free- diseases resistant, free- virus resistant crops; selection of good quality crops; propagation in short period of time; increasing fitness of crops; allowing crops to remain accessable throughout the time. Also, Microbial biotechnology has allowed the development of biofertilizers and given ability to charaterize, identify and diagnose plant diseases. Besides, other types of technologies that brought a great change in the development of modern agricultural productivity of Rwanda, including precision agriculture, such as drone technology, Unmanned Aerial Systems (UAS) [40,41], IoT (internets of things); agricultural mechanization; greenhouse and hydroponics, as well as various irrrigation systems. Despite agriculture improvement which have been brought by these technologies, the population growth is disproportionately increasing compared with the people needs, thus, there is a sharp need increase in agricultural productivity for maintaining a balance between people demands and food availability and reduction of climate impediments. To catch up modernised agriculture, it requires a serious discussion about agriculture economic importance, investement and allocation of funds in modern agricultural technoloyg research, perpetual subsidy to the farmers and rational utilization of available resources and pervasive technologies. However, these Discourses require not only the government intervention, but all sectors as well, including stakeholders, private institutions and individual commitment.

CONFLICT OF INTEREST

The author declares that there is no conflict of interest.

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