



# Revisiting Agricultural Technologies in the 4IR Era

Nonceba Ntoyanto-Tyatyantsi<sup>(✉)</sup> and Anthea Amadi-Echendu

Preller Street, Muckleneuk, Pretoria, South Africa  
ntoyan@unisa.ac.za

**Abstract.** Food security is becoming a growing problem worldwide. Much focus should therefore be placed on the agricultural sector with a view of equipping the sector for increased food production capabilities. The agricultural sector is changing rapidly globally due to the fourth industrial revolution (4IR) mega technologies, resulting in smarter ways to farm. These technologies allow farmers to maximise production remotely while controlling every aspect of crop farming such as pest control, soil conditions, crop monitoring, and soil moisture. These advances will allow farmers to be more profitable, efficient and environmentally friendly. However, evidence suggests that small-scale farmers are left behind in the use of 4IR mega technologies in South Africa.

The purpose of this paper is to highlight the use of various 4IR technologies in the agricultural sector by using a desktop review of current literature. The paper recommends for a government-driven entity to be established that will focus on building capacity for small-scale farmers to build more sustainable and bigger businesses to assist in increased food production through the introduction of 4IR technologies.

## 1 Introduction

Food security is a global phenomenon that also forms part of the 2030 Agenda for Sustainable Development in Sustainable Development Goals. Failure to grow enough food may lead to food insecurity. Food may need to be imported, thus inflating food prices which may further lead to poverty as households may not be able to afford the higher food prices. According to the 2001 policy brief of the Food and Agriculture Organisation (FAO) of the United Nations, “food security exists when all people, at all times, have physical and economic access to sufficient safe and nutritious food that meet their dietary needs and foods preferences for an active and healthy life” Policy Brief [1].

Du Toit (2011) clarifies the meaning of food security at three levels:

- 1) **At national level:** food security “refers to the condition whereby the nation is able to manufacture, import, retain and sustain food needed to support its population with minimum per capita nutritional standards”.
- 2) **At community level:** food security means “the condition whereby the residents in a community can obtain safe, culturally accepted, nutritionally adequate diets through sustainable systems that maximises community self-reliance”.

- 3) **At household level:** “food security refers to the availability of food in one’s home which one has access to and when the member of the family does not live in hunger or fear of starvation”.

United Nations (UN) organisations forecast population growth to be between 8.3 and 10.9 billion people by 2050. Such growth rates will require a 50%–75% increase in food supply. At the same time, the needs of developing countries will double, including a 60% growth of rice-consuming countries and Sub-Saharan African growth by 250% Prosekov and Ivanova [3]. According to the UN data, agricultural production will have to grow with 75% by 2050 Godfray et al. [4]. Modern technologies may assist to increase food production through enhanced fertility of land, using organic ocean resources, switching to renewable energy sources, advances in genetics, and breeding more productive breeds of animals Prosekov and Ivanova [3].

In addition, many people have adopted a healthy eating lifestyle whereby emphasis is placed on healthy food habits, public health, quality of food, environmental protection and empowerment of communities. The role of local food production has thus become more important. Aquaponics, gardening and sustainable customised agriculture are emerging as practices in cities. Digital platforms provide new marketplaces to match supply and demand. In addition, a diversified range of alternative food production and supply chains has emerged. Considering the anticipated food shortages, it stands to reason that strategies need to be pursued now to mitigate these shortages. This paper will explore various 4IR technologies that may be used within the agricultural sector to increase food production. It further will look at SMEs as a vehicle to increase food production sources. This paper will focus on technologies that can be introduced as assets into subsistence farming practices to enable small-scale farmers to increase their business yields. In addition, the circular economy promotes greater land productivity, reduction of waste in the food value chain, improvement of soil nutrients to increase the value of land and the indorsement of soil as assets.

## 2 The Ecological Imperative

Carbon dioxide produced by human activities is one of the main greenhouse gases (GHG) responsible for climate change. Managing the carbon emissions has become the biggest social, economic and political challenge in recent years. In December 2015, the world’s nations agreed in Paris to a goal of “holding the increase in the global average temperature to well below 2 °C above preindustrial levels and pursuing efforts to limit the temperature increase to 1.5 °C above preindustrial levels” UNFCCC [5]. This requires public and private entities’ pursuance to curb greenhouse gas emissions from all sectors. The global food system is responsible for ~21–37% of annual emissions Mbow et al. [6].

Agriculture is particularly susceptible to changes in climate. South Africa is a dry country and farming is highly dependent on weather patterns. Ofoegbu et al. [7] opine that, for South African small-scale farmers, the changes in climate are resulting in higher temperatures, unpredictable rainfall patterns and droughts becoming more frequent. That, coupled with the fact that South Africa is already a water scarce country, means that

planning and practicing small scale agriculture is becoming more tenuous. It is therefore imperative to review strategies to optimise agricultural processes and the optimisation of resources. The circular economy is one such strategy that has been gaining support across various industries.

The circular economy (CE) entails the end-of-life management of a product whereby a product's functional life is extended through reintroduction into the supply chain as non-waste Govindan and Soleimani [8]. No production in a circular economy is wasted, thus advancing from the current linear 'take-make-dispose' economy. A CE is planned and designed to be a regenerative industrial system and restores used products, uses renewable energy, removes toxic chemicals and aims for the eradication of waste by using environmentally friendly designs, resources systems and business models. CE promotes reuse, remanufacturing, rebuilding, recovery, restoration and recycling. The agricultural sector is reliant on natural resources and cycles as primary inputs into crop and livestock production. Regenerative agricultural systems like crop rotation, minimum till and cover cropping may be used to preserve the sustainability of the natural systems that support agricultural production Shrestha et al. [9]. Using resources efficiently and the reuse of consumer products may encourage more sustainable agricultural business models.

### 3 Technologies

Droughts causes water scarcity that have a direct impact on the ecosystem, livestock, wildlife and humanity, which in turn negatively affect food production. Factory farming or automated indoor farming has gained prominence, particularly in areas that have water scarcity. Produce is grown in vertical stacks under LED lights. Plants are grown in a water-based solution instead of soil through a hydroponic indoor growing system that allows for vegetables and fruit to be grown throughout the year Firbank et al. [10]. In Pretoria, South Africa, CAN-Agri is a business that provides a vertical farming solution to produce leafy greens in a controlled environment ([www.can-agri.com](http://www.can-agri.com)). Kranji farms in Singapore grow vegetables on 9 m-tall towers made of tiers of planting troughs that rotate around an aluminium frame that caters for 10% of the vegetable market in Singapore. Valcent products uses multi-level rotatable, stacked plastic trays in a climate-controlled glasshouse enclosure to produce tomatoes that are exported globally. The vegetables require only 8% of the water required by traditional farming. Mirai in Japan produces 10,000 heads of lettuce per day which is 100 times more per square foot than traditional farming; produced with 40% less energy, 80% less food waste, and 99% less water usage than traditional outdoor farming Benke and Tomkins [11].

Automation of outdoor farming is also advancing well. Artificial intelligence systems and machines perform tasks like raising seedlings, replanting and harvesting Bannerjee et al. [12]; Han et al. [13]. Precision farming uses information and technologies (GPS, satellite imagery, control systems, sensors, robots, variable rate technology, telematics, software, etc.) to improve crops and increase yields, reduce harvest times, and reduce costs and environmental impact by focusing on soil preparation, seeding, and harvesting. FruitLook is an information technology that is used by farmers in the Western Cape in South Africa that helps deciduous fruit and grape farmers to be water efficient and

climate-smart. The Chameleon and Wetting Front Detector Sensors have enabled small scale farmers in Mozambique, Tanzania, and Zimbabwe to cut down irrigation frequency fifty times and double productivity Ncube et al. [14].

Speed of driverless machines and tractors can be adjusted through cloud-based platforms to fertilise, plow or harvest fields, while locations are monitored Baskerville [15]. Agrorobots can be used to identify and kill weeds in targeted areas by using cameras and sensors, thus reducing the use of pesticides where they are not needed. In addition to cost reductions, a reduction of the environmental footprint of the farm can be achieved. Replacing tasks that people previously performed implies that people may eventually not be needed to grow crops at all. All functions in future will be controlled by a central artificial intelligence mechanism Ponnambalam et al. [16].

DNA testing of crops can be invaluable to adjusting herbicides and other products used in agricultural processes. GPS locations can be stored in the cloud to provide historic information of how crops change over time in specific locations. The farmer's attention could be centred to areas where specific interventions are needed instead of applying techniques and products to the entire crop. The result may yield bigger crops (bigger quantities), less chemicals being used, and better harvests (enhanced quality) at a reduced overall cost Peace [17].

Food Circles Network is a new way of organising food systems and agriculture that links the different role-players of food production ([www.showmefood.org](http://www.showmefood.org)). It is concerned with the safe production and consumption of food. Rural farmers are promoted in the region where their farms are situated. These community-supported agricultural programmes may counter many criticisms raised over food security, food safety, health, as well as ecological and social sustainability associated with the industrialisation of food chains. In addition, community gardening can also help to connect food producers and food consumers in the same geographic regions. The result could build more self-reliant and resilient food networks whereby food is grown on unused land that are not being used Fox-Kämper et al. [18]. Permaculture (permanent agriculture) revisits traditional agricultural methods of not ploughing soil to retain moist, rotating cultures and using complementary crops in order to replenish depleted soils. Small scale farming is potentially more intense and productive as it is presumed that smaller farms produce more food per area. Nutrient recovery (nitrogen and phosphorus) in wastewater can be converted into fertiliser that can be used for agriculture and feedstock Krebs and Bach [19].

Blockchain technologies may in turn be used to link the agricultural supply chain for easier traceability of food to provide for shorter delivery time to market. It is important to be able to trace the origin of food products. Regulators should be able to identify the source and extent of food contamination for example Aldag and Eker [20]. It can also be used to link global networks to enable peer-to-peer transactions in self-organising communities in the economy. A peer-to-peer operating platform can replace complex contracting models as no mediating financial institution needs to be involved. Blockchain also improves transparency as information cannot be changed once it has been entered into the system and it can be viewed by the entire value chain. Private blockchains can be put together for a ringfenced supply chain. A blockchain based supply chain traceability system using RFID and Blockchain technology was proposed to ensure the traceability

of wine from the grape to the bottle distribution Biswas et al. [21]. AgriDigital is an Australian agricultural commodity management platform provider that uses blockchain technology in a verification system to record data such as pharmaceuticals administered to animals Rogerson and Parry [22].

Technologies that reduce carbon emissions by providing sustainable energy supplies, storage and demand solutions, as well as waste reduction and the preservation of clean water are preferred. The wireless sensor network nodes use batteries that consume limited energy within days, depending on the duty cycle of the application. Renewable energy sources like solar photovoltaic energy can increase the sensor's lifespan. Harvesting energy by converting energy from the environment into usable electricity by drawing energy from the sun, the wind, solar, geothermal heat, hydropower, biomass, waste burning safe nuclear power and water (oceans tides) has become a major focus area globally Sharma et al. [23]. The use of data is a core interface between social and technological innovations. Big data analytics helps make sense of vast amounts of data and provide deeper insights into production processes, quality and risk management Lohmer and Lasch [24]. Using the analysis of data, farmers can predict the amount of rainfall that might occur in a given season and even the incidence of flooding. This will assist the farmers in terms of planning and deciding what to grow and when to grow it. In Southern Africa the weather patterns have become unpredictable and with descriptive and predictive analytics farmers can determine the optimal solution Chen et al. [25].

Drones are used for the spraying of pesticides on crops as well as crop monitoring and this has allowed for a larger surface area to be covered than the traditional knapsack sprayer would have covered Veroustraete [26]. In irrigation, drones with hyper-spectral, multispectral, or thermal sensors can recognise parts of a field that are dry or need improvements. They are also able to calculate the vegetation index, which describes the comparative density and health of the crop and show the heat signature Ahirwar et al. [27].

## 4 The 4IR Technologies and Sustainable Development

Climate change affects agricultural yield, which may interfere with food supply chains and progress towards a zero-hunger future. Climate action shows that progress by AI will encourage knowledge and modelling of potential weather and climate prediction and response analytics. Precision agriculture will enable farmers to detect crop diseases early and enhance productivity and returns from rural poverty Silvestre and Țîrcă [28]. Climate control systems and hydronics technologies help minimise water, land and nutrient usage in vertical farming. Technologies such as sensor, AI, robotics and drones reduce greenhouse gas emissions, create critical eco-systems, and promote nature and water conservation Mishra and Maheshwari [29]. Another main area in which sustainable development can be achieved through the fourth industrial revolution is clean energy and less carbon emissions. Energy for development and sustainable energy solutions are required for long-term sustainability. Big data platforms will enable earth management by monitoring carbon emissions and provide precision analytics for agricultural management Østergaard et al. [30]. Table 1 provides a summary of the 4IR technologies highlighted in this paper that may assist to enhance the agricultural sector.



**Table 1.** Summary of the 4IR technologies proposed to solve problems in agriculture

Problems in agriculture	Technologies proposed	Solution
Droughts that cause water scarcity	Climate control system, artificial lighting (LED's) and hydroponics	Automated indoor farming
Automation of outdoor farming	Artificial intelligence systems	Precision farming
High cost of labour and energy usage	Agrorobots	Reduction in cost of labour and of the environmental footprint
Lack of supply chain traceability	Blockchain technologies	Improves traceability and transparency
Carbon emissions	Wireless sensor network nodes	Sustainable energy efficiency
Unpredicted rainfalls	Big data analytics	Descriptive and predictive analytics assist in determining the optimal solution
Pesticides	Drone-based sprayers	Crop monitoring and management
Lack of agricultural space	Vertical farming	Using smaller spaces by leveraging height and not distance to grow crops

## 5 Mitigating Environmental Changes/Challenges

Circular economy as a resource, offers a solution to some of the most demanding issues in sustainable development, and has gained popularity. The circular economy seeks to redress waste pollution and overexploitation of mineral and other resources. Materials that are being used in processes are now used with their end-of-life possibilities in mind. Because of reuse and recycling capabilities, production is now less dependent on virgin raw materials. Recycling should be approached with caution as some materials become toxic if they were recycled too many times. Leakage of plastic in water must be prevented as it may affect the water resources used in agriculture which in turn may affect food production. Bioplastics that have wide use in food and beverage packaging, health care, textiles, agriculture, automotive or electronics need to be biodegradable to reduce the ecological footprint.

Undesirable changes in water systems, caused by climate change, are addressed with collaborative geo-engineering efforts by scientists, companies and private actors. The plastic and chemicals released into the oceans and water systems can cause much harm in the form of ocean pollution and acidification. New water-harvesting solutions provide water for agriculture or drinking in areas that suffer from low rainfall; and they help to mitigate floods Lazurko and Venema [31].

## 6 The Small-Scale Farmer/Entrepreneur

Small medium and micro enterprises (SMME's) play a significant role in the economies of developing countries and play a greater role in the socio-economic stimulation of South Africa. SMME's contribute around 50% to the national Gross Domestic Product (GDP) and believed to be employing up to 60% of the labour force Bruwer [32]. Small-scale farmers have the potential to create employment, provide for food security through increased food supply and contribute significantly to poverty alleviation Oluwatayo [33].

Challenges that small-scale farmers are facing include low profitability, problems in marketing their produce, poor infrastructure and a paucity of policies that support small-scale farmers. The small farmers are disadvantaged as they compete with big farmers who benefit from economies of scale and own a sizeable chunk of the value chain. Land sizes that are becoming smaller coupled with the fact that urbanisation is reducing agricultural land Ferris [34]. Reducing land sizes can however work to the benefit of small farmers. According to Krebs and Bach [19], small farms (1–2 ha) cultivate 12% and even smaller family farms (less than 1 ha) cultivate 72% of the world's agricultural land, and therefore secure nutrition for more of the world's population.

Chisasa [35] states that financial institutions consider a number of factors which include: security, size of the farm, the income of the household, the net worth of the family as well as the demographic characteristics when assessing credit applications. Chauke et al. [36] note that about 77% of the farmers use land as collateral for loans advanced to them. It stands to reason that farmers with a positive net worth are more likely to obtain loans. Small scale farmers are at a disadvantage because they do not own high value assets and are unable to secure finance necessary to grow their farming operations. They therefore mostly participate in subsistence farming.

## 7 The South African Agricultural Landscape

The South African agricultural landscape is one that is dominated by large scale farmers who are predominantly white. South Africa therefore has a de facto bimodal agricultural system which prior to 1994 was epitomised by the interference of the state in the sector through the giving of subsidies to commercial white farmers Lepheane [37]. There is a plethora of laws that were passed before 1994 that gave rise to the dual nature of South African agriculture which include inter alia the 1913 Natives Land Act, the Development Land and Trust Act 18 of 1936, Group Areas Act 36 of 1966, and the Black Homelands Citizenship Act 26 of 1970 Coles [38]. Land distribution in South Africa has created a scenario in which the rural areas are dominated by large scale farms which occupy about 88% of the available agricultural land. This has left only 12% of the land for the 72% of the rural population which is largely black without the necessary infrastructure needed for successful agricultural practices Ministry for Agriculture and Land Affairs South Africa [39].

Despite the intended consequences of policy instruments there are inconsistencies that have emerged. Gates [40] contends that small-scale farming in South Africa, as with rest of Southern Africa, is currently not sustainable given the extent of the damage caused

to the environment. Unsustainable farming practices is further compounded by insufficient financial resources to acquire technology that will align practices, products and processes that will result in sufficient and profitable yields that preserves the environment for future generations Khwizhili and Worth [41].

## **8 A Case Study Example from the Automotive Sector in South Africa**

A few years ago, the automotive sector in South Africa faced a dilemma when manufacturers wanted to close their operations in South Africa. The closing of automotive manufacturing facilities would have resulted in a significant reduction in GDP and numerous job losses.

The Automotive Industry Development Centre (AIDC) was established to strengthen global competitiveness, stabilise jobs in the automotive sector as well as to enhance Gauteng Province as the automotive industry destination of choice. The AIDC has accelerated economic growth within the automotive industry through strategic partnerships with government, non-governmental agencies and industry leaders by focusing on skills development and training, enterprise development, incubation programmes, management of incentive programmes and facility management. Since their incorporation, vehicle manufacturing in South Africa has soared and infrastructure development has grown.

The AIDC established incubation programmes to support black-owned entrepreneurs during their business' start-up phases. These start-up businesses benefitted by receiving subsidised rental space within the incubation facilities, mentorship and training by professionals with business development and financial support. The resultant benefits include nurturing aspirant entrepreneurs into successful businesses; providing business support, mentoring and training to the incubatees, and identifying new opportunities for the SMMEs in the automotive sector to enhance local content for the sector.

## **9 The Way Forward**

Although many initiatives have been formulated in the agricultural space to advance small scale farmers (Agricultural Black Economic Empowerment; restructuring of land reform), and to particularly assist black farmers, more can be done to assist with skills transfers and mentorship in addition to making money and land available to small-scale farmers. A similar intervention to what was done in the automotive space with the AIDC is required in the agricultural sector, whereby government works on a long-term plan to grow the agricultural infrastructure, upskill farmers and assist to equip farmers with technological advancements to enhance agricultural practices and yields. In addition, government can provide security for making funding available to small scale farmers as part of the programme so that modern technologies and much needed training can be financed.

Strategic partnerships can assist to make much needed technologies available to small-scale farmers to use in their businesses. Servitisation collaborations with key partners may be concluded whereby these partners can provide equipment and technologies



as part of a service agreement to small scale farmers while they are being incubated. As part of the incubation process, these small-scale farmers can build their businesses to a point where they become self-reliant and independent within the agricultural economy. Warren [42] points out that farmers could invest in producing food products that target specific niche markets, transport and also opening up their farms to domestic tourism. For this to be effective there is need for farmers to have access to the internet and other technologies. Government and the private telecommunications companies can play a part by making sure that rural areas have access to fast and reliable internet. A study in Hungary concluded that, if there is proper access to technology, the gap between the small farmers and the big farmers will be reduced Boros-Papp and Várallyai [43].

There is also scope for investing in areas and technologies such as hydroponics and urban farming, but farmers need assistance with soil analysis, help with harvesting as well as post-harvest technologies and financing Venter [44]. The shift to commercial farming by the rural and small-scale farmers should be measured. Economies of scale could be achieved faster if the farmers work together as consortiums. For example, the waste from crop farming can be used to feed the animals while the waste from the animals can be used to generate biogas to produce vegetables. Given that most of the small-scale farmers are farming in areas that have poor soils, this could be a solution to minimising waste and making the soils more suitable for farming in order to yield larger crops. Lastly, it is crucial for small-scale farmers to be supported in their local communities. A collaborative approach among the farmers may allow for community needs to be met and for a more distributed approach to fulfilling their community's needs. Farmers can decide to diversify the products they grow and farm to avoid oversupply of certain products while there are shortages of others which will also enable all parties to benefit in the value chain. Currently, small-scale farmers compete with larger farming businesses to sell their products and end up incurring expenses in trying to sell their products that often are not prioritised at markets. The supply chain needs to be shortened to make the products less expensive to the end users and allowing fresher products to reach consumers earlier on in the process. This can be achieved by making products available within the community.

## 10 Conclusion

This paper reviewed literature that pertains to the agricultural sector with specific focus on the South African agricultural environment. It is a known fact that the anticipated food insecurity necessitates the implementation of technologies and mechanisms to enhance food production and yields. It is also important to grow food in a sustainable manner that does not cause harm to the environment. Consumers have also become more health conscious and as such also demand healthier food options. Although policies have been enhanced to incorporate small scale black farmers, changes are not occurring at a fast-enough pace, and the value of the programmes put into place are therefore diminished. There is a need for a more structured, long-term, and large-scale project to be put into place to drive growth in the agricultural system, with particular assistance and support to be provided for small scale famers. By planning towards infrastructural growth in agriculture, Africa and in particular South Africa, can be placed on a trajectory to supply food to other continents by 2050 and beyond.

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