Similarities and Differences between Precision Agriculture and Digitalisation

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The fourth industrial revolution affects all sectors of the economy, including agriculture. This has led to increasing agricultural digitalisation (which is also called agriculture 4.0 or A 4.0) in farms. According to Szalavetz, agricultural digitalisation refers to “the infusion of digital technologies in and the consequent transformation of agricultural pre-production, production, production-related support, and post-production activities.”

Keywords: digital technologies ; value chain digitalisation ; land reform ; proactive land acquisition strategy ; behavioural factors

1. The Concept of Agricultural Digitalisation

The fourth industrial revolution affects all sectors of the economy, including agriculture. This has led to increasing agricultural digitalisation (which is also called agriculture 4.0 or A 4.0) in farms. According to Szalavetz [1], agricultural digitalisation refers to “the infusion of digital technologies in and the consequent transformation of agricultural pre-production, production, production-related support, and post-production activities.” There are several technologies that enable agricultural digitalisation and application domains within agriculture that have been identified in the literature [2]. The agricultural digitalisation technologies are the internet of things, data analytics, artificial intelligence and machine learning, image processing, cloud computing–cyber physical systems, unmanned aerial vehicles, geographic information systems, communication technologies, robotics and automation as well as augmented and virtual reality [2][3][4][5]. Moreover, the relevancy and applicability of these technologies across agricultural-specific domains have also been identified, including but not limited to crop, soil, pest, irrigation, and water management [2][4]. Value chain application domains include storage, logistics, yield, and market demand forecasting, as well as digital marketplaces [2][3][4].

Digitalisation has historically occurred in three stages. The first wave of digitalisation entails the technical digitisation of analogue content and services without fundamentally altering the industry structure. Digitalisation’s initial wave makes no major modifications to the tightly connected layer of product architectures. According to Yoo et al. [6], in the second wave of digitalisation, the decoupling of previously tightly tied devices (networks, services, and content) occurs. Digital content and services may now be delivered over a general-purpose IP network and software-enabled devices, resulting in convergence at numerous levels, including network, device, and market. As a result, established divisions between product categories and industries are continually moving. For example, voice service totally becomes device- and network-independent, with the same level of quality offered regardless of whether the customer is using a fixed-line phone, a desktop computer, or a mobile phone. Similarly, other media services such as music, books, e-mail, and movies can be supplied via a variety of different network types and devices.

The third wave of emerging technologies is distinct from the previous waves. A new fusion of diverse sorts of digital breakthroughs in recent waves of digitalisation is increasingly being witnessed. Likewise, physical and repetitive jobs are being enhanced using rich digital traces and intelligent digitalised tools. In principle, comprehensive digitalisation can incorporate all seven features of digital materiality into every action, behaviour, and activity performed in human daily lives. Digital traces of physical acts, events, and movements in the physical, social, and virtual worlds may be kept, recorded, monitored, analysed, and reprocessed at an unfathomable scale and rate [6].

The process of digitalisation can be easily illustrated using Bukht and Heeks’s [7] three-scope approach to the digital economy. The first scope is the digital (IT/ICT sector), comprising hardware manufacture, information services, software, IT consulting, and telecommunications (**Figure 1**). ICTs have brought tremendous transformation to the agricultural sector. Evidence of ICT utilisation and impact in agriculture is widely documented [8][9][10]. The ownership of computers, cellphones, etc. is used to measure ICT adoption in these studies. Despite extensive literature on the digital economy, the subtle distinction between ICT, digitisation and digitalisation has not been emphasised. In agriculture, the separate phases of the digital economy remain poorly understood. The second scope is the digital economy, which is based on offering digital services as well as increasing the use of sharing and platform economies. The third and last scope of the digital economy is the digitalised economy, where the technologies of the fourth industrial revolution are integrated within businesses to transform business models. Thus, this three-scope approach distinguishes between the IT/ICT sector, the digital economy, and digitalised economy.

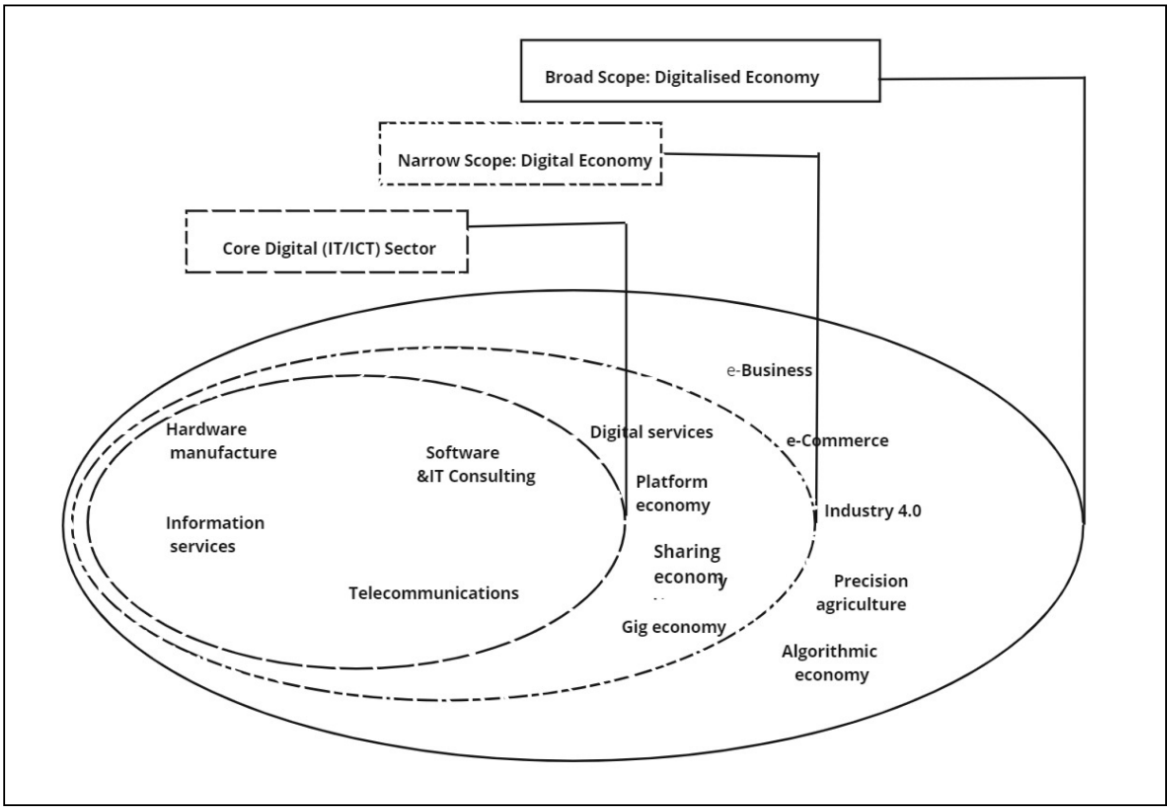

Figure 1. Digital Economy Continuum.— Source: Bukht and Heeks [7].

Digitalisation in agriculture has enabled the introduction of new agricultural digital solutions such as mobile applications, blockchain, the internet of things, drones, and big data into a set of existing precision agricultural technologies (PAT). Adoption of precision agriculture has been on the rise [11]. The economic effect of digitalisation on agriculture is still being debated, but its potential to enhance innovation or create new business opportunities is certain.

Although evidence on the digitalisation of farm processes is still scant, empirical literature on the perspective of IT-enabled organisational capabilities is well established. The IT sector has been around and has been a major focus in literature during the second and third industrial revolutions. The perspectives on IT-enabled organisational capabilities suggest that organisational/process capabilities are a critical mechanism through which IT assists enterprises in creating business value. Organisational learning, knowledge management, talent management, new product development, business agility, and a proactive environment are just a few examples of these intermediate/process (dynamic and operational) organisational competencies. In the literature on the commercial value of IT, this perspective has emerged as the main framework for theoretically and empirically resolving the IT productivity dilemma [12][13][14]. However, questions about the business value of digitalisation remain. Evidence, although still scanty, on digitalisation adoption and impact has emerged.

2. Precision Agriculture and Digitalisation

In the agricultural digital solutions adoption literature, Michels et al. [15] have referred to certain agricultural digital solutions such as drones as recent inventions added to PAT. Nevertheless, agricultural digitalisation includes PAT, which makes the digitalisation context broader than precision agriculture (**Figure 1**). Digitalisation in agriculture focuses on the transformative nature of agricultural digital solutions. Agricultural digital solutions are rendered infrastructural under digitalisation and have the potential to optimise the operational, financial, and marketing decisions of farmers. While adoption of PAT has been skewed towards developed and large-scale commercial farms [16], widespread adoption of agricultural digital solutions is expected even in remote areas of low-income countries because of the rapid expansion of aggrotech.

3. Drivers of Digitalisation Adoption

Empirical literature on the drivers of the digitalisation of agriculture takes many different directions. The first one deals with the factors that predict the adoption of agricultural digital solutions. Performance expectancy, effort expectancy, social influence, and facilitating conditions are behavioural factors that are likely to predict adoption of agricultural digital solutions, with exogenous variables such as age, gender, etc. more likely to play a mediating role. Several empirical studies have shown a positive correlation between the intention to adopt digital agricultural solutions and performance expectancy [11][16][17]. There are mixed results on the role that facilitating conditions play in predicting the intention to adopt. While Michels et al. [11] argued that facilitating conditions are only relevant for determining actual adoption, Molina-Maturano et al. [16] found the intention to adopt agricultural apps to be strongly associated with facilitating conditions in Mexico.

Although no significant relationship has been found between effort expectancy and the intention to adopt an agricultural app in Mexico [16], effort expectancy is considered a good indication of the user-friendliness of a particular technology. It is therefore argued to be a strong predictor of the intention to adopt agricultural digital technologies. As these studies are both based on farmers' perceptions, Mexican farmers may perceive overcoming constraints associated with learning digital solutions as important as opposed to German and Chinese farmers, who may enjoy the dynamic capability associated with their advanced economies. Michels et al. [11] reported a positive relationship between smartphone crop protection app adoption and social influence (i.e., the extent to which certain individuals influence the adoption belief of the farmer). Similarly, Sun et al. [17] found that social influence significantly affects adoption of the internet of things in China. Although Molina-Maturano et al. [16] did not confirm the positive effect of social influence in Mexico, farmers' social networks are important for the adoption of new technologies. Digital solutions such as agricultural apps are still in development and pilot phases in Mexico [16], suggesting the poor role played by farmer networks in predicting adoption.

Other studies that have considered the role that farm and farmer characteristics, besides behavioural factors, play in determining adoption have focused on factors influencing actual use. Michels et al. [15] revealed farm size, age, and literacy on PAT to be the factors that affect the actual adoption of drones by German large-scale farmers. Farmers' age, farm size, knowledge about specific crop protection apps, potential for crop protection, and potential for reducing negative environmental effects have been identified as significant predictors of willingness to pay for crop protection apps in Germany [18]. The evidence produced in these studies is inconclusive and varies by context. They demonstrated that while some factors are significant determinants of digitalisation in some regions, they are insignificant in others. Moreover, the evidence produced is only related to the adoption of one dimension of digitalisation, namely the adoption of agricultural digital solutions. Thus, the need for further research is justified, particularly in the context of South Africa.

The most commonly used framework to study digitalisation adoption is the unified theory of acceptance and use of technology (UTAUT) framework. It was developed after an extensive review of eight theoretical frameworks of behavioural adoption and has been cited as the most comprehensive framework [19]. The basic UTAUT framework considers four constructs: performance expectancy, effort expectancy, facilitating conditions, and social influence [19]. With reference to agricultural smartphone apps for crop protection, Michels et al. [11] used the basic UTAUT framework to assess the factors influencing behavioural intention adoption. Extensions of the basic model with additional constructs exist. The mastery approach, goal orientation approach, trust, and personal innovativeness are the additional constructs considered in the investigation of factors affecting agricultural app adoption intention in Mexico [16]. Exogenous variables are normally included as moderating variables in the model.

Another model that has also been used to understand technology acceptance is the trans-theoretical model of adoption (TTMA). Unlike UTAUT, adoption is viewed as a gradual process under TTMA. In Michels et al. [15], the idea of considering adoption as binary is abandoned, and a measure that accounts for more than two stages of adoption is considered. With the exception of Mikhail et al. [20], who estimated the impact of digitalisation on the financial performance of the agro-industrial complex in Russia, the focus in agricultural digitalisation literature has been on the adoption of specific agricultural digital solutions. There are notable attempts to determine the impact of digitalisation in other fields.

4. Perspective on the Digitalisation of the South African Agricultural Sector and Available Options for Proactive Land Acquisition Strategy Farmers

Agricultural digital solutions applications are dependent on the nature of the job that must be performed. Moreover, their synergistic nature accommodates several applications by farmers promoting value chain integration. With different contributions from various agricultural digital solutions, value chain digitalisation in the South African agricultural sector takes several dimensions, including supply chain optimisation and unlocking finance opportunities.

4.1. Access to Markets

Participation by smallholder farmers in global supply chains is often difficult in Africa due to associated high participation costs and low productivity levels. Through initiatives that provide farmers with essential services and market access, unlocking and optimising the supply chain solves the problem of exclusion. The combination of AI-powered platforms with physical warehouses and logistical infrastructure by companies enables cost-cutting and expansion of operations by the producers through supply chain optimisation [21].

Increased consumer demand for the traceability of products has been associated with digital technologies that improve the transparency of the value chain. Blockchain technology for the tracking of agricultural produce allows farmers to access essential accounting information. Moreover, verification of providers' regulatory compliance is possible through cloud computing technologies. E-commerce offers direct market linkages between the farmer and end-consumers, offering farmers value-proposition opportunities and the exclusion of exploitative intermediaries.

4.2. Unlocking Opportunities for Finance

There are several ways in which various government institutions and private commercial banks try to provide funding to South African farmers, particularly smallholder farmers who continue to face start-up or expansion financial constraints. While commercial banks have also attempted to use agricultural data collected by aggrotech companies to provide finance to farmers, a large proportion of farmers remain unbanked in South Africa. Fintech companies are beginning to take advantage of digital technologies such as mobile money to offer unbanked farmers solutions that are related to finance. Crowd farming is one of these solutions and has enabled farmers to access the necessary working capital from people who cannot farm while also giving them an opportunity to own tangible assets such as cows through crowdfunding. Pay-outs are also calculated by the insurance companies based on the satellite information on crops and weather, and this reduces information asymmetries and risk.

4.3. Agricultural Digitalisation and Land Reform Sustainability

Technology adoption has always been one of the ways to achieve agricultural sustainability. Particularly, farmers' adoption of sustainable agricultural technology is espoused in the literature. For example, Hatzenbuehler and Peña-Lévano [22] have examined a range of sustainability-focused technologies that are applicable to smallholder farmers in the Global South, emphasising their potential to enhance food availability and stability. Dash et al. specifically emphasise the contribution of the most important technologies, renewable energy and ICT, in achieving sustainable farming practices. In Indonesia, the adoption of sustainable rice farming practices has been associated with positive contributions to farmers' livelihoods and perceptions of change [23]. Thus, literature widely advocates for the adoption of technology to promote sustainable farming practices. In addition, the type of technology that is adopted is important. Hence, literature has also emphasised how the advent of fourth industrial technologies and their adoption would help foster agricultural value chain sustainability.

Various studies have contended that the implementation of the fourth industrial revolution would facilitate efficient and effective value chain processes leading to economic, environmental, and social sustainability. Arvanitis and Symeonaki [24] have underscored the significance of interdisciplinary collaboration and the implementation of cutting-edge technologies to facilitate agricultural production and value chain management, thereby promoting sustainable farm management. The significance of digital transformation in agriculture, encompassing data analysis and process automation, in fostering economic, environmental, and social sustainability in supply chains is underscored in Hrustek [25]. Yahya and Yahya [26] have emphasised the advantages of Agriculture 4.0, including cost reduction and increased yields. However, there are difficulties associated with implementing these technologies to ensure the long-term viability of crop production. In China, the low adoption rate of sustainable agricultural technologies has been attributed to small-scale production and insufficient market demand [27].

Digitalisation of the value chain can assist the South African agricultural sector in achieving long-term sustainability by mitigating the sector's pervasive inequality. The extensive disparities present in the South African agricultural sector have been extensively documented, often stemming from historical land dispossession during the apartheid era [28]. Efforts to address these inequalities through land redistribution reforms and programmes supporting smallholder farmers in South Africa have yielded limited success [28][29]. The enduring disparity in South Africa's agricultural industry may lead to uneven implementation of digital technology. The existing disparity in the agricultural sector of South Africa has the potential to impede the achievement of the advantages linked to the digitisation of agriculture. However, the implementation of advanced digital technologies to modernise farms would support the long-term viability of land reform. The land reform programme offers an opportunity to address the potential digital divide within South Africa's agricultural sector [30].

The redistributive land reform programme can be used to digitally transform South African agriculture. However, the main objective of the land reform programme in South Africa is to address the issue of inequality within the agricultural sector. It is not widely seen as a strategy for facilitating the digital transformation of the agricultural sector in the country. Mazwane et al. [30] contend that by integrating digital transformation goals into the redistributive land reform policy, it is possible to simultaneously address sectoral inequalities while enhancing efficiency and revitalizing struggling redistributed farms, thereby ensuring long-term agriculture sector sustainability.

Therefore, rising from the historical land dispossession during the apartheid era, attempts to rectify these disparities through land redistribution have yielded limited results. The introduction of advanced digital technologies provides an avenue for the modernisation of farms and the bridging of these gaps, thereby lending support to the enduring viability of land reform in South Africa. By incorporating digital transformation objectives into the redistributive land reform policy, it becomes possible to tackle sector-specific inequalities while simultaneously boosting efficiency and rejuvenating redistributed farms. This, in turn, ensures the long-term sustainability of the agricultural sector. Nevertheless, it is important to consider the adoption intentions of farmers and the influencing behavioural factors thereof.

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