The Journal of
Law, Social Justice
& Global Development

Embracing the Data Revolution for Development: A Data Justice Framework for Farm Data in the Context of African Indigenous Farmers

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Article Information

Issue: 25: 2020: General Issue
This article was published on: **10 May 2021**
Keywords: digitalisation, agriculture in Africa, data revolution, digital agriculture, farming.
Journal ISSN: 1467-0437 **Article DOI**: 10.31273/LGD.2019.2502.

Abstract

This article examines the challenges that the digitalisation of agriculture in Africa brings with respect to ownership and control of data from the perspective of African indigenous farmers as data originators. It discusses the phenomena of the data revolution and digital agriculture in Africa, mapping out the ecosystem of digital agriculture by identifying general trends, key players, types and features of digitalisation driven by the capabilities of mobile and network infrastructure as well as by higher-level digitisation supported by data infrastructures capability. By situating farm data as a constitutive element of traditional knowledge of agricultural production that is subjected to 'datafication', the article outlines the challenges of access to data and of unequal utilisation of data as having an impact on development imperatives that necessitate better control of data flows. It proposes data justice as a conceptual framework for an Africa-wide governance of farm data in which the challenges on access to data and unfairness in its utilisation are addressed in a manner consistent with the continent's aspirations for intra-regional relations

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Introduction

Agricultural systems are increasingly depicted as digital landscapes as the digitalisation of agriculture becomes one of the significant features of technological transformations in the twenty-first century. The collection, aggregation, and processing of data from multiple data sources in the digital landscape of agriculture brings data governance questions that affect the organisation and management of agricultural production while at the same time raising intricate concerns regarding the ownership, privacy, and safety of farm data.

The digitalisation of agriculture is one of the significant features of technological transformations in the twenty-first century. Agricultural systems are increasingly depicted as digital landscapes, as shown by such expressions as 'smart' (Guerrini 2020) and 'predictive' agriculture (Food and Agricultural Organization 2018), 'precision farming' (Rasmussen 2016), 'farming 4.0' (Adam 2016) and the 'fourth industrial revolution' in agriculture (Nijhuis and Herrmann 2019).

The new digital landscape in agriculture rests on the collection, aggregation, and processing of data from multiple data sources by multiple actors. Thus, data governance strategies are needed to guide the important shifts that digitalisation brings regarding the organisation and management of agricultural production while at the same time addressing the intricate concerns that have arisen regarding the ownership, privacy, and safety of farm data. This article examines the challenges that the digitalisation of agriculture in Africa brings with respect to ownership and control of data and proposes a framework for governing the allocation of rights in data and for ensuring control over data from the perspective of African indigenous farmers.

The digitalisation of agriculture in Africa is an aspect of the data revolution that holds potential for development and sustainability. African indigenous farmers can realise the potential of the data revolution if inequalities in access to and over utilisation of data are systematically addressed to support development endeavours. Predominant regimes for the allocation of rights in data favour exclusive data ownership by such intermediaries as data collectors, aggregators, processors, and users. As originators of data, African indigenous farmers contribute to farm data that later becomes a subject of proprietary control. African indigenous farmers face the challenges of inequality in access to data and of unfair utilisation of data. These challenges hold negative repercussions for African countries' development aspirations as proprietary control of data restricts the countries' ability to control the transborder flow of data. This article proposes the development of an Africa-wide data governance framework in which the challenges on access to data and unfairness in its utilisation are addressed in a manner consistent with the continent's aspirations for intra-regional relations.

To accomplish this objective, this extended article is structured as follows. Sections 2 and 3 set the background by discussing the phenomena of the data revolution and digital agriculture in Africa, respectively. The discussion in Section 2 creates an understanding of the 'data revolution' and its relation to development. Section 3 maps out the ecosystem of digital agriculture in Africa, identifying general trends, key players, types, and features of digitalisation of agriculture in Africa that form the cornerstone of data utilisation and governance. The discussion identifies aspects of digitalisation that are driven by the capabilities of mobile and network infrastructure on the one hand, and higher-level digitisation supported by data infrastructures capability, on the other. Section 4 identifies African indigenous farmers as originators of data, whereas Section 5 situates farm data as a constitutive element of traditional knowledge systems of agricultural production that is subjected to datafication.

Section 6 explores the challenges to African indigenous farmers in the face of the increased datafication of traditional agricultural systems. The challenges of access to data are outlined as resulting from technological barriers and due to exclusivity of proprietary control of data. Similarly, unequal utilisation of data is discussed as posing a challenge to the survival of traditional agricultural systems in light of the emergence of the data marketplace in which data are shared with and transferred to global actors. Given the exploitative aspects of such inequality in the utilisation of data, this section also analyses the implication of the data revolution for development. It highlights the increased shift of power to private corporations in the collection and processing of data and sheds light on development imperatives that necessitate better control of data flows.

In Section 7, predominant frameworks for the governance of farm data are discussed. The discussion demonstrates the insufficiency of a privacy framework to regulate access and control of farm data from the perspective of African indigenous farmers as data subjects. Strategies for collective management of farm data as data commons under open data and creative data licensing regimes and under an emerging framework of data philanthropy are also identified as providing a model of governance for data. Given the inadequacy of these frameworks and models to address the challenges identified, Section 8 proposes data justice as a conceptual framework for an Africa-wide governance of farm data. A data governance framework focused on instrumental perspective aims at controlling the impact of data irrespective of claims of rights underlying the data. Section 9 discusses how such perspective supports African countries' interest to data sovereignty through data localisation schemes. A distributive rights-based perspective to data justice addresses the challenges of inadequate access and unequal utilisation of data through recognition of rights and by defining such rights' contents. Section 10 outlines the basis for the recognition of African indigenous farmers as rights holders and elaborates how such rights are consistent with emerging personal data economy models and are necessary to ensure indigenous farmers' control of access to their data. Section 11 is the Conclusion.

Section 2: The Data Revolution and Development

According to the United Nations (UN), the 'data revolution' is a phenomenon that marks a unique departure from the past, when 'a relatively small volume of analog data was produced and made available through a limited number of channels', to the generation and flow of data from various sources and through different channels with a markedly different 'speed and frequency' (Letouzé 2016: 8). Such flow of data is coupled with 'the rise in the number and variety of sources from which it emanates' (Letouzé 2016: 8). In this context, the data revolution explains the vitality of 'big data' and 'small data' in a data-driven economy in which individuals and firms use data to create new goods and services and to solve complex problems (Aaronson 2019). It is noted that 'big data is revolutionising 21st century business without anybody knowing what it actually means' (Emerging Technology from the arXiv, 2013). Understanding the phenomenon of data revolution entails, therefore, a brief discussion of what 'big data' and 'small data' are, and of how the two are related.

There is presently no working definition of the term 'big data' (Hu 2015: 794). The classic definition of big data comes from a 2001 Gartner report that anchored the definition on several data-specific characteristics called the 'three Vs' of big data: volume, velocity, and variety (Laney 2001). The report proposed that volume refer to the amount of data, velocity to how rapidly data are produced, and variety to diversity of the data formats (Laney 2001). From a technological point of view, the 'three Vs' definition of big data is taken as 'high-volume, high-velocity and high-variety information assets that demand cost-effective, innovative forms of information processing for enhanced insight and decision making' (Richards and King 2014: 394). Later, the concept was expanded to include a fourth V, veracity, which refers to 'the level of reliability associated with certain types of data' that brings issues of trust and uncertainty with regards to data and the outcome of analysis of the data (Jung and Kim 2014: 54).

Big data is not to be understood merely in terms of size. According to Cukier and Mayer-Schoenberger, 'big data is also characterised by the ability to render into data many aspects of the world that have never been quantified before … "datafication"' (Cukier and Mayer-Schoenberger 2013: 29). Datafication is commonly understood as putting a phenomenon 'in a quantified format so it can be tabulated and analysed' (Cukier and Mayer-Schoenberger 2013: 78). Distinguished from digitisation, i.e. 'turning analogue information into computer readable format' (Gattiglia 2015: 115), datafication is a process in which data are standardised through systemic classification or categorisation to be aggregated, processed, and analysed computationally (Ambrose 2015). As an aspect of big data, datafication is manifest in a variety of forms and can also, but not always, be associated with sensors/actuators and with the Internet of Things (Ambrose 2015). The National Institute of Standards and Technology explains that big data is data which 'exceed(s) the capacity or capability of current or conventional methods and systems' and as such 'the notion of "big" is relative to the current standard of computation' (Emerging Technology from the arXiv, 2013). Similarly, the OECD notes that 'big data represents large and complex, often unstructured, datasets that are difficult to work with using conventional tools and techniques' (OECD 2016: 48). This description of big data contrasts with that of small data, which is described as being 'thought of as solving discrete questions with limited and structured data, and the data are generally controlled by one institution' (Ferguson 2014: 1-2).

As a distinct term that emerged in reaction to 'big data', small data 'often offer information that is not contained (or containable) in big data' (Lazer, et al. 2014: 1205). Given that common definitions of 'big data' put as a necessary prerequisite advanced computing storage and processing capacity, 'big data expressly or implicitly precludes human storage and processing capacity; … as a result, a small data … involves things that humans can create and grasp using human judgment alone' (Hu 2015: 778). According to Kitchin and Lauriault, small data are 'characterized by their generally limited volume, non-continuous collection, narrow variety, and are usually generated to answer specific questions' (Kitchin and Lauriault 2014: 463). While size seems a factor in the distinction between big data and small data, 'the very factors that have enabled big data are enabling more traditional data collection' (Lazer, et al. 2014). Moreover, 'small data are increasingly linked and scaled into data infrastructures that make them more big data-like—that is, amenable to combination with big data and open to analysis using big data analytics, though the data themselves do not hold the inherent ontological characteristics of big data' (Kitchin and Lauriault 2014: 464). As such, big data and small data reinforce and support each other and can be explained as features of the critical change of data analytics 'using data from all traditional and new sources, and providing a deeper, clearer understanding of our world' (Lazer, et al. 2014). For this reason, instead of the common expression 'big data revolution' (Cukier and Mayer-Schoenberger 2013: 17-18) this article focuses on the 'all data revolution' in analysing the uniquely distinctive role of data in the economy (Lazer, et al. 2014).

The 'revolution' aspect of data signals a historically significant shift that data brings to the methodological and philosophical approaches and perceptions of information in decision making and production (Hu 2015: 798-99). In this respect, the expression of data as 'the new oil' has been commonly used to highlight the distinctive role of data in the data-driven economy in a parallel fashion to the role of oil in fuelling the mass production economy (Yu 2007: n.1). A data-driven economy is an economy in which 'firms are creating new products and services built on various types of data—often combining data sets and gaining new insights about how people and systems behave' (Aaronson 2019: 2). The expertise, capital, and infrastructure to nurture data-driven firms is concentrated in the high-income countries. However, lower and medium-income countries (LMICs) are becoming the fastest-growing markets for data-driven goods and services (Aaronson 2019: 3). The UN Expert Group on the Data Revolution for Sustainable Development warns that there are huge and growing inequalities in access to data and information and in the ability to use it, which may further widen the gaps between high-income countries and LMICs, between information-rich and information-poor people, and between the private and public sectors (UN Secretary-General Independent Expert Advisory Group on the Data Revolution for Sustainable Development 2014).

The significance of data to achieving the Sustainable Development Goals (SDGs) is often expressed in terms of realising the indicative value of data under SDG indicator 17.18 through a mechanism for the availability of high quality and reliable data. A data governance that ensures a standardisation of data and that creates a high level of trust between subjects of data and those that access it serves such a goal. Embracing the data revolution for development, however, goes beyond serving the indicative value of data; it requires realising the unique value of data in the data-driven economy and achieving a data governance that can set rules and systems targeted at minimising inequality in the production, access to, and utilisation of data. Thus, data governance for development should aim at deliberate actions to balance the rights of individuals and companies that are increasingly able to collect, aggregate, analyse, and utilise data with the benefits of such data to the collective in development endeavours.

The data revolution is a composite of three closely interrelated digital infrastructures that the UNCTAD identifies as components of the digital economy: communication networks; software packages and related capabilities; and data platforms (UNCTAD 2018: 6). The first refers to the phenomenon of the Internet as a tool for the collection and flow of data. Despite limitations of infrastructure, the LMICs have seen a significant increase in mobile and network technology (Letouzé 2016: 9).[1] An aspect of communications networks that has emerged as an enabler for the flow of data in economic activities is now referred to as the 'Internet of things (IoT)': the interconnection of devices and objects embedded with sensors and software and network connectivity, which facilitates their communication with one another (Adam 2016). The second component relates to the increasing use and development of software across a range of economic activities, often accessed through computing cloud technologies (Adam 2016). A key component of the digital infrastructure driving the data revolution involves data platforms, 'which provide the means to mine and analyze data … providing the basis for generating huge profit streams and potentially changing the relative positions of countries in terms of their shares in global production, consumption, investments and international trade' (Adam 2016: 7). Data platforms are entities that 'collect, collate and combine layers of data to form "Big Data" and transform them to commercial uses by processing, analysing and exploiting it' (Adam 2016: 7).

Given the centrality of agriculture to Africa's development (Chitonge 2015), development endeavours that utilise the above digital infrastructures have significant presence in the field of agriculture (Kah n.d.). The significance of effective data governance will be evident in development activities that are key to meeting the SDG priorities of ending poverty and hunger as well as of promoting inclusive and sustainable industrialisation, as the adoption of data-intensive digital infrastructures is growing in agriculture. Before discussion of the features of data governance that are imperative to supporting development endeavours in agriculture in the African context, it is necessary to conduct an overview of the emerging and growing trends of deploying digital infrastructures, with a focus on agriculture.

Section 3: Digital Agriculture in Africa

The data revolution in agriculture is often invoked in relation to individual farmers' use of sophisticated technologies in what is increasingly recognised as 'smart' and 'predictive' agriculture or 'precision farming' in industrialised countries with a high degree of on-farm mechanisation (O'Grady and O'Hare 2017: 179). The data revolution in agriculture is not, however, restricted to the industrial world where advanced technologies are deployed for farming activities. In the African context, digitalisation in agriculture has a unique feature that involves the deployment of digital infrastructures in which indigenous farmers, agricultural advisory service providers, and entrepreneurs participate in deploying communication networks and software-enabled applications in various aspects of agricultural economy as well as in creating platforms that utilise data for defined and undefined purposes

[1] Mobile phone penetration, measured by the number of mobile phones per 100 habitants, was 96 percent in Botswana, 63 percent in Ghana, 66 percent in Mauritania, 49 percent in Kenya, 47 percent in Nigeria, 44 percent in Angola, and 40 percent in Tanzania. See http://www.google.com/fusiontables/Home/> (Source: Google Fusion Tables) in UN Global Pulse, *supra* note 6 at 9.

related to agriculture (Jensen, et al. 2016).[2] A recent study reported that, as of 2019, there are at least 390 distinct, active initiatives that use digital technologies, innovations, and data to transform business models and practices across the agricultural value chain and address bottleneck solutions across the continent (Tsan, et al. 2019). The discussion in this section provides an overview of the ecosystem of digital agriculture in Africa, identifying predominant activities and efforts in the digital landscape, in which the generation, collection, processing, and utilisation of data is of paramount importance. Such efforts and activities can broadly be classified as comprising those that incorporate mobile and network communications capability, and those that utilise digital infrastructures of higher computing capability in which data collection and aggregation are a key component.

Mobile and Network Communications in Agriculture

The earliest form of digital agriculture in Africa involved the deployment of information communication technologies (ICTs), through the use of mobile and network technologies to support indigenous farmers' agricultural activities. Such uses mainly involved the provision of agricultural advisory services, the facilitation of agricultural transactions, and the creation of market linkages. In the realm of agricultural advisory services, ICTs are deployed to offer on-demand (pull) or periodically distributed (push) information and guidance in the agricultural value chain of production and marketing, including in pre-production planning and agricultural input production and marketing (e.g., seed production management) (Mayhunduse and Holmner 2019). First-generation ICT initiatives provided relatively general information and advice via agents such as government extension officers, NGO staff, agribusinesses' agents, financial service provider agents, and lead farmers. In Uganda, for example, mobile phones are used for data collection and compilation regarding 'disease incidence, crop management practices, availability of agricultural information, importance of banana to food security, income and knowledge of banana disease control practices' (Nakato, et al. 2016: 210-309). Community Knowledge Workers, 'local leaders who actively disseminate and collect information on their communities', have used mobile applications to collect a wealth of information from indigenous farmers, which was then compiled and sent to a centralised database in urban centres (Nakato, et al. 2016: 210-309).

Many of the early ICT initiatives evolved to deliver more tailored information and advice through data about GPS locations on the farm and other specifics on the farmers, as well as weather and climate information. For example, Farmerline is an agricultural service initiative in Ghana that aims 'to help farmers to increase their yields, productivity and profit by means of mobile-phone information and for farmers to develop sustainable businesses' (Andrason and van Schalkwyk 2017: 7). The company sends text messages with agrarian, economic, and financial information, and provides web platforms and mobile applications to disseminate and collect agricultural data (Andrason and van Schalkwyk 2017: 7). Notably, the data that is used with Farmerline is said to be sourced from the government's meteorological services and from the Ministry of Food and Agriculture which is 'combined with data collected by Farmerline' to make up the information that is accessible by the various groups, including farmers (Andrason and van Schalkwyk 2017: 8). Similar initiatives exist in the form of iShamba in Kenya,[3] iCow in Kenya, Tanzania, and Ethiopia,[4] and Verdant Agritech in Nigeria.[5]

In the provision of market information, the Ethiopian Commodity Exchange (ECX) and Kenyan

[2] Although the terms 'digitisation' and 'digitalisation' are often used interchangeably, the two have slightly different meanings. While digitisation refers to 'turning analogue information into computer readable format', digitalisation refers to 'the way many domains of social life are restructured around digital communication and media infrastructures.' This article uses 'digitisation' and 'digitalisation' distinctly, cognisant of the analytical value that can be drawn from the different meaning of the two terms. See Brennen, S.J. and Kreiss, D., 'Digitalisation'.

[3] Started in 2015, iShamba has almost 350,000 registered farmer clients. See Anonymous (2020) 'IShamba: Shamba Shape Up's farmer information service' Available at: https://ishamba.com [accessed 20th July 2020].

[4] Started in 2012, iCow currently has over 820,000 registered farmers. See Anonymous (n.d.) 'ICow, a farmers best friend'. Available at: https://www.icow.co.ke [accessed 21st July 2020].

[5] See https://verdant.ng [accessed 20th November 2020].

Agricultural Commodity Exchange (KACE) are two examples that rely on network capability to provide data directly to farmers. The ECX was established with the goal of transmitting 'commodity price information to farmers in real time', thereby feeding 'market data … directly to farmers via electronic display boards in 31 centres spread across Ethiopia as well as on the exchange's website' (Rogstadius 2009). It also transfers data through text messaging to interested mobile phone users and in four local languages via automatic telephone messages (Rogstadius 2009). Similarly, the KACE collects, updates, analyses, and provides reliable and timely market information and intelligence on a wide range of crop and livestock commodities, targeting actors in commodity value chains, with particular attention to smallholder farmers and small-scale agribusiness. Esoko is an example of a private initiative that is principally directed at using ICT-based data for businesses, while constituting individual farmers as a secondary market. Its aim is described as providing a 'communication platform whereby smallholder farmers can easily and successfully be reached' while offering 'information and communication services for agricultural markets' through text messaging to mobile phones information such as 'automated alerts containing agrarian and economic information … text and voice messages on market prices … weather forecasts, bids, and crop production protocols' (Mavhunduse and Holmner 2019, 93-94).

In the realm of banking involving agricultural transactions there is M-Pesa, Kenya's much-publicised mobile banking service. Cited as one of the most successful mobile payment systems in the developing world, M-Pesa had by 2018 expanded to almost 16 million active customers with over 90,000 agent outlets across the country, extending the reach of services in rural populations by facilitating communication that is not restricted by distance, volume, medium, or time (Gray, et al. 2018). M-Pesa is especially relevant to the expansion of technology in rural areas, as it also provides supporting services for other companies offering services that require monetary transactions (Baumüller 2016: 143,147-48).

The uses of ICTs in the category of mobile and network communications largely rely on the Internet as a tool to connect with software-enabled devices, leveraging on the network capability of mobile technology. Despite the limits of the Internet infrastructure in most African countries, ICTs have been widely adopted to reach large numbers of farmers in the provision of diverse agricultural services, as well as in supporting agricultural transactions and in facilitating access to agricultural markets. The salient feature of the various uses in the category of mobile and network capability is the collection of data from indigenous local farmers and the mixing of these data with publicly accessible weather and market data to provide farmers with readily available data and information. The type of data collected and utilised in this category of capabilities largely resembles small data that do not necessarily conform to the advanced computing storage and processing capacity associated with big data. Aspects of the data revolution with features of big data can be seen in African agriculture with respect to certain solutions that are engaged in a high level of collection, aggregation, and utilisation of data through digital platforms with high-level data storage infrastructures.

Digital Platforms with Data Infrastructure Capability

A growing feature of digital agriculture in Africa is the deployment of technologies with high-level infrastructure for data aggregation and storage. In this respect, cloud computing presents itself as an element of the digital infrastructure that is distinct from mobile and network infrastructures in its data storage and communication capabilities. The distinguishing feature of digital agriculture in this respect is that solutions and platforms capture a high quantity and quality of data, combining data collected through mobile network infrastructures about individual farmers with those collected through 'big data' techniques of barcode scanning, real-time tracking and monitoring, GPS mapping, geo-spatial sensing, and satellite imagery. The digital agriculture solutions in this category are engaged in a vast array of activities ranging from the provision of precision agriculture advisory solutions to market linkage and supply chain management as well as macro-agriculture intelligence services (Tsan, et al. 2019).

In the realm of precision agriculture advisory solutions, a study by the Technical Centre for Agricultural and Rural Cooperation (CTA) identifies a general trend of emerging platforms that combine in-depth farmer profiles with transaction, weather, satellite, drone, and field/machinery sensor data in order to generate highly tailored and dynamic advice regarding every element of farm operation (Tsan, et al. 2019:45).[6] There are trends toward detecting and tracking the spread of crop and animal diseases to allow early identification as a crucial first step to deploying control measures. Image recognition software is being used to collect thousands of pictures of cassava plants in Tanzania to evaluate the applicability of transfer learning from a deep convolution neural network model for the cassava image datasets, meaning data is used to teach the software the difference between the various images, with the hope of enabling it to differentiate between diseases and their stages (Ramcharan, et al. 2017: 4). The overall goal of such technology is to enable farmers to easily take a picture and allow the mobile device to determine the disease and the level at which it has harmed the plant, thereby allowing for the farmer to take action, if available, while at the same time tracking outbreaks of diseases. Examples of mobile-based solutions include pest-specific apps such as Boa Me in Ghana, Rise Africa in South Africa, and Nuru in Kenya for the fall armyworm[7], as well as large-scale multi-crop solutions like CABI's Plantwise [8] and the Waterwatch Cooperative's Crop Disease Alert application.[9]

While some initiatives integrate drone imagery with other data sources to develop customised farmer advice,[10] there also exist soil and crop diagnostic advisory services in which big players such as Yara International, IBM, and Microsoft experiment through diagnostic applications and field-sensor-based tools.[11] Precision advisory solutions that big technology players are deploying include Microsoft's Farmbeats (and related Digital Agriculture Platform) in Kenya and the Tata Consulting Services' (TCS) InteGra precision agriculture advisory platform in South Africa; and precision agriculture start-ups like AgrInfo/Jembe in Tanzania, Zenvus and Kitovu in Nigeria, ND Lentera in Kenya.

There are also increased uses of communication networks to facilitate agricultural transactions, such as banking, payments, and insurance. ICT applications in this category are aimed at facilitating access to information and services to stakeholders, allowing farmers to make and receive payments with lower transaction costs, ensuring a better interface between the insurer and the insured, building a credit record for farmers, and enabling farmers to invest in productivity based on market and weather patterns (Protopop and Shanoyan 2016: 179). FarmDrive, a prime example of actors in this category, 'connects unbanked and underserved smallholder farmers to credit, while helping financial institutions cost-effectively increase their agricultural loan portfolios' (Ekekwe 2017). To provide financial institutions with 'an agriculturally relevant and data-driven model to assess risk and development loans that fit the needs of smallholder farmers', FarmDrive collects such information as individual farmer, agronomic, environmental, economic, and satellite data, which is then used to connect farmers 'to loans and financial management tools, all through [their] mobile phone'.[12] Similarly, the Kilimo Salama Program—involving several organisations including UAP insurance, the Syngenta Foundation

[6] Examples of such solutions are Sat4Farming in Ghana, Earth-I's Accord project in East Africa, Geodatics in Kenya. See ibid at 45.

[7] See https://fallarmywormtech.challenges.org [accessed 20th November 2020].

[8] Launched in 2012, Plantwise is a global donor-funded network of health plant clinics and plant doctor agents that advises farmers on how to diagnose and treat pests and diseases. Anonymous (n.d) 'Plantwise - Lose less, feed more'. Available at: http://www.plantwise.org [accessed 20th July 2020].

[9] Waterwatch Cooperative is an NGO which is scaling an AI-enabled pest and disease surveillance and advisory system in East Africa, reaching 500,000 registered farmers in 2019. See Anonymous (2020) 'Waterwatch Foundation. Preserve our living planet'. Available at: https://waterwatchcooperative.com [accessed 20th July 2020].

[10] For example, Astral Aerial in Kenya, AgrInfo Jembe in Tanzania, Charis in Rwanda, AcquahMeyer Drone Tech and Ziongate Geospatial's Airborne Agric solutions in Ghana, ThirdEye in Mozambique, and WeFly Agri in Côte d'Ivoire. See ibid. at 46.

[11] See https://waterwatchcooperative.com [accessed 20th November 2020].

[12] See https://farmdrive.co.ke [accessed 20th November 2020].

for Sustainable Agriculture, and Safaricom (Protopop and Shanoyan 2016)—helps farmers 'manage the risks from rainfall variability by covering farmers' inputs rather than outputs and using the data-driven objective index to determine indemnities therefore eliminating the need for traditional subjective evaluation by the loss adjuster' (Protopop and Shanoyan 2016). Kilimo Salama's service is described as offering '"pay as you plant" type insurance which enables smallholder farmers to insure their agricultural inputs against adverse weather conditions, such as drought or excessive rain' (Asenso-Okyere and Ayalew Mekonnen 2012).

Another context in which data are collected and utilised is in the tracking and traceability of agricultural products in supply chains. As a key feature of its mandate to connect smallholder farmers in Ethiopia with export markets, the ECX has established, in partnership with IBM, an integrated traceability system in which vast amounts of data are collected on quality, health, and safety standards, as well as the movement of commodities along the supply chain (IFC 2017). Operational in East Africa and Central America, FarmForce collects real-time production data from farmers and field staff 'which [is] then directly transmitted to the exporter's server and analyzed for further management, logistics and distribution decisions' (Protopop and Shanoyan 2016: 184). In its Cargill Cocoa Project, FarmForce conducts 'barcode-based, bag-level tracking of each bag of cocoa from the farmer through the value chain, to confirm the origin of each bag of cocoa on delivery', which allows 'real-time management of each farmers' certified volume … transparent monitoring and evaluation on farmer livelihoods and the impact, of supplying cocoa to Cargill [and support of] farmer cooperatives to become more professional through day-to-day management systems enabling data-driven decision making' (Farmforce 2018). In Uganda, AgriLife collects data on farmers' production history, demography, input use, and transaction data in order to 'project production capacity, predict demand for inputs, estimate borrowing capacity and [build] credit risk profiles' with the ultimate goal of bringing 'all of the stakeholders along the agribusiness supply chain into an integrated data-driven system in order to meet smallholder farmers' needs faster and more effectively' (Protopop and Shanoyan 2016: 183).

Beyond precision advisory services, agricultural transactions, and supply chain management of tracking and traceability, there are aspects of digital agriculture targeted at the provision of macro-agriculture intelligence and some emerging 'super platforms', also referred to as 'integrated digital agriculture marketplaces' (Tsan, et al. 2019: 88). With respect to the provision of macro-agriculture intelligence, the CTA study identifies three dozen key actors in Africa, comprising:

'…government or donor [agriculture] data analytics and surveillance platforms; surveillance and (more rarely) forecasting tools, typically focused on weather data or food security but often now starting to integrate other data sources and analytics use cases for the benefit of government decision makers; the agronomy research community and its funders; commercial agriculture data analytics platforms that draw on and integrate third-party data and then put productised self-service data, data analytics and data visualisation tools into the hands of decision makers; commercial remote sensing and weather data analytics specialists that have proprietary data collection assets and specialise in specific data types, but also develop value-added data intelligence products marketed to agriculture decision makers or other agri-intelligence intermediaries; and custom [agricultural] data analytics providers that bundle data and data analytics with consulting and advisory models (e.g., working with agriculture sector investors or specific agribusinesses to deliver value-added market intelligence insights or support specific decisions)' (Tsan, et al. 2019: 85-86).

Emerging 'super platforms' are solutions that deliver a fully integrated digital value proposition directly to farmers and to other agricultural value chain intermediaries. In a typical model, super platforms 'combine digitally-enabled market linkages, digital finance, and digital advisory services into an integrated service bundle for farmers' (Tsan, et al. 2019: 88). These solutions have the potential to leapfrog the physical infrastructure gap in Africa's agriculture by linking farmers to buyers and to the broader ecosystem of finance, agricultural advice, and other services such as the purchase of farm inputs. For example, the MobiGrow platform is a bank-led platform in East Africa that combines elements of advisory services, market linkages, and payments and credit.[13] Safaricom's Digifarm solution, as well as Econet, feature advisory services, credit extension, and input-side market linkages.[14] MasterCard's Lab for Financial Inclusion in Nairobi launched the agriculture value chain digitisation solution now operating in East Africa as MasterCard Farmer Network (MFN) and in India as e-Rythu (Mastercard 2020).

In general, digital agriculture has grown in Africa, evolving from an early use of mobile and network technologies in the provision of farmer's information to a more advanced use of digital infrastructures that aggregate and store farm data as a key feature of the data revolution. The nature and scale of the various solutions in the digital agriculture phenomenon vary. While some of the digital agriculture solutions may have limited scalability, a growing number of them have been the subject of exploratory acquisitions, innovative partnerships, and new product development by 'big tech' players like Microsoft, Google, IBM, Bosch, and Alibaba, as well as 'big agri' incumbents like Bayer, Syngenta, Yara, John Deere, and UPL (Tsan, et al. 2019). As these players enter the agricultural ecosystem, their impact on traditional agricultural systems needs to be assessed in the context of a data governance framework that regulates the relationship between indigenous farmers as data originators and others as data collectors, aggregators, processors, and users.

Section 4: African Indigenous Farmers as Participants in Digital Agriculture

The digitalisation of agriculture through the various initiatives reviewed above is largely a result of a collaborative process in which smallholder farmers, technology start-up operators, agricultural service providers, agricultural extension workers, and government agencies participate in the production, collection, aggregation, and processing of data about farms and farmers. In this ecosystem of digital agriculture, it is essential to understand who African indigenous farmers are and their status as smallholder farmers as well as their qualifications as originators of data.

Africa's indigenous farmers are, to a large extent, a subgroup of the smallholder farmers who are key sources of food and agriculture on the continent. Due to the heterogeneity of the group, the task of defining 'smallholder farmer' is difficult (Chamberlin 2007: 3-5; Kalita, et al. 2012). The most common definition prioritises the size of the farm as understood by the maximum number of hectares of land owned by a household or a person—often designated as less than two hectares (Lowden, et al. 2016: 16). Also referred to as 'family farms', such small-scale farms produce 70 per cent of Africa's food supply (International Fund for Agricultural Development 2013). However, farm size is a dynamic concept that changes as a country's overall economy grows and non-agricultural sectors develop and, as such, the International Food Policy Research Institute (IFPRI) suggests a departure from simply 'small' versus 'large' (Fan, et al. 2013: 2). According to the IFPRI, distinctions should be drawn among smallholder farms based on their profitability: subsistence farms without profit potential, subsistence farms with profit potential, and commercialised smallholder farms (Fan, et al. 2013: 5). Each of these categories of small-scale farms faces different constraints that can be addressed through different policy and programmatic channels. While those with profit potential face soft constraints such as limited capital, markets, information, infrastructure, and friendly technologies, those without profit potential face soft and hard constraints such as poor soil, low rainfall and high temperatures, remote locations, and high population density. (Fan, et al. 2013: 5). Commercial smallholders are already involved in profitable agricultural activities but are often held back from scaling up their commercial activities by factors such as limited access to capital and risk-reducing tools (Fan, et al. 2013: 5). African indigenous farmers participate

[13] See https://ke.kcbgroup.com/business/agri/MobiGrow [accessed 20th November 2020].
[14] Anonymous (2020) 'Value Chain Services - EcoFarmer'. Available at: https://www.ecofarmer.co.zw/value-chain-services [accessed 20th July 2020].

in digital agriculture as smallholder farmers who consume the majority of their farm output but are held back from participating more actively in commercially oriented agriculture by a variety of constraints. A data governance framework that embraces the data revolution in agriculture would target these groups with strategies that would help in the attainment of SDGs in meeting their needs.

While being a smallholder alone may qualify most African farmers as being an 'African indigenous farmer', there are some qualifications that need to be met for the recognition of such farmers as originators of farm data in a data governance framework. First, it is often difficult to determine who qualifies as 'farmer.' Sometimes, self-identification and membership in farmer groups is given weight (Gray, et al. 2018: 5-6). However, those who identify as farmers may not necessarily receive most of their income from agriculture (Gray, et al. 2018: 5-6). In addition, given the various roles women can play on plots owned by men, classifying who in the household is a farmer needs to account for female management of farms (Nelson and Swindale 2013): women form a significant constituent of African indigenous farmers, as smallholders in Africa are predominantly women (Food and Agricultural Organisation 2011).

Second, indigenous farmers are distinguished from other smallholder farmers based on their role as custodians of a systemic body of knowledge that results from the accumulation of experience, informal experiments, and understanding of their environment (Tella 2007). In this respect, the term 'African indigenous farmers' refers to local farmers and indigenous communities who, the Food and Agricultural Organisation (FAO) attests, adopt sustainable livelihoods through expertise, skills, and practices developed based on their lived experiences in the course of meeting their subsistence needs (Food and Agricultral Organization 2009). Throughout Africa, small plots of land near homesteads used as home-gardens form locally adapted, complex farming systems in which solutions such as 'soil fertilizers, mulching ingredients and crop management materials are locally developed, always available, affordable, and culture-specific' (Bergman and Jordaan 2017).

Third, indigenous farmers are also qualified as sources of data linked to a unique body of knowledge they utilise on the farm. In the digitalisation of agriculture, data that the various digital platforms exclusively own as a commercially valuable asset is collected from diverse sources. Official statistics systems, public sector sources (such as meteorological offices and government registries), civil society data communities, and the scientific data community all form a key part of national data ecosystems in Africa (Chinganya, et al. 2016). A salient feature of the data revolution in agriculture, however, is the collection of data that is generated by and from indigenous farmers regarding the farm. In the aggregation and processing of data from various sources in the data ecosystem (such as demographic, personal, nutritional, weather, market, and transactions data, etc.), it is the farm itself that 'pulls together' such data, and, as such, the common denominator for aggregating data is the farm, not the farmer. As such, the description of 'farm data' is employed in this article, instead of a more general description of 'farmers' data' or 'agricultural data'.

Indigenous farmers' claim to farm data arises from their unique contribution as originators of the data and its relationship to traditional knowledge (TK). The following section briefly discusses the nature of such a relationship.

Section 5: Traditional Knowledge and Farm Data

Data are the key inputs and outputs of digital agriculture solutions. As the above discussion indicates, the digital agriculture in Africa is heavily reliant on data collected from indigenous farmers by actors that utilise mobile networks and software enabled digital technologies. In this respect, the phenomenon of the data revolution in Africa manifests a different dimension from the so-called 'industrial revolution in agriculture' in the Western world, whereby farmers are directly involved in the collection, aggregation, and, often, utilisation of data through ownership of technologies that have unique capabilities to collect data (Nijhuis and Herrmann 2019). While the data revolution presents a new challenge of data governance in the agricultural sector in general (GODAN 2016), in the African context it brings the added challenges of recognition of contributions and of control over the knowledge underlying farm data.

Farm data are understood as mainly encompassing 'data generated and collated on the farm for use only on the farm; generated and collated off the farm, for use on the farm; and generated and collated on the farm for use off the farm' (Maru, et al. 2018). These categories are named, respectively, as localised, imported, and exported data (Maru, et al. 2018). The digital agriculture phenomenon involves the collection of data about farmers' practices that belong both to the farm as well as to their transactions off the farm. In solutions powered by mobile network capabilities, as well as those with digital infrastructures, information collected from farmers regarding pre-harvest, harvest, and post-harvest practices and their role in the movement of agricultural products across the supply chain all form an important component. In this respect, localised data forms an essential feature of 'imported data', primarily comprised of 'climatic data and market prices that have been interpreted and customized for on-farm use' (Maru, et al. 2018: 2). The third component, 'export data', refers to data that, 'while collected from farmers (or their farms using sophisticated tools like drones or remote sensing) … is usually processed, aggregated or combined with other data and information generated elsewhere' (Maru, et al. 2018: 2). In this context, 'export data' includes that derived from local and imported data, often taking the form of higher-level interpretation, under the guidance of TK when it concerns indigenous farmers.

Because of the intentional aspect of data creation, the very notion of data is intertwined with the ideas, instruments, practices, contexts, and knowledge used to generate, process, and analyse them (Kitchin and Lauriault 2014: 2). In particular, the notion of data among indigenous farmers is intertwined with the concept of data sovereignty, which is 'linked with indigenous peoples' right to maintain, control, protect and develop their cultural heritage, traditional knowledge and traditional cultural expressions, as well as their right to maintain, control, protect and develop their intellectual property over these' (Kukutai and Taylor 2016). Thus, it is noted in a recent study that 'the line between "data" and traditional knowledge is blurred', especially with respect to farm data in the African context (GODAN 2016: 4).

Datafication typically disembeds the knowledge associated with physical objects by decoupling them from the data associated with them (Gattiglia 2015). In this sense, data are often expressed in discrete units and are represented with the use of binary numbers (Oguamanam 2019). However, farm data—as constitutive of localised, imported, and exported data—are derived from the underlying TK in indigenous farmers' practices. Agricultural activity among indigenous farmers essentially involves engagement with subjects of farm data under 'an epistemic orientation that aggregates a complex environmental and ecological worldview.'[15] The agricultural activities that form the essence of farm data, such as patterns of crop use and selection, soil types and fertility, disease detection and remediation, climate and ecological condition, etc. essentially involve a process rich in spiritual insights and ecological and environmental ethics. Such a process, based on careful observations of natural phenomena, is 'a source of new knowledge for nurturing of new genetic resources, new varieties of plants and animals and of innovative responses to the environmental dynamic that continue to inform and enrich agricultural innovation constituting proverbial treasure trove of data in its various compartmentalisation.' [16] While activities such as the mapping of crop yields, the tracking of seed varieties, the analysis of soil nutrients, the diagnosis of plant diseases, and the recording of post-harvest processing take the form of localised data when conducted through the use of ICTs, their significance is diminished unless they are interpreted and applied in particular contexts of use that yield imported and exported data. In digital agriculture, ICTs facilitate the storage, access, retrieval, and sharing of TK that has

[15] Personal Communication with Dr. Chidi Oguamanam, February 17, 2020.
[16] Ibid.

relevance throughout the agricultural value chain (Tella 2007: 185). Thus, indigenous farmers contribute to the generation of farm data as a derivative of their economic, ecological, cultural, and spiritual interpretations of their surroundings in a TK-based practice at the farm level (Brush 2005). As such, a data governance framework ought to recognise these farmers as stakeholders who contribute to data generation and use.

Section 6: Challenges of the Data Revolution to African Indigenous Farmers

Digital agriculture presents an opportunity by which farmers and rural entrepreneurs are provided with a dizzying array of products and services to boost agricultural production and improve their livelihoods (Spielman 2019). According to the agricultural intensification hypothesis, as population pressure increases, so agricultural production moves toward a greater emphasis in mechanisation and to increased technical skills (Salvati 2010). In this context, farmers' embrace of digital agriculture will grow as part of the trend of 'Africa's digital transformation' in which the adoption of digital technologies, tools, and services in agriculture is widely visible (Malabo Montpellier Panel 2019). While some of these digital technology solutions emerged as pilot projects, and some are small-scale initiatives, the pace of growth of technologies, platforms, and services and their scalability is projected as having the potential to leapfrog and lead the way in the application of digital technologies along the agriculture value chain (Malabo Montpellier Panel 2019). As the above discussion shows, digital agriculture initiatives that take the form of tech-startups by local entrepreneurs have recently become the subject of acquisition and exploration by big multinational corporations (Tsan, et al. 2019). In addition, such corporations directly take part in data-intensive initiatives that involve indigenous farmers as participants in the agricultural value chain of production and marketing.[17] In light of the scalability of existing digital agriculture initiatives, and given the role of powerful entities in the collection and processing of farm data, the challenge of the data revolution to indigenous farmers lies in the lack of policies and regulations that guarantee their access to and control over the utilisation of farm data and ensure such data are utilised to inform development endeavours. Indigenous farmers face the threat of inequality and injustice in access to data and their utilisation, with negative implications for development policy at the national level.

Access to Farm Data

Farmers utilise data as a vital input for agricultural production. Farm data are essential for their planning of agriculture, pre-production preparations, production processes, and post-production processing, including for market transactions over production. However, farmers' access to farm data can be limited by two factors: (1) de facto control of the underlying digital infrastructure, and (2) exclusivity of data ownership rights. With respect to the first, access to and use of data is possible through ownership of physical assets in which data are stored. Ownership of the digital infrastructures for the collection, sharing, and storage of data is of paramount importance for accessing and using data. Often, data become exclusive to the person or company having actual access to the data stored in hardware infrastructure.

In the context of indigenous farmers, ownership of mobile technology is the major means of accessing farm data. Mobile phone text messaging and voice data are mostly used to access such things as agrarian information, market prices, weather forecasts, bids, and crop production protocols. However, farmers face hindrances in accessing farm data collected, processed, and stored using software-enabled digital capabilities. Accessing and using such data entails access to devices with high computing ability, such as smart phones, laptops, and computers. For example, Feed the Future Ghana Agricultural Development and Value Chain Enhancement gathers and stores farmers' data using a chip in farmer identification smartcards that each farmer owns, but it is explained that 'farmers could not directly use the data [although] the smartcard became a valued identification tool' (Andrason and van Schalkwyk 2017: 10). The above-mentioned CTA study

[17] See https://waterwatchcooperative.com [accessed 20th November 2020].

reports that, even though digital solutions for agriculture have already registered over 33 million smallholder farmers and pastoralists across the continent, just 42 percent of these actually used with any frequency the solutions they had registered for, while the number of highly active users was likely in the 15 to 30 percent range on average across all case areas (Tsan, et al. 2019). Farmers' access to data is limited as one aspect of the so-called 'digital divide'—the gap between those who can access digital information and use it and those who are excluded (Peroni and Bartolo 2018). As one FAO study indicates, rural women in particular face barriers in accessing ICTs because of their limited education and financial and time constraints (FAO 2011). In this respect, the adoption of digital technologies is 'often aligned with the models and production systems of large, incorporated, industrial scale farmers, much of which are merely out of reach for smaller farmers' (Rotz, et al. 2019).

In some cases, indigenous farmer groups can develop the capacity to access data stored in devices with high computing abilities. Especially in remote rural areas, public extension services are the key source of information on new technologies, and, often, they use technologies for accessing data to improve productivity and the overall wellbeing of farmers. (FAO 2011: 32). In such cases, however, the access and use of farm data can be limited by ownership rules. It is often asserted that 'farmers own their data', however, there is lack of understanding of what this ownership entails (FAO 2011: 32). Ownership of data is usually governed by intellectual property rules that limit access to data by creating exclusivity to individuals and corporations. Justified as protecting investment in the collection, interpretation, processing, and, sometimes, the creation/generation of data, ownership rights in relation to data mainly exist in the form of copyrights, database rights, technological protection measures, and confidential information/trade secrets (Scassa 2018: 5-15). Patents and plant breeder's rights can also be used to limit access to some farm data, in addition to privacy laws and contractual arrangements that deal with aspects of data (GODAN 2016: 7-10). The digital agriculture phenomenon creates an imbalance in access to data, as actors in the data revolution assert ownership rights under these rules and make farmers' access to data conditional on remunerations and licences. For example, data collected by Esoko in West Africa are 'not publicly open and are only made available to clients as part of the value-added service' (Andrason and van Schalkwyk 2017: 10). In addition to limited access, the rise of 'data intermediaries' in agriculture is a global phenomenon that, in the African context, has the potential to create dependency through unequal utilisation of data and may have impacts on development efforts.

Unequal Utilisation of Data

The data revolution has created 'data intermediaries' that capitalise on the value of data in what is recognised as the 'data market place'—a place that can be understood as a digital platform on which data products are traded, and comprised of neutral intermediaries, data vendors, and data consumers (Spiekermann 2019: 210). Neutral intermediaries offer ICT platforms that allow others to upload and sell their data products subject to varying licensing models (Spiekermann 2019: 210). Data vendors (also called data brokers, aggregators, consolidators, or resellers) are those that gather together data into privately held infrastructures and offer it to others, mostly for a given fee (Schomm, et al. 2013: 16). These vendors can source data from both public and private sources; through aggregation from freely available sources, through generation using proprietary methods, or by buying from other vendors (Kitchin and Lauriault 201: 472). While vendors can sell data either by their own or through market platforms, intermediaries that operate the data market can also sell their data. Vendors scale up small data and crunch them with big data 'to construct a suite of derived data products, wherein value is added through integration and data analytics, creating profiles of individuals, groups and places, and predictions' (Kitchin and Lauriault 2014: 472).

Mostly working within an existing value network such as the agricultural or health sectors, intermediaries match supply and demand between data suppliers and data consumers who 'use data to gain insights, develop applications, and make decisions' (Baarbb, et al. 2019: 8).

The emergence of the data market place in agriculture creates an unequal relationship between intermediaries as data collectors, third-party actors in agriculture as data consumers, and indigenous farmers as data contributors. In the utilisation of data in the marketplace, there is no means of accounting for the contribution of indigenous farmers as stakeholders. For example, a data vendor such as Farmerline or Esoko sources their data from public sources such as the government's meteorological services and from the Ministry of Food and Agriculture. For such data to be valuable, it is then combined with data collected from farmers. IBM and other providers of cloud-based infrastructure store huge amounts of such farm data, and with the increasing role of infrastructure providers to act as data vendors, the data can be shared with data users, such as firms that operate in various markets including actors in the agricultural value chain. Contractual licences on access to and use of data often regulate the relationship between intermediaries and users in the data market, but do not account for indigenous farmers in their role as originators of such data.

The data revolution, therefore, creates unequal utilisation of data. For African indigenous farmers, this inequality can be expressed in different forms. First, farmers can be in a weak position in their dealings with other actors in the agricultural value chain. Armed with data collected from farmers, those other actors—input providers, local collectors, exporters, and importers—can dictate the terms of their transactions. In addition, there is concern that data can be shared with traders, commodity brokers, or competitors who would know a harvest's potential results based on expected acreage or yields (Soares 2016: 229).

Second, the data revolution can have a more serious impact on farmers in the utilisation of data for the delivery of agricultural inputs and services. Globally, a growing number of Agricultural Technology Providers (ATPs) engage in the practice of 'prescriptive planting', in which prescriptions are offered to farmers—for a fee—by collecting and analysing data generated on their farms (Bunge 2014). Such practices offer farmers a great benefit, as they increase a farm's efficiency by analysing data. African indigenous farmers benefit from similar utilisation of data by intermediaries such as Farmerline and Esoko (Andrason and van Schalkwyk 2017). Recent global trends have seen that ATPs are acquired by and partnered to global agricultural input providers, such as Monsanto and Dupont, to consolidate the provision of agricultural inputs and services based on farm data (Monsanto Company 2013).[18] Through the sharing that is enabled by the data marketplace, farmers' data can be used to control every aspect of their agricultural production. The insights derived from data collected through ICTs reflect those of farmers using particular digital technologies or services, and without the context provided by TK it is difficult to pin down biases and to understand what the data represent (González-Bailón, et al. 2012). Under these circumstances, the desires and needs of farmers in agricultural production may be affected by data-guided solutions of industrial actors. This leads to dependency that interferes with indigenous farmers' own control of their production system, which involves discretionary choices in the 'cultivation of culturally appropriate staples' (Barber 1992).

Although farmers contribute to the generation of farm data as originators, they do not benefit from value exchanges over data in the marketplace. Monetisation of data is key to realising their economic value in a data revolution that is often referred to as the 'data gold rush' (Kroes 2014). While data intermediaries engage in collecting, processing, and re-selling farm data to firms that operate in various markets, data originators do not have a means of sharing the proceeds. Even

[18] For example, Monsanto paid $930 million to acquire the Climate Corporation, a company that provides 'hyper-local weather monitoring, agronomic data modeling, and high-resolution weather simulations to deliver a complete suite of full-season monitoring, analytics and risk-management products.' Anonymous (2013) 'Monsanto to Acquire the Climate Corporation, Combination to Provide Farmers with Broad Suite of Tools Offering Greater On-Farm Insights'. Available at: http://news.monsanto.com/press-release/corporate/monsanto-acquire-climatecorporation-combination-provide-farmers-broad-suite [accessed 20th July 2020]. Similarly, DuPont has partnered with a weather and market analysis firm, DTN/The Progressive Farmer, while John Deere has agreed to allow DuPont and Dow Chemicals to use data collected from its machines for planting recommendations. Bunge, *supra* note 144.

though farmers are considered to continue to own farm data under typical 'terms and conditions' for its collection, such terms and conditions do not provide for value returns when the data are sold to others; nor do they offer farmers continued access to the data.[19] Limitations on access to data and inequality in the utilisation of data have implications for the pursuit of development in the African context.

Farm Data and Development

By enabling the generation of data, control of access to data, as well as their processing, analysis, and interpretation, the data revolution leads to a power shift from states to private actors regarding the course of development. In this respect, Taylor and Broeders identify two trends of the revolution that can have impacts on development. First, as private actors acquire the power to count, categorise, and visualise citizens of LMICs through the use of various technologies, 'data [are] primarily collected and processed by corporations and only secondarily accessed by governmental authorities', if at all (Taylor and Broeders 2015: 229-37). The unprecedented level of data that corporations collect to monitor, track, and analyse the various activities in agriculture instead 'trickles upward towards more powerful, technologically adept collaborators' under various models of data sharing, including via the data marketplace (Taylor and Broeders 2015: 229-37). Second, the data revolution is creating new country 'data doubles', by which 'new sources of digital data start to parallel or even supplant national data collection efforts', thereby constituting new population-level databases and maps that are visible to corporations only as consumers and markets (Taylor and Broeders 2015: 229-37). The implication of these trends is that development interventions in LMICs are becoming the mere 'byproduct of larger-scale processes of informational capitalism' (Taylor and Broeders 2015: 229). In this respect, the data revolution brings new forms of 'data relations', understood as 'new types of human relations which enable the extraction of data for commodification' (Couldry and Mejias 2018: 336-49).

In addition, corporations that hold data can be empowered to draw conclusions on a policy level about LMICs, thereby exposing macro-agricultural policy to the influence and control of global multinational entities (Taylor and Broeders 2015: 233). Such influence and control is contrary to African indigenous peoples' and their governments' right to food sovereignty, it being 'the right of peoples and sovereign states to democratically determine their own agricultural and food policies' (McIntyre, et al. 2009).

Beyond influencing development policy, data control and ownership may lead corporations to autonomously pursue programs 'they define as development-related, rather than aiming to fill a gap left by state capacity' (Taylor and Broeders 2015: 223). Taylor and Broeders mention IBM's rollout of Project Lucy in Kenya, by which IBM promises to '"solve Africa's grand challenges" including "healthcare, education, water and sanitation, human mobility and agriculture" using artificial intelligence and big data analytics' (Taylor and Broeders 2015: 223). While the project involves feeding all the published economic and social data available from Sub-Saharan African countries into IBM's Watson supercomputer in order to data-mine for answers to questions, it provides an example of how power over data translates into power to determine what constitutes development by a corporation primarily motivated by profit and market share (Taylor and Broeders 2015: 233).

The various modes of data collection and the inequalities in access and utilisation, as well as corporations' domination in the collection and processing of data, have sometimes drawn the rhetoric of 'data colonialism', in a parallelism with colonialism's impact in the economic exploitation of LMICs (Couldry and Mejias 2018; Thatcher, et al. 2016). The concern of 'data colonialism' becomes all the more real because of the way farm data are archived and stored. Much of the world's data today is stored in the cloud infrastructure ('large corporate data centres with sophisticated computers that provide computing and storage as a service') (Aaronson 2019:6). Cloud servers are often located abroad—in high income countries—and the data stored is subject to a foreign country's laws and often accessed

[19] See terms and conditions in https://farmdrive.co.ke [accessed 20th November 2020].

under constantly changing terms of use (Pinto 2018). Often, data are unconditionally and freely transferred from African-based firms and corporations to European and US headquarters tasked with exploiting the data (Mann 2017: 5). Some have pointed out the moral and ethical questions in situations where data generated by or about users who lack the most basic resources in LMICs is locked up in foreign data centres of corporations who claim full and exclusive ownership and do not allow access by national governments or NGOs trying to exploit the data for socio-economic development (Taylor 2016).

As the discussion in this section indicates, the empowerment of private actors as primary actors in development planning on account of their ownership and control of data carries the risk of dependency for African countries and brings to indigenous farmers the loss of control over their own agricultural system. Through monopolistic control of data, intermediaries transform farm data to profitable products and services while indigenous farmers face barriers in access to and control of the data. As contributors to the generation of data, farmers require access to data to support their livelihood. Farmers also need control over access to their data, as exchange of data through intermediaries in the marketplace results in exploitative utilisation of data. African countries need to devise a data governance model that balances the rights of private actors engaged in the collection and processing of data with those of the contributors. In this respect, it is necessary to briefly examine existing models for data governance in Africa that have relevance for regulating farm data. There are two predominant models of data governance that cater to data originators' interests and have relevance to farm data—the privacy model and the data commons framework—while a third model—the Intellectual Property Rights (IPRs) model—is geared towards the interests of collectors and processors of data.

Section 7: Frameworks for Governance of Farm Data

There is currently no dedicated legal framework regulating the collection, ownership, control, and sharing of farm data at the African continental or other jurisdictions and continents. Farm data can, however, be subjected to governance models of IPRs, privacy laws, and collective data sharing frameworks. IPRs determine ownership and control of data in varied ways under the domestic intellectual property law of countries within the framework of the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) as well as under the European Union (EU) Database Directive (Scassa 2018). IPRs models account for the rights of data collectors, aggregators, and processors, mainly taking the form of copyrights, database rights, technological protection measures, and confidential information/trade secrets. With respect to data originators, however, the predominant framework for regulation is a model of privacy protection with respect to personal data. There are also emerging data sharing models that aim at governing data as a collaborative process among originators, collectors, and processors. The following subsections discuss the relevance of the privacy framework and collective data sharing frameworks for protecting the rights of African indigenous farmers as originators of farm data.

The Privacy Model of Governance

From the perspective of data subjects that often originate data, the collection, aggregation, and sharing of data is regulated with respect to 'personal data'. Personal data protection frameworks generally regulate the rights and duties of data subjects (i.e., individuals who are the subject of personal data), data controllers (individuals who, either alone, jointly, or in common with others, determine the purposes for and the manner in which any personal data are processed), and data processors (any person other than an employee of a controller who processes data on behalf of the controller). Data protection laws generally tend to be more 'procedural', mainly serving to ensure procedural integrity of consent in data processing with less regard to the results of data utilisation and access (Politou, et al. 2018: 1). As such, personal data frameworks mainly address the privacy interests of data subjects in the processing, collection, and aggregation of personal data. As a mixture of personal, non-personal, and anonymised data from different sources, farm data presents a unique challenge for data governance. In such circumstances, the question remains as to how farmers can exercise better control over their data as data subjects. To determine the scope of coverage of farm data under personal data frameworks, it is necessary to consider the relationship that farm data has with personal, non-personal, and anonymised data.

The African Union Convention on Cyber Security and Personal Data Protection (AU Convention) provides a personal data protection framework which African countries may transpose into their national legislation and which encourages them to recognise the need for protecting personal data. The Convention defines 'personal data' as: *' …any information relating to an identified or identifiable natural person by which this person can be identified, directly or indirectly in particular by reference to an identification number or to one or more factors specific to his physical, physiological, mental, economic, cultural or social identity.'* (African Union Convention 2014)

This definition is similar to that under the EU's General Data Protection Regulation (GDPR), which is broadly acknowledged as setting the global standard for data privacy: (Shwartz 2019: 94): *'…any information relating to an identified or identifiable natural person ('data subject'); an identifiable natural person is one who can be identified, directly or indirectly, in particular by reference to an identifier such as a name, an identification number, location data, an online identifier or to one or more factors specific to the physical, physiological, genetic, mental, economic, cultural or social identity of that natural person*' (EU 2016).

Under both definitions, to qualify as personal data the information in question must relate to an individual. An important task in determining the scope of personal data is establishing the kind of connection required between the information in question and an individual. The term 'relating to' might be fulfilled whenever the data reveals an identified or identifiable person. However, questions arise as to whether 'personal data' applies narrowly—to circumstances when the information is directly about a particular person—or also broadly—when the information primarily concerns objects, processes, or events and refers to individuals only indirectly (Witzleb and Wagner 2018: 4). According to the EU's Article 29 Working Party (an advisory body that provides the most authoritative guidance on data), for data to 'relate' to an individual at least one of three elements—the content, purpose, or result element—needs to be present (Council of Europe 2007). The 'content' element can be established when the information is about a particular person in the most literal understanding of 'relating to' (Council of Europe 2007). The 'purpose' element exists when the information is used or is likely to be used with the purpose of evaluating, treating in a certain way, or influencing the status or behaviour of an individual compared to other individuals (Council of Europe 2007). As for the 'result' element, data can be considered to 'relate' to an individual because their use is likely to have an impact on a certain person's rights and interests, considering all the circumstances surrounding the precise case (Council of Europe 2007). This element is fulfilled if, at a minimum, an individual may be treated differently from other persons as a result of the processing of such data (Council of Europe 2007).

Farm data, as a composition of localised, imported, and exported data, fulfills the elements of 'personal data' as long as the data relates to a particular farmer or to a collective of farmers. Information about the production activities of farmers at a particular farm in the form of localised data directly relates to farmers. Other information acquired from others sources regarding the farm—such as weather and climate data, as well as processed data in the form of market information and transaction records—indirectly relates to farmers, as such information can be used for the purpose of differential treatment of one farmer vis-à-vis another or is otherwise likely to have some impact on the rights of farmers. Given the broad understanding of 'relating to', a specific piece of information can represent the personal data of more than just one person at the same time, depending on what element is present with regard to each one (Council of Europe 2007). Thus, farmers who contributed to localised data may be a subject of imported and exported data when the information is processed and aggregated with others' data for analytic uses such as the provision of agricultural inputs or for predicting prices for crops—uses that have differential impacts on farmers.

Additionally, 'personal' data requires that data be closely associated with the data subject who must, of necessity, be identified and identifiable. While the primary means of identifying a data subject is the ability to find out his or her name, the subject can also be identified through other means that render them 'identifiable'. It is the existence or non-existence of the possibility of identification that distinguishes farm data from personal data. As farm data—in the form of localised data as well as its derivations in the form of imported and exported data—primarily deal with information related to the farm, the extent to which such information can be used to identify farmers renders the data either personal or non-personal data. According to Recital 26 of the EU GDPR, to determine whether a person is identifiable 'account should be taken of all the means likely reasonably to be used, such as singling out, either by the controller or by any other person to identify the natural person directly or indirectly' (Vollmer n.d.). Going beyond the mere hypothetical possibility of singling out an individual, factors such as the cost of conducting identification, its intended purpose, the way processing is structured, and the interests at stake for the individuals are all taken into account in determining whether the subject is identifiable (Council of Europe 2007). Where such identification is not possible, the information can be considered 'anonymised' data (Council of Europe 2007). Anonymised data does not fall in the category of 'personal data' and, hence, is not the subject of personal data protection frameworks.

There are vast circumstances under which farm data can be considered 'non-personal', either because the data cannot be considered to relate to an individual, or because the individual cannot be considered to be identified or identifiable. Moreover, the frontiers between personal and non-personal can be blurred, given that anonymised data remain potentially subject to de-anonymisation because of the unreliability of anonymisation techniques (de Montjoye, et al. 2013: 2-3). While identification may not be possible at the time of processing, data aggregation techniques have brought about a technical ability to identify previously anonymous data sets, resulting in a gradual failure of anonymisation in such a way that the same piece of data may be more or less easily identifiable (Purtova 2017). Thus, data analytic capabilities have resulted in the general increase in the quantity of data available and in more data being 'personal', as the ability to make connections between people and data is done more rapidly and in new ways. However, farm data, which is not always about humans directly and is often anonymised, is beyond the scope of privacy legislation and remains unregulated.

The blurring of lines between personal and non-personal when it comes to farm data brings the difficult task of dealing with the individual subject of the data and with the holder of the aggregated datasets. While data subjects may originate data as subjects of personal data, much of farm data does not necessarily qualify as personal and, as such, farmers can be contributors to farm data without necessarily being data subjects.[20] In this context, farmers qualify as originators and contributors to data that is often collected by third parties though ICTs. While collectors and users of data often control data through proprietary models and engage in various data sharing arrangements, originators of data lack the legal means to assert control over data to which they contributed either as subjects or otherwise. How can farmers control access to farm data once it is handed over to third parties, and how can African countries effectively control the use that can be made of that data, in particular the use intermediaries make of aggregated datasets stored in cloud infrastructures?

Predominantly, data collection and use are undertaken through data subjects' waiver by

[20] For this reason, African indigenous farmers are best characterised as 'data originators' in relation to farm data, instead of just 'data subjects' whom privacy legislations recognise as bearers of rights. In the data justice framework proposed in this article, the rights of farmers are recognised as originators of data.

consent of control over data.[21] Often, such a contract-based grant of consent to the collection and use of data is conducted without investigating the terms of that consent or understanding the ends to which the data might be used. Under such circumstances, the literature reveals an approach to regulating access to and control over data that has relevance to farm data: collective management of data under data commons.

Data Commons and Collective Management of Data

In the light of the increasing importance attached to access, control, and utilisation, various tools have emerged as a means of collective management and sharing of data, largely between collectors and users. In these circumstances, private companies hold rights in data under intellectual property laws, but access is granted through contractual licences and agreements. Three major strategies are used to access and share data: 'open data' licences, 'Creative Commons' licences, and data philanthropy.

'Open data' is a movement that emerged with the goal of making data freely available to the public through a machine-readable format and accessible by users. Open data is characterised by loose (or even absent) IP-based controls over access, so that data are used, re-used, and redistributed only subject to 'the requirement to attribute and/or share' (Kitchin and Lauriault 2014: 49). Different licensing terms and conditions govern the use or reuse, reworking, redistribution, or reselling of data among users in an open data framework (Kitchin and Lauriault 2014: 49).

The 'Creative Commons' licence is another initiative for the distribution of different types of content, including data. It is a social certification scheme that offers layers of licences ranging from the permissive to the restrictive.[22] Version 4 of the Creative Commons licence is used to openly license data that are held both in copyrights and sui generis database rights (Baarbb, et al. 2019: 17).

The concept of 'data philanthropy' refers to private-sector data-sharing with researchers, nonprofits, governments, and the public (Pawelke and Tatevossian 2013). It is a collaborative scheme in which 'corporations [would] take the initiative to anonymize (strip out all personal information) their data sets and provide this data to social innovators to mine the data for insights, patterns and trends in realtime or near realtime' (Letouzé 2016: 25). Although the main features of this form of data sharing are not yet clear, 'data philanthropy' emerged as a theoretical and social movement aimed at fostering knowledge and information sharing through the use of data for the public good (McKeever, et al. 2018).

Open licence, Creative Commons and data philanthropy together constitute a means of managing data as a common asset among collectors and users. When it comes to farm data, the conception of 'data commons' under these governance mechanisms often deals with the relationship between collectors, processors, and users of data and does not address the interests of farmers as data contributors with a stake in accessing data and maintaining control in its utilisation. Open data approaches to data commons are often proposed as facilitating collaboration with 'actors in the public, private, and development sectors' so that data 'benefits society as a whole while protecting individual security and privacy' (World Economic Forum 2012).

In the data economy, however, intermediaries gather data from public sources and mix them with data from private sources into privately-held infrastructures for resale on a for-profit basis. Such data are regarded as proprietary and are expected to be shared for some sort of remuneration, mostly by monetisation through a platform (Richter and Slowinski 2018: 50). Because of corporate control of data through proprietary rights, farmers lack the ability and permissions to access and utilise data, while all the power resides with the companies who have the permission and capability to store, manage,

[21] For example, the EU Code of Conduct on Agricultural Data provides for a contractual mode of regulating the relationship between data originators, processors, and users. See Anonymous (2018) 'EU Code of Conduct on Agricultural Data Sharing by Contractual Arrangement'. Available at: https://www.ecpa.eu/sites/default/files/documents/AgriDataSharingCoC_2018.pdf [accessed 20th July 2020].

[22] See https://creativecommons.org/licenses [accessed 20th November 2020].

and manipulate it (Richter and Slowinski 2018: 221; Rotz, et al. 2019: 211). As a recent study by GODAN affirms, 'open data approaches, if applied flatly to solve both accessibility and sharing problems and in all types of agri-food systems, are not enough to guarantee equity without a suitable governance framework' (Maru, et al. 2018). Thus, there is a need for a governance framework that addresses the demand of farmers to assert control over data and its utilisation in the data economy.

Section 8: Data Justice as a Conceptual Framework for the Governance of Rights in Farm Data

'Data justice' is a term which has become prominent in recent times as a conceptual tool to examine the relationship between datafication and social justice. There are different framings of data justice that have emerged within different fields of critical data studies. Taylor identifies three main approaches to conceptualising data justice: one addressing the ways in which data used for governance can support power asymmetries; another focusing on the ways in which data technologies can provide greater distributive justice through increased visibility to the disadvantaged; and another that is interested in how practices of 'dataveillance' can impact on the work of social justice organisations (Taylor 2017: 6). As conceptualised in the works of Heeks and Renken, the second framing of data justice is a suitable framework in which to evaluate and understand data governance from the perspective and with the priorities of development (Heeks and Renken 2016). This framework will be used to outline features of data governance that have relevance to indigenous farmers' interests in access to and utilisation of farm data in the African context.

Based on an analysis of the emerging literature on data justice, and drawing on the extensive literature on global and social justice, Heeks and Renken identify three features of data justice: instrumental, procedural, and distributive rights-based. Instrumental justice looks at the outcome of use of data, focusing on fair use (Heeks and Renken 2016: 93). This perspective holds that data justice in developing countries only relates to the impact of the use of data, irrespective of who owns that data. The procedural justice perspective is concerned with fair handling of data along all parts of the value chain (Heeks and Renken 2016: 93). At a minimum, procedural justice requires fairness in the 'processes that handle data—its capture, input to a data system, processing, storage and output' (Heeks and Renken 2016: 93). 'Fairness' in this context encompasses the control which individuals maintain by granting or withholding consent in the data-handling process. Distributive rights-based justice maintains that enactment of data rights determines distribution of data and, hence, advocates for fair distribution of data. While the most frequently-cited determinant of distribution is data privacy, there are other rights that a data justice framework affirms can be derived from the UN Universal Declaration of Human Rights—the rights of data access (from Article 19) and ownership (from Articles 17 and 27) (Heeks and Renken 2016: 94).

Data protection frameworks such as the GDPR and the African Convention address the question of procedural data justice with respect to personal data. Given the inadequacy of such frameworks in accounting for farm data, as discussed above, the instrumental and distributive rights-based perspectives on data justice are relevant to addressing the challenges of data governance in farm data. In this respect, the instrumental perspective on data justice speaks to the impact of the data revolution on development imperatives. The structural shift that the data revolution is bringing to the way data are collected, utilised, and stored unfairly impacts African indigenous farmers in their development endeavours. Corporate control of access to newly generated and mixed data limits public bodies' and NGOs' consumption of data for development-oriented efforts in agriculture. Various public bodies and NGOs in LMICs increasingly depend on accessing data to carry out various agricultural advisory services (Francis 2014).

Implementing data justice with regard to farm data requires an Africa-level farm data governance framework that, in line with recent proposals for model frameworks adopted at the local, national, or regional level (GODAN 2016), can be emulated at the national level. The following sections discuss the features that such a governance framework should exhibit, guided by the instrumental and distributive rights-based perspectives on data justice. Addressing the negative impacts of the data revolution on development from an instrumental perspective requires taking measures that ensure African governments maintain control of and access to farm data originating within their boundaries. If the negative impact of the data revolution on indigenous agricultural systems and its negative repercussions for development is to be minimised, African governments will need to assert greater control over how corporations use farmers' data. Such control can be accomplished through data localisation schemes that incorporate the essence of data sovereignty.

Section 9: Data Localisation and Data Sovereignty

An instrumental data justice framework would support African governments' control of access to data originating within their boundaries. The development imperatives of the data revolution necessitate measures that ought to be targeted at ensuring public bodies' control of access to data that has macro-economic policy importance. In the context of cloud-computing storage infrastructures, such measures also need to ensure that data of such of importance is not subjected to the laws of another jurisdiction. Data localisation and sovereignty are two interrelated concepts that support the desire of states to control data originating from their territories in this manner.

'Data localisation' refers to requirements to keep collecting, processing, or storing of data within the jurisdiction where it was generated (Willems and Kamau 2019: 238). According to Chander and Le (2015: 680), it can be understood as encompassing any measure that encumbers the transfer of data across national borders. In its implementation, data localisation can take three forms: (i) requirements to store all data types across all industry sectors in facilities located inside the state; (ii) requirements to store specific subsets of data in facilities located inside the state; and (iii) requirements to transfer data only to states with adequate legislative and security measures in place, for particular purposes, and for a limited time (Peng and Liu 2017: 193-94). The first and second of these represent the broad and narrow scope of schemes that require data residency. Compliance with data residency requires hosts to build or rent data centres in the specified jurisdictions rather than be able to choose wherever those centres might be most logically located. The third form requires data transfer restrictions, subjecting the transfer of data from one jurisdiction to another on certain conditions (Determan, et al. 2015).

Different rationales are invoked to justify data localisation (Selby 2017: 227).[23] In the African context, localisation is necessitated by the need for governments to ensure data sovereignty, understood as designating 'the right of States in relation to other States to govern the collection and ownership, including access and use of data that is domiciled within their jurisdiction' (Oguamanam 2018: 207). The dynamics of global data flows render it almost impossible to identify the location of farm data at any given moment, as well as which jurisdiction's law would govern it (Peng and Liu 2017: 206). Conflict of law rules provide that legislative jurisdiction over data can be based on the nationality of the Internet user (the data subject), the location of Internet service suppliers, or the location of data (Eubank 2016: 176-81). Governments supporting data localisation schemes are increasingly asserting legislative jurisdiction over data based on the location of the data as a straightforward proposition (Eubank 2016: 181). Such a data residency requirement as a basis for assuming jurisdiction is, however, tenuous in an age of cloud computing infrastructure (Eubank 2016: 178).

In addition, studies show that data residency requirements have negative economic implications for local technology industries (Chander and Le 2015: 721-30; Selby 2017: 29). Data sovereignty, instead of data residency, is

[23] These rationales include arguments that data localisation: (1) provides better information security against foreign intelligence agencies; (2) supports the local technology industry; (3) protects the privacy and security of citizen's data; and (4) supports local law enforcement (Selby, J. 2017, 227).

logically asserted by states with the highest incidence of contact with the specific data (Oguamanam 2018). While residency as a localisation tool may have a sound basis for data subsets such as health information and sensitive personal data, with respect to farm data, localisation goals are better achieved through transfer restrictions that ensure the data sovereignty of African states. In such circumstances, data sovereignty serves the interest of a state in the sanctity or integrity, including the security, of data and cultural and other contextual sensitivities associated with data, irrespective of the residency of the data (Oguamanam 2018: 3).

A data transfer restriction regime for farm data can be informed by the two approaches for regulating international transfer of personal data—adequacy and accountability. The adequacy approach, as incorporated in the EU's GDPR, requires that any transfer to a country outside the EU must be made in accordance with a transfer justification that has been approved in advance by the European Commission (Phillips 2018: 576). The European Commission gives prior approval of a foreign legal framework that has been deemed adequate, in which case transfer requires no further justification. In the absence of such determination of adequacy, data transfer needs to be justified based on a number of considerations (Phillips 2018).[24] An accountability framework, as reflected in Canada's Personal Information Protection and Electronic Documents Act (PIPEDA), provides that an organisation subject to it 'is responsible for personal information in its possession or custody, including information that has been transferred to a third party for processing' (Personal Information Protection and Electronic Documents Act 2000). Taking this approach, an inadequate foreign data protection regime does not preclude transfer, as a comparable level of protection can be accomplished through contractual or other means (Phillips 2018).

An adequacy approach to cross-border transfer is preferred to an accountability approach, in that the latter leaves compliance in the hands of private actors while the former involves control of data transfer by a public entity. An adequacy approach can be incorporated into an Africa-wide data governance framework for farm data within the existing institutional mechanisms of personal data protection under the AU Convention. Although the Convention has not currently taken effect (it has not yet been ratified by 15 of the 54 AU member countries), a number of African countries have either implemented or taken steps toward data protection laws inspired by it (UNCTAD 2020). The AU Convention mandates the establishment of a National Personal Data Protection Authority that ensures data are processed in accordance with the provisions of the Convention (African Union Convention 2014). In ensuring adequacy, the Data Protection Authority can subject cross-border transfers of data to the condition that the country to which data are transferred recognise the rights of farmers as data originators in farm data. If African countries adopt a model data governance framework for farm data, such a requirement would serve as an impetus for them to introduce legislation that recognises the contribution of farmers to farm data. This arrangement accommodates the need for movement of data within Africa as per the ethos of the recently concluded African Continental Free Trade Area (AfCFTA). While such a requirement would deter data flow to non-African countries that do not have similar arrangements, it can serve as a stepping stone for a data governance framework for farm data at the international level. In the absence of an international treaty that governs access to and ownership of farm data along the imperatives of the development policies of African countries, restrictions on cross-border transfer are necessary to ensure that farmers' data are not subjected to free exchange on the marketplace via intermediaries. Supporting restrictions on cross-border transfer of data, therefore, a further pillar of governance for farm data ought to be the recognition of farmers as rights holders in farm data and the elaboration of the content of such rights.

[24] These include consent of the data subject, the incorporation of standard 'model clauses' that have been previously approved by the EU Commission into binding contracts between the sender and recipient, the existence of a code of conduct approved by the European Commission, and binding corporate rules.

Section 10: Recognition of Rights for Data Originators

Measures of data localisation necessitated by the instrumental approach to data justice need to be supplemented with actions targeted at implementing distributive rights-based data justice perspectives. The implementation of distributive rights-based justice requires the recognition of rights that address the challenges of access to data by indigenous peoples and ensures fairness in the utilisation of data in the marketplace.

Under the EU's GDPR, individual subjects of personal data are granted a number of rights that include the right to be informed about the collection and use of their data, the right of access, the right to erasure, and the right to data portability. The AU Convention mandates its signatories to establish a domestic legal framework that strengthens similar fundamental rights. It is expected that the data protection regimes of African countries incorporate the individual rights of data subjects recognised under the GDPR. A growing body of literature proposes that these individual rights be recognised as the property rights of data subjects to achieve individual control over their personal data, enabling subjects to enforce control over personal data against allcomers (Purtova 2017; P.B Hugenholtz 2017). Such an approach has significance as a means of giving back to the individual control over data pertaining to them (Janger 2003), as a means of exercising 'informational self-determination' understood as 'the capacity of the individual to determine in principle the disclosure and use of his/her personal data' (Hert and Gutwirth 2009: 14). A data justice framework requires that subjects are afforded rights that are separate from privacy rights. The recognition of property rights over farm data is, however, problematic for several reasons.

Firstly, given the fluid boundary between identifiable and non-identifiable data, establishing, exercising, and managing transparent property rights in personal data might prove problematic (Purtova 2017: 15). It is highly probable that the likelihood of identifiability would change from low to high at any given time as more data are aggregated, and it would be a challenge to determine who exercises property rights over which data. Even in the context of anonymised data, the recognition of property rights often supports technology owners and is considered to 'likely raise considerable complications with the future development of a sound and holistic data governance regime' (Yu 2020).

In addition, the utilisation of farm data in the African context has development implications that necessitate public policy imperatives for access to and control of data by public bodies. The recognition of property rights in data results in control over data by data subjects, which can then be alienated through simple waiver of rights (Purtova 2017). The instrumental perspective on data justice requires acknowledging the development imperative that requires actors other than a data subject to exercise control over data that otherwise would be subject to market exchange by data intermediaries, otherwise reinforcing the hand of private actors in data utilisation.

Indigenous farmers' practising of TK in agriculture involves the exchange of knowledge and information commonly shared among communities as a collective. Farm data in the form of localised data as well as its derivatives can typically be considered as 'relating to' farmers as a manifestation of the collective exercise of TK on the farm. Indigenous farmers can be data contributors without necessarily meeting the legal requirements for being data subjects through personal identifiers. As such, a data governance for farm data ought to recognise the collective contribution of farmers as data originators. The basis for such recognition stems from Article 27(2) of the UDHR, which states that 'everyone has the right to the protection of the moral and material interests resulting from any scientific, literary or artistic production of which he [or she] is the author'. The same right is recognised under Article 15(c) of the 1966 International Covenant on Economic, Social and Cultural Rights (ICESCR). While this right is often fulfilled through intellectual property rights protections that data collectors, processors, and aggregators acquire as 'authors' of such data, a data justice framework extends such protection to cover 'data produced as a by-product of our actions—our 'data exhaust'—and perhaps also to data that is produced about us, given we are ultimately the origin of that data' (Heeks and Renken 2016: 94). Article 27(2) may be fulfilled through 'non-property-based moral rights-like protection' instead of through mainstream intellectual property rights (Yu 2007: 1090-92). The recognition of farmers as originators of farm data in this manner can be satisfied through demonstration of the connection between the data in question and those farmers in the broader light of how the data 'relates to' them. Thus, farmers hold rights to farm data not only when the data are about them in the most literal understanding of 'relating to' but also when the connection with them is determined through the content, purpose, and result elements (Witzleb and Wagner 2018: 4).

The distributive rights-based perspective in a data justice framework not only requires the recognition of farmers as rights holders, but also the determination of the contents of such rights. In this respect, the protection of 'moral and material interests' covers two different types of interests: one 'safeguards the personal link between authors and their creations and between peoples, communities, or other groups and their collective cultural heritage', while the latter 'enable[s] authors to enjoy an adequate standard of living' (CESCR, General Comment No. 17). These rights are often expressed in terms of the recognition of IPRs and, hence, the contents of rights are stated to be those of IPRs. However, it is important to note that 'nowhere in [Article 27(2) of the UDHR] is anything mentioned about intellectual property rights' and that the rights exist 'regardless of the protection offered by current intellectual property laws and treaties' (Yu 2007: 1080). Thus, a data governance framework for farm data need not recognise IPRs as being the content of rights to be held by indigenous farmers. However, such a framework should address the challenges that farmers face in the wake of the data revolution—those of access to and unequal utilisation of data.

Addressing such challenges necessitates the recognition of farmers' economic interests in farm data. One of those interests takes the form of access to data that has relevance to agricultural practices. The right to access personal data is an important feature of data protection frameworks such as the GDPR. The scope of such rights is, however, limited to personally identifiable data. As a mixture of personal with publicly accessible and proprietary data, access to farm data entails entitlement to a broader set of data. Once farmers are recognised as rights holders, they should be entitled to access derivations of their own localised data that exist by way of imported and exported data. Given that 'trust is seen as the major precondition for data sharing', the guarantee of access to farm data gives farmers the requisite trust needed to share their data (Richter and Slowinski 2018: 14).

Another aspect of farmers' economic interest in farm data relates to its utilisation in the marketplace. It has been noted that 'the freedom to control the terms of one's engagement with data markets is an essential component of any data justice framework because it underpins the power to understand and determine one's own visibility' (Taylor and Broeders 2015: 9). A distributed rights-based perspective to data justice should, therefore, assign rights to farmers so that they have a say in how farm data are used, including how the benefits are distributed (Taylor and Broeders 2015: 94). Indigenous farmers face the risk of dependency on agricultural technology providers that arises from data-based control of every aspect of agricultural production. They also face the risk of exploitation as benefits from value exchanges of their data are captured by brokers and intermediaries. A framework to counteract these risks entails recognising farmers' rights to control data and to materially benefit from exchanges of data in the marketplace. The former concerns the need for control of farm data that has implications for macro-agricultural policy in the African context, while the latter concerns the need to account for farmers' share in the data marketplace, consistent with the emerging concept of the personal data economy (PDE).

The concept of PDE refers to models of data transfer and control by which data originators monetise their data by offering them in a marketplace (Elvy 2017). PDE models increase transparency of data-trade transactions by allowing originators to more easily recognise the inherent value of their data to themselves and to companies (Elvy 2017). A number of startups offer markets for data in which, based upon their own preferences, individuals can decide what kind of personal data they want to sell or license (and under what restrictions).[25] In the current data marketplace, where brokers dominate, PDE models give originators the platform to fairly benefit from the market value of their data, thereby limiting the exploitative relationship between originators and intermediaries. A governance framework built on justice needs to acknowledge farmers' economic interest in data that can be monetised through exchanges in a PDE marketplace.

Farmers' interests in farm data extend beyond the ability to benefit materially to their capacity to obtain information about who is buying their data and to prevent transactions of their data in certain circumstances. In this respect, the recognition of farmers' rights in data needs to be connected with their ability to control the final destination of their data in the marketplace. Given the limited capacity of farmers to assert such control, an integrated data governance framework for farm data should outline the roles and responsibilities of a Data Protection Authority in authorising cross-border transfers of data. One such responsibility would presumably include the guarantee of informed consent from contributors to cross-border transfer. Such consent may be withheld in circumstances where transfer risks the survival of indigenous agricultural systems by creating the risk of dependency in the relationship between farmers and global agricultural technology providers.

11: Conclusion

The digitalisation of agriculture in Africa has made data governance on the continent an issue of considerable importance. Introducing a governance framework that appropriately balances the interests of stakeholders in farm data and addresses concerns arising in access to and utilisation of data has significance for the attainment of the SDGs. The existing framework at the continental level, and those that are emerging at a country level, mainly address the issue of data governance in terms of the privacy concerns of data subjects. While those privacy interests remain the cornerstone of a data governance framework, the increasing deployment of digital initiatives in African agriculture demonstrates the importance of data to the continents' agricultural economy. A privacy framework of data governance does not consider the significance attached to farm data as a currency for participating in agricultural economic activities. Neither do proposals for the collective management and sharing of data in the form of data commons sufficiently address the interests of originators who contributed to the generation and acquisition of data in the first place. There is a need to craft a framework that recognises the inherent and inalienable rights and interests of indigenous farmers relating to the collection, ownership, and application of data on their practices, knowledge, ways of life, and farmland. Understanding the importance of data in the data economy necessitates a recognition of a governance framework that addresses the challenges of access to data by originators, inequalities in the utilisation of data among participants in the data value chain, and the impact of data in the design of development policies and programs by African governments.

A data justice framework for data governance offers a distributive justice approach in the allocation of rights among those who collect, aggregate, and process data and those groups or communities to whom the data pertains. While the former entrenches their ownership and control of data through proprietary data ownership models largely built on IPRs, proposals for the recognition of the rights of the latter remain undeveloped. The recognition of novel property rights for data subjects, advanced in some quarters as a counterweight to assertions of ownership by intermediaries, would bring

[25] See for example, https://digi.me/what-is-digime [accessed 20th November 2020].

conceptual and theoretical complications and would have practical difficulties in enforcement. Although such recognition may give the originator of data individual control over data, it could have less significance as data becomes more valuable when mixed with other data. When it comes to indigenous farmers, the process of data generation and use is a collaborative process of cultural and economic participation in agricultural production. As a collective, this situation would negatively impact the development aspirations of African farmers. A data governance framework needs to be designed to support the pursuit of long-term developmental interests and address distributional concerns arising from the utilisation of data.

The first step in accomplishing the goal of development and fair distribution of rights involves the recognition of farmers as stakeholders in farm data. Such recognition is similar to the protection of the interest of data subjects in a privacy framework, but extends beyond the realm of privacy protection that can easily be waived through consent. The recognition of the rights of farmers to farm data should include guarantees of access to data that originated from their farm, even when such data takes the form of imported and exported data; an entitlement to fair value returns upon monetisation of data when it is exchanged in markets; and a degree of control over the sharing of culturally sensitive data outside of the expectation of farmers.

A possible route to the implementation of the proposed framework would be through a continental-level model data governance framework that can be recommended to member countries' domestic legislation. It might be in the form of a protocol to the current African Union Convention on Cyber Security and Personal Data Protection, which could tackle the issue of farm data governance. Such an instrument has the potential to fill a visible gap in the realm of international and continental governance of data. Conceivably, it might contribute to the creation of a continental economic zone envisaged by the AfCFTA by facilitating data flows. Facilitating such flows across the continent through the adoption of domestic data governance legislation is desirable. However, ensuring data sovereignty on the African continent necessitates a restriction on trans-border data flows. In such a framework, the instrument would prescribe the conditions for international data transfers. Such conditions would address the threats of dependency and other challenges to African agriculture arising from control of farm data by big multinational corporations. As things stand, such corporations are in the position of actors with the requisite expertise to implement digital infrastructures. Given the significance of agriculture to the African economy, and with the increased recognition of the role of the data revolution, the appropriate framework should enable a greater role for indigenous farmers, their associations, state institutions, and non-profit entities in utilising data to shape and support development policies and programs.

Acknowledgements

The research for this article was carried out under the auspices of the Open African Innovation Research (Open AIR) network, which is a partnership led by the University of Cape Town, the University of Johannesburg, the University of Ottawa, the American University in Cairo, Strathmore University in Nairobi, and the Nigerian Institute of Advanced Legal Studies. The author acknowledges the support provided for this research by Open AIR, the Social Sciences and Humanities Research Council of Canada, and the International Development Research Centre. In addition, the author extends sincere gratitude and deep appreciation to Dr. Chidi Oguamanam, whose feedback and recommendation immensely improved the article. The author also thanks Joe Torchia for excellent research assistance.

References

Asenso-Okyere, K. and Ayalew Mekonnen, D. (2012) 'The importance of ICTs in the provision of information for improving agricultural productivity and rural incomes in Africa', United Nations Development Programme, 2012 (015): 11.

Baarbb, J. and B.M. and de Beer, J. (2019) 'A data commons for food security', *African Journal of Information and Communication* 23: 17.

Barber, B. (1992) 'Jihad vs. Mcworld'. Available at: http://www.theatlantic.com/politics/foreign/barjiha.htm [accessed 20th July 2020].

Baumüller, H. (2016) 'Agricultural service delivery through mobile phones: local innovation and technological opportunities in Kenya' in Gatzweiler, F. and von Braun, J. *Technological and institutional innovations for marginalized smallholders in agricultural development*, New York: Springer: 147-48.

Bergman, M. and Jordaan, H. (2017) *Toward A Sustainable Agriculture: Farming Practices and Water Use*, Basel: MDPI.
Bruhn, J. (2014) 'Identifying useful approaches to the governance of indigenous data', *International Indigenous Policy Journal*, 5: 2
Brush, S. (2005) 'Biodiveresity, biotechnology, and the legal protection of traditional knowledge', *Washington University Journal of Law and Policy*, 17: 59.
Bunge, J. (2014) 'Big data comes to the farm, sowing mistrustseed makers barrel into technology business'. Available at: https://www.wsj.com/articles/no-headline-available-1393372266 [accessed 20th July 2020].
Malabo Montpellier Panel (2019) 'Byte By Byte Policy Innovation for Transforming Africa's Food System with Digital Technologies', Malabo Montpellier Panel Report. Available at: https://www.mamopanel.org/resources/digitalization/reports-and-briefings/byte-byte-policy-innovation-transforming-africas-f/ [accessed 20th July 2020].
UN Committee on Economic, Social and Cultural Rights (CESCR), General Comment No. 17: The Right of Everyone to Benefit from the Protection of the Moral and Material Interests Resulting from any Scientific, Literary or Artistic Production of Which He or She is the Author (Art. 15, Para. 1 (c) of the Covenant), 12 January 2006, E/C.12/GC/17, available at: https://www.refworld.org/docid/441543594.html [accessed 15 April 2021].
Chamberlin, J. (2007) 'Defining Smallholder Agriculture in Ghana: Who are Smallholders, What Do They Do and How Are They Linked with Markets?' Ghana Strategy Support Program, Background Paper GSSP 0006.
Chander, A. and P. Le, U. (2015) 'Data nationalism', *Emory* LJ 677, 64(3): 680.
Chinganya, O. & Ndiaye, M. & Perini, F., et al. (2017) 'Africa data revolution report 2016: highlighting developments in African data ecosystems.' Available at: https://www.africa.undp.org/content/rba/en/home/library/reports/the_africa_data_revolution_report_2016.html [accessed on 20th November 2020].
Chitonge, H. (2015) *Economic Growth and Development in Africa*, Abingdon: Routledge.
Couldry, N. and Mejias, U. (2018) 'Data colonialism: rethinking big data's relation to the contemporary subject', *Television and New Media*, 20(4): 336-49.
Council of Europe (2007) Opinion 4/2007 on the concept of personal data, (2007) Working Paper 136 [Opinion 4/2007]. Available at: https://www.clinicalstudydatarequest.com/Documents/Privacy-European-guidance.pdf [accessed 24th July 2020].
Cukier, K. and Mayer-Schoenberger, V. (2013) 'The rise of big data: how it's changing the way we think about the world', *Foreign Affairs* 28, 92(3): 29.
de Montjoye, Y., Hidalgo, C., Verleysen, M., et al. (2013) 'Unique in the crowd: the privacy bounds of human mobility', *Scientific Reports*, 3(1): 1376.
Determann, L., Bekeschenko, E. and Perevalov, V. (2015) 'Residency requirements for data in clouds—what now? Available at: https://www.bakermckenzie.com/~/media/Files/BDSUploads/Documents/equity%20equation/residency%20requirements%20for%20data%20in%20clouds%20%20what%20now.pdf [accessed 20th July 2020].
Ekekwe, N. (2017) 'how digital technology is changing farming in Africa'. Available at: https://hbr.org/2017/05/how-digital-technology-is-changing-farming-in-africa [accessed 20th July 2020].
Elvy, S. (2017) 'Paying for privacy and the personal data economy', *Columbia Law Review*, 117: 1393–1400.
Emerging Technology from the arXiv, (2013) 'Artificial intelligence: the big data conundrum: how to define it?'. Available at: https://www.technologyreview.com/2013/10/03/82990/the-big-data-conundrum-how-to-define-it/ [accessed on 20th November 2020].
EU (2016) 'Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the Protection of Natural Persons with Regard to the Processing of Personal Data and on the Free Movement of Such Data'. Available at: https://eur-lex.europa.eu/eli/reg/2016/679/oj [accessed on 20th November 2020].
Eubank, R. (2016) 'Hazy jurisdiction: challenges of applying the stored communications act to information stored in the cloud', *George Mason Journal of International Commercial Law*, 7: 176-181.
Fan, S., et.al. (2013) 'From Subsistence to Profit: Transforming Smallholder Farms', Washington, D.C.: International Food Policy Research Institute: 2.
Farmforce (2018) 'Farmforce case studies: cargill cocoa and chocolate.' Available at: https://www.theexplorer.no/contentassets/e5f4f874920a44d89ba7c680700e13df/farmforce-case-study---cargill-cocoa-110319.pdf [accessed on 20th November 2020].
Ferguson, A. (2014) 'Big data and predictive reasonable suspicion', *University of Pennsylvania Law Review* 163: 329.
Food and Agricultural Organization (2009) 'Adaptation to Climate Change in Agriculture, Forestry and Fisheries: Perspective, Framework and Priorities', Rome: FAO
Food and Agricultural Organization (2018) 'Combining IoT and predictive analytics in agriculture.' Available at: http://www.fao.org/e-agriculture/blog/combining-iot-and-predictive-analytics-agriculture [accessed on 20th November 2020].
Food and Agricultural Organisation (2011) 'The State of Food and Agriculture: Women in Agriculture: Closing the Gender Gap in Development', Rome: FAO.
Francis, J. (2014) 'Modern ICTs and rural extension: have we reached the tipping point?'. Available at: https://www.rural21.com/english/news/detail/article/modern-icts-and-rural-extension-have-we-reached-the-tipping-point-00001059 [accessed 20th July 2020].
Gattiglia, G. (2015) 'Think big about data: archaeology and the big data challenge', *Archäologische Informationen*, 38: 115.
Gatzweiler, F. and von Braun, J. (2016) *Technological and institutional innovations for marginalized smallholders in Agricultural Development*, New York: Springer.
González-Bailón, S., Wang, N., Rivero, A., et al. (2012) 'Assessing the bias in communication networks sampled from Twitter'. Available at: https://arxiv.org/pdf/1212.1684.pdf [accessed 20th July 2020].
Gray, B., Babcock, L., McCord, M., et al. (2018) 'Digital farmer profiles: reimagining smallholder agriculture', in *Digital Development for Feed the Future*: 15.
GODAN (2016) 'Ownership of open data: governance options for agriculture and nutrition'. Available at: http://www.godan.info/documents/ownership-open-data-governance-options-agriculture-and-nutrition-0 [accessed 20th July 2020].
Guerrini, F. (2020) 'The Future of agriculture? smart farming'. Available at: https://www.forbes.com/sites/federicoguerrini/2015/02/18/the-future-of-agriculture-smart-farming/#30087ba83c42> [accessed 20th July 2020].
Gutwirth, S. (2009) *Reinventing Data Protection?* Dordrecht: Springer.
Heeks, R. and Renken, J. (2016) 'Data justice for development: what would it mean?' *SSRN Electronic Journal*, 34(1): 90
Hu, M. (2015) 'Small data surveillance v. big data cybersurveillance', Washington and Lee *Public Legal Studies Research Paper Series*, 794.
IFC, (2017) 'Creating agricultural markets: how the ethiopia commodity exchange connects farmers and buyers through partnership and technology.' Available at: https://www.ifc.org/wps/wcm/connect/2e56f2f3-68e9-4e66-93d2-bcf78a1a0e05/EMCompass+Note+37+Ethiopia+Exchange+FINAL+April+27.pdf?MOD=AJPERES&CVID=lKMu2iQ [accessed on 20th November 2020].

'International Covenant on Economic, Social and Cultural Rights' (1966). Available at: https://www.ohchr.org/en/professionalinterest/pages/cescr.aspx [accessed 20th July 2020].
International Fund for Agricultural Development (2013) ‚Smallholders, Food Security and the Environment', Rome: IFAD.
Janger, E. (2003) 'Muddy property: generating and protecting information privacy norms in bankruptcy', *WM & Mary L Rev*, 44: 1801.
Jensen, I., Craig, R., Pooley, J., et al. (2016) 'Digitalisation', in *International Encyclopedia of Communication Theory and Philosophy*, Hoboken: Wiley and Sons.
Jung, J. and Kim, P. (2017) *Big Data Technologies and Applications*, New York: Springer.
Kah, M. (n.d.) 'Africa is leapfrogging into digital agriculture'. Available at: https://www.un.org/africarenewal/web-features/africa-leapfrogging-digital-agriculture [accessed 20th July 2020].
Kalita, D., M'Cormack, F. and Heirman, J. (2012) 'A literature review on farmer voice', *ALINe Working Paper* 3: 8.
Kitchin, R. and Lauriault, T. (2014) 'Small data in the era of big data', *GeoJournal*, 80: 463.
Kroes, N. (2014) 'The data gold rush, european data forum athens'. Available at: https://www.europa-nu.nl/id/vji7e1ozx5z8/nieuws/speech_kroes_the_data_gold_rush?ctx=vh87km1jz6v2&s0e=vhdubxdwqrzw [accessed 20th July 2020].
Kukutai, T. and Taylor, J. (2016) *Indigenous Data Sovereignty: Toward An Agenda*, Canberra: ANU Press.
Laney, D. (2001) '3D data management: controlling data volume, velocity, and variety'. Available at: http://blogs.gartner.com/doug-laney/files [accessed 20th July 2020].
Lazer, D., Kennedy, R., King, G., et al. (2014) 'The parable of Google flu: traps in big data analysis', *Science*, 343: 1205.
Lesigne, M. (n.d.) 'Data protection developments in Africa'. Available at: https://www.researchworld.com/data-protection-developments-in-africa [accessed 20th July 2020].
Letouzé, E. (2016) 'Big data for development: challenges and opportunities', UN Global Pulse.
Lowder, S., Skoet, J. and Raney, T. (2016) 'The number, size, and distribution of farms, smallholder farms, and family farms worldwide', *World Development*, 87:16.
Mafongoya, P. and Ajayi, O. (2017) *Indigenous Knowledge Systems and Climate Change Management in Africa*, Wageningen: CTA.
Mann, L. (2017) 'Left to other peoples' devices? a political economy perspective on the big data revolution in development', *Development and Change* 49(1): 5.
Maru, A., Berne, D., De Beer, J., et al. (2018) 'Digital and data-driven agriculture: harnessing the power of data for smallholders', Global Open Data for Agriculture and Nutrition Initiative.
Mastercard (2020) 'The Mastercard farmer network.' Available at: https://www.mastercard.us/en-us/about-mastercard/corp-responsibility/social-sustainability/the-mastercard-labs-for-financial-inclusion.html [accessed on 20th November 2020].
Mavhunduse, F. and Holmner, M. (2019) 'Utilisation of mobile phones in accessing agricultural information by smallholder farmers in Dzindi irrigation scheme in South Africa', *Africa Journal of Library, Archives and Information*, 29 (1): 94.
Mayer-Schönberger, V. and Cukier, K. (2013) *Big Data: A Revolution that Will Transform How We Live, Work, and Think*, Boston: Houghton Mifflin Harcourt.
McIntyre, B., Herren, H., Wakhungu, J., et al. (2009) *Agriculture at Cross Roads, International Assessment of Agricultural Knowledge, Science and Technology for Development*, Washington: IAASTD.
McKeever, B., Greene, S., MacDonald, G., et al. (2018) *Data Philanthropy, Unlocking the Power of Private Data for Public Good*, Washington: Urban Institute.
Meeco (2018) 'Zero Knowledge Proofs of the Modern Digital Life, White Paper'. Available at: https://digify.com/a/#/view/55d40168f67c4676bed9e49ed99832fc [accessed 20th July 2020].
Mkumbo, W. (2017) 'The role of ICTs and indigenous knowledge in enhancing household food security in Tanzania', *International Research: Journal of Library and Information Science*, 7: 230.
Monsanto Company (2013) 'Monsanto to Acquire The Climate Corporation, Combination to Provide Farmers with Broad Suite of Tools Offering Greater On-Farm Insights.' Available at: https://www.businesswire.com/news/home/20131002005749/en/Monsanto-to-Acquire-The-Climate-Corporation-Combination-to-Provide-Farmers-with-Broad-Suite-of-Tools-Offering-Greater-On-Farm-Insights [accessed on 20th November 2020].
Nakato, G., Beed, F., Bouwmeester, H., et al. (2016) 'Building agricultural networks of farmers and scientists via mobile phones: case study of banana disease surveillance in Uganda', *Canadian Journal of Plant Pathology*, 38(3): 309-10
Nelson, S. And Swindale, A. (2013) 'Feed the future agricultural indicators guide'. Available at: https://www.agrilinks.org/sites/default/files/resource/files/FTF_Agriculture_Indicators_Guide_Mar_2015.pdf [accessed 20th July 2020].
Nijhuis, S. and Herrmann, I. (2019) 'The Fourth industrial revolution in agriculture'. Available at: https://www.strategy-business.com/article/The-fourth-industrial-revolution-in-agriculture?gko=75733> [accessed 20th July 2020].
OECD (2016) 'Technologies for Better Tax Administration A Practical Guide for Revenue Bodies: A Practical Guide for Revenue Bodies', Paris: OECD Publishing.
O'Grady, M. and O'Hare, G. (2017) 'Modelling the smart farm', *Information Processing in Agriculture*, 4(3): 179.
Oguamanam, C. (2018) *ABS: Big Data, Data Sovereignty and Digitisation: A New Indigenous Research Landscape*, Cambridge: CUP.
Oguamanam, C. (2019) 'Indigenous data sovereignty: retooling indigenous resurgence for development', CIGI Paper No. 234: 3.
Pawelke, A. and Tatevossian, A. (2013) 'Data philanthropy: where are we now?' Available at: https://www.unglobalpulse.org/data-philanthropy-where-are-we-now [accessed 20th July 2020].
Peng, S. and Liu, H. (2017) 'The legality of data residency requirements: how can the trans-pacific partnership Help?', *Journal of World Trade*, 51(2): 193-94.
Peroni, M. and Bartolo, M. (2018) 'The digital divide' in Bartolo, M. and Ferrari, F., eds. *Multidisciplinary teleconsultation in developing countries*, Cham: Springer.
Personal Information Protection and Electronic Documents Act, SC 2000, c. 5 (2000). Available at: https://laws-lois.justice.gc.ca/ENG/ACTS/P-8.6/index.html [accessed 20th July 2020].
Phillips, M. (2018) 'International data-sharing norms: from the OECD to the general data protection regulation', *Human Genetics*, 137(8): 576.
Pinto, R. (2018) 'Digital sovereignty or digital colonialism?' Available at: https://sur.conectas.org/en/digital-sovereignty-or-digital-colonialism [accessed 20th July 2020].
Politou, E., Alepis, E. and Patsakis, C. (2018) 'Forgetting personal data and revoking consent under the GDPR: challenges and proposed solutions', *Journal of Cybersecurity*, 4(1):1.
Protopop, I. and Shanoyan, A. (2016) 'Big data and smallholder farmers: big data applications in the agri-food supply chain in developing countries', *International Food and Agribusiness Management Review*, 19: 179.
Purtova, N. (2017) 'Do property rights in personal data make sense after the big data turn? individual control and transparency', *Journal of Law and Economic Regulation*, 10(2): 40.
Purtova, N. (2018) 'The law of everything: broad concept of personal data and future of EU data protection law', *Law, Innovation and Technology*, 10(40).
Ramcharan, A., Baranowski, K., McCloskey, P., et al. (2017) 'Deep learning for image-based cassava disease detection', *Frontiers in Plant Science*, 8(1852): 4.

Rasmussen, N. (2016) 'Precision agriculture to market manipulation: a new frontier in the legal community', *Miibb, JL SCI and Tech*, 17: 494.
Richards, N. and King, J. (2020) 'Big data ethics', *Wake Forest L Rev*, 49: 394.
Richter, H., and Slowinski, P. (2018) 'The data sharing economy: on the emergence of new intermediaries', *IIC - International Review of Intellectual Property and Competition Law*, 50: 4.
Rogstadius, J. (2009) 'Visualizing the ethiopian commodity market'. Available at: http://liu.divaportal.org/smash/record.jsf?pid=diva2%3A225449&dswid=-5940 [accessed 20th July 2020].
Rotz, S., Duncan, E., Small, M., et al. (2019) 'The politics of digital agricultural technologies: a preliminary review', *Sociologia* 59(2): 211.
Salvati, L. (2010) 'Mediterranean desertification and the economic system'. Available at: https://core.ac.uk/download/pdf/6430177.pdf [accessed 20th July 2020].
Scassa, T. (2018) 'Data ownership', CIGI Paper No. 187: 4
Schomm, F., Stahl, F. and Vossen, G. (2013) 'Marketplaces for data: an initial survey', ACM SIGMOD Record, 42(1): 16.
Schriber, S. (2020) 'Smart agriculture sensors: helping small famers and positively impacting global issues, too.' Available at: https://www.mouser.ca/applications/smart-agriculture-sensors/ [accessed 20th November 2020]
Schrijver, R. (2016) 'Precision Agriculture and the Future of Farming in Europe'*, Scientific Foresight Study*, STOA.
Selby, J. (2017) 'Data localisation laws: trade barriers or legitimate responses to cybersecurity risks, or both?', International Journal of Law and Information Technology, 25(3): 227.
Sennuga, Olayemi S. (2020) 'Role of information and communication technologies (ICTs) in enhancing food utilisation among smallholder farmers' households in northern Nigeria', *Information and Knowledge Management*, 10.
Shwartz, P. (2019) 'Global data privacy: the EU way', *NYU L Rev*, 94 :(771.
Soares, J. (2016) 'The new frontier: how sharing of big data in agriculture interferes with the protection of farmers' ownership rights over their data', *San Joaquin Agric Law Review*, 26 : 229.
Spiekermann, M. (2019) 'Data marketplaces: trends and monetisation of data goods', *Intereconomics*, 54(4): 210.
Spielman, D. (2019) 'Policy, regulation, and digital agriculture in Africa.' Available at: https://www.agrilinks.org/post/policy-regulation-and-digital-agriculture-africa [accessed on 20th November 2020].
Stepanov, I. (2019) 'Introducing a property right over data in the EU: the data producer's right—an evaluation', *International Review of Law, Computers & Technology*, 34(1).
Taylor, L. (2016) 'The ethics of big data as a public good: which public? whose good?', *Philosophical Transactions of the Royal Society A*. Available at: https://royalsocietypublishing.org/doi/full/10.1098/rsta.2016.0126 [accessed on 20th November 2020].
Taylor, L. (2017) 'What is data justice? The case for connecting digital rights and freedoms globally', *Big Data and Society*, 4(2): 6.
Taylor, L. and Broeders, D. (2015) 'In the name of development: power, profit and the datafication of the global south', *Geoforum* 64: 229-37.
Tella, R. (2007) 'Towards promotion and dissemination of indigenous knowledge: a case of NIRD', *International Information & Library Review*, 39(3-4): 185.
Thatcher, J., O'Sullivan, D. and Mahmoudi, D. (2016) 'Data colonialism through accumulation by dispossession: new metaphors for daily data', *Environment and Planning D: Society and Space*, 34(6): 990-1006.
Tsan, M., Totapally, S., Hailu, M., et al. (2019) *The digitalisation of African agriculture report 2018–2019*. Available at: http://www.fao.org/family-farming/detail/en/c/1199305/ [accessed 20th November 2020].
UN Secretary-General Independent Expert Advisory Group on the Data Revolution for Sustainable Development (2014) *A World that Counts: Mobilizing the Data Revolution for Sustainable Development*. Available at: https://www.undatarevolution.org/report/ [accessed 20th July 2020].
UNCTAD (2020) 'data protection and privacy legislation worldwide.' Available at: https://unctad.org/en/Pages/DTL/STI_and_ICTs/ICT4D-Legislation/eCom-Data-Protection-Laws.aspx [accessed on 20th November 2020].
UNCTAD (2018) 'South-South digital cooperation for industrialisation: a regional integration agenda'Available at: https://unctad.org/en/PublicationsLibrary/gdsecidc2018d1_en.pdf [accessed 20th July 2020].
The Universal Declaration of Human Rights (1948):Available at: https://www.un.org/en/about-us/universal-declaration-of-human-rights [accessed 20th July 2020].
Van Zyl, O., Alexander, T., De Graaf, L., et al. (2012) 'ICTs for Agriculture in Africa.' Available at: https://inba.info/ict-in-africa_574a2a61b6d87f5f2d8b48fc.html [accessed 20th November 2020].
Vollmer, N. (n.d.) 'Recital 26 EU General Data Protection Regulation (EU-GDPR). Privacy/Privazy according to plan'. Available at: https://www.privacy-regulation.eu/en/r26.htm [accessed 20th July 2020].
Willems, A. and Kamau, M. (2019) 'Of binding provisions and trust marks; roadmap to a global legal framework for the digital economy', *Legal Issues of Economic Integration*, 46(3): 238.
Witzleb, N. and Wagner, J. (2018) 'When is personal data "about" or "relating to" an individual? a comparison of Australian, Canadian and EU data protection and privacy laws', *Canadian Journal of Comparative and Contemporary Law*, 4: 293.
World Economic Forum (2012) 'Big data, big impact: new possibilities for international development.' Available at: http://www3.weforum.org/docs/WEF_TC_MFS_BigDataBigImpact_Briefing_2012.pdf [accessed on 20th November 2020].
Yu, P. (2007) 'Reconceptualizing intellectual property interests in a human rights framework', *C Davis L Rev*, 40: 1090-92.
Yu, P. (2020) 'Data producer's right and the protection of machine-generated data', *Tulane Law Review*, 93: 859-929.