

**THE FUTURE OF THE WESTERN CAPE AGRICULTURAL  
SECTOR IN THE CONTEXT OF THE 4<sup>TH</sup> INDUSTRIAL  
REVOLUTION**

**Review: Agriculture in 4IR & its drivers – A global  
perspective**

**November 2017**

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# 1. Agriculture in the evolution of industrial revolutions

## Introduction

In a previous discussion the evolution of industrial revolutions was explored at a macro level. This section is devoted to a global perspective on agriculture during this evolution. Initiated in Britain, the 1<sup>st</sup> Industrial Revolution probably marks the most important turn of events in world history, at any rate since the invention of agriculture and cities. At that point in history, farming in Britain was already largely for the market, and manufacturing had long been diffused from the feudal legacy. Agriculture was already set to carry out its three fundamental functions in an era of industrialisation, i.e., to increase production and productivity, to feed a rapidly growing non-agricultural population; to provide a large and increasing surplus of potential workers for the towns and industries; and to provide a mechanism for the accumulation of capital to be used in the more modern sectors of the economy. In addition, the infrastructure necessary to drive the entire economy forward was already being created, notably in shipping, port facilities, and the improvement of roads and waterways, and... the political landscape was already positioned to profit.<sup>1</sup>



Figure 1: Ploughing scene, 18<sup>th</sup> century<sup>2</sup>

By 1700, Britain was already particularly different compared with its continental rivals due to its high degree of urbanisation and the relatively small share of the economy devoted to agriculture.<sup>3</sup> But what gave rise to this, and how did it evolve?

## Agriculture in the 1<sup>st</sup> Industrial Revolution

The 1<sup>st</sup> Industrial Revolution ranging from around 1750 to 1840, triggered by the invention of the steam engine and the construction of railroads ushered in mechanical production.

However, it is important to note the significance of changes in farming and agriculture from the mid-1600s across Britain that paved the way for the Industrial Revolution. The changes that occurred in agriculture were driven by demands for more food to support its growing population (Collectively, these changes became known as the 'Agricultural Revolution'). Many historians are of the conviction that without these changes industrialisation would not have been possible from 1750 onwards.<sup>4</sup>

As far as technology and capital investment is concerned, changes over this period were, however, modest until the 1840s when agricultural science and engineering are considered to have reached maturity. The vast increase in output which enabled British farming in the 1830s was achieved by general adoption of methods pioneered in the earlier 18<sup>th</sup> century, through rationalisation and extension of cultivated areas; thus, highlighting the achievements through social rather than technological transformation.<sup>1</sup> Furthermore, there was a sharp decline in the percentage of the population employed in agriculture, with only one in four Britons still working the land by 1850. In fact, the British agricultural labour share in 1750 itself was unusually low comparable to most European countries which had more than two-thirds of the workforce employed on the land.<sup>5</sup> A contributing factor was of course the more than 4000 Enclosure Acts that were passed by the British Parliament during the Agricultural Revolution which transferred areas of common land previously worked by small groups of local farmers into the hands of private landowners. These smaller areas of land were joined together to create large farms enclosed by hedges or stone walls. By 1790, three-quarters of all farming land in Britain was enclosed by wealthy landlords, who rented this land to tenant farmers, causing social unrest and many poor people forced off the land they had farmed free of charge for generations. Many migrated to the cities to become part of the new industrial working classes, while others immigrated abroad.

The upside of the new commercial approach to farming led to improved management of the crops with amongst others the adoption of the 'four-field system' where each season, the crops are rotated, implying that no field was left fallow and the soil in each field was kept high in minerals and nutrients. In addition, early to mid-1800s, new farming machinery was introduced, such as mechanical drills for planting seed, reaping machines for harvesting crops and threshing machines to separate the valuable grain from the stalks of wheat and barley plants. These machines made farming more efficient and increased profitability. Year on year, the volume of land that could be prepared, farmed and harvested in a season increased. By the 1840s, fertilisers were also widely in use, further raising the productivity of the land. Furthermore, improvements in animal breeding and rearing became common practice, with people such as agriculturalist Robert Bakewell that began selective breeding of livestock from the late 1700s. He developed a new breed of quick-fattening sheep with finer wool and tastier

meat, called the New Leicester, and bred cattle for beef production, producing stronger animals, larger in size and of better quality.<sup>4</sup>

## Agriculture in the 2<sup>nd</sup> Industrial Revolution

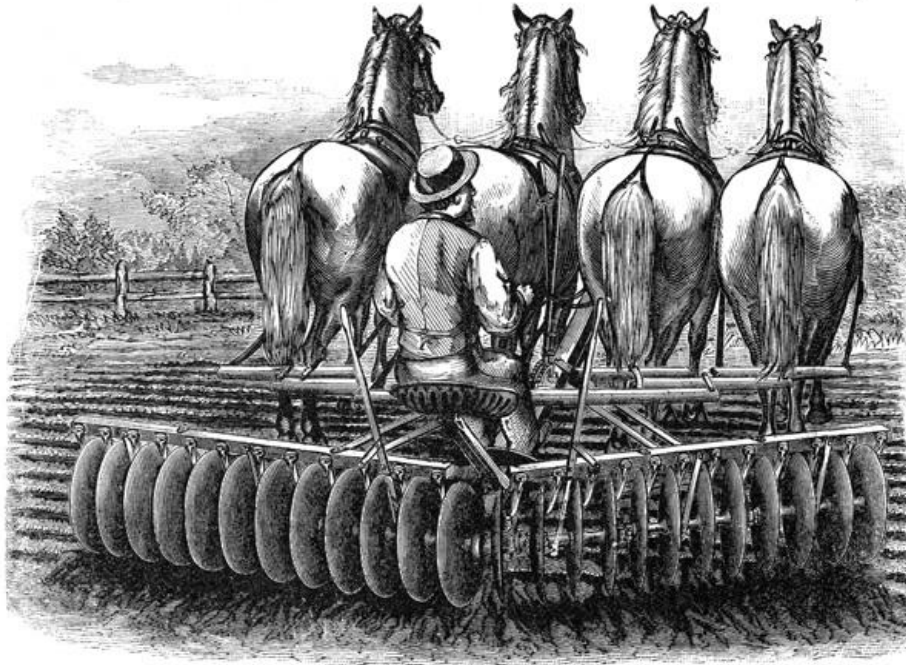
Late in the 19th century, leading into the early 20th century (between 1870 and 1914) introduced the 2<sup>nd</sup> Industrial Revolution, ushering in the arrival of electricity and the assembly line which made mass production possible. Agriculture, however, differs from most other sectors in that nature to a large extent dictates the conditions and pace of production. Work is performed in large fields and the quality of the effort by farmers cannot be fully appreciated until harvest. Subsequently, economies of scale in industry are larger because the production process is constrained only by human ingenuity and not by nature, as is the case with agriculture.<sup>6</sup>

In this period, the adoption of the new farming methods based on fodder crops and stall-fed livestock continued rapidly, but although new implements and tools appeared on the scene, the usual obstacles to technological progress in agriculture delayed adoption. Inventions that were useful in some environments failed elsewhere. A few “general-purpose” technologies such as barbed wire (invented in 1868) were introduced, but the bulk of technology was site- and crop specific. Rather, agricultural productivity significantly improved due the extended use of fertilizers, with farmers learning to use nitrates, potassium, and phosphates produced by the chemical industries.

The productivity gains in European agriculture are hard to imagine without the gradual switch from natural fertiliser, produced mostly on location by farm animals, to commercially produced chemical fertilisers. Fertilisers were not the only scientific breakthroughs in farming: the use of fungicides, such as Bordeaux mixture, invented in 1885 by the French botanist Pierre-Marie-Alexis Millardet in 1885, helped overcome the dreaded potato disease that had overwhelmed Ireland forty years earlier.

Technological progress external to agriculture affected food supplies in many ways. Steel implements, drainage- and irrigation pipes, steam-operated threshers, seed drills, and mechanical reapers slowly but surely improved productivity and extended the supply of food and raw materials. Yet, adoption was slow, and modern tools and techniques continued to coincide with manual operations that had not changed in centuries. Mechanising agriculture involved overcoming some technical difficulties. For example, most work in agriculture, such as weeding, picking, and milking, was carried out by movements of the human fingers, as opposed to the sweeping or beating motions of the human arm. Furthermore, the mechanisation of agriculture was slow (compared to manufacturing) due to the lack of power substitutes. In most

industrial processes, production can occur at the site of the power source, and the application of more efficient energy sources was subsequently rather simple. However, in agriculture, the power sources had to be brought to the production site (i.e., the land) for most activities, and thus ploughing, harrowing, reaping, raking, and binding remained dependent on draft animals long after manufacturing and transportation had adopted the steam engine.



**Figure 2: Ploughing scene, late 19<sup>th</sup> century<sup>7</sup>**

The application of steam power to agriculture could therefore not be considered a success. Only where the work could be carried out near the power source, did mechanisation come relatively early: the threshing machine built in 1784 by the Scotsman Andrew Meikle spread quickly, as did the winnowing machine built in 1777 by a London mechanic, James Sharp. These machines were attached to steam engines in the first half of the 19<sup>th</sup> century, but remained something of an exception. The internal combustion engine solved all that, and by the eve of World War I, the first tractors and combines were being introduced on both sides of the Atlantic.<sup>8</sup>

To get a sense of agricultural developments at this point in the discussion, Figure 3 below illustrates the agricultural timeline along with the evolution of industrial revolutions up to the advent of the 3<sup>rd</sup> in the 1960s, which is explored in the next section.

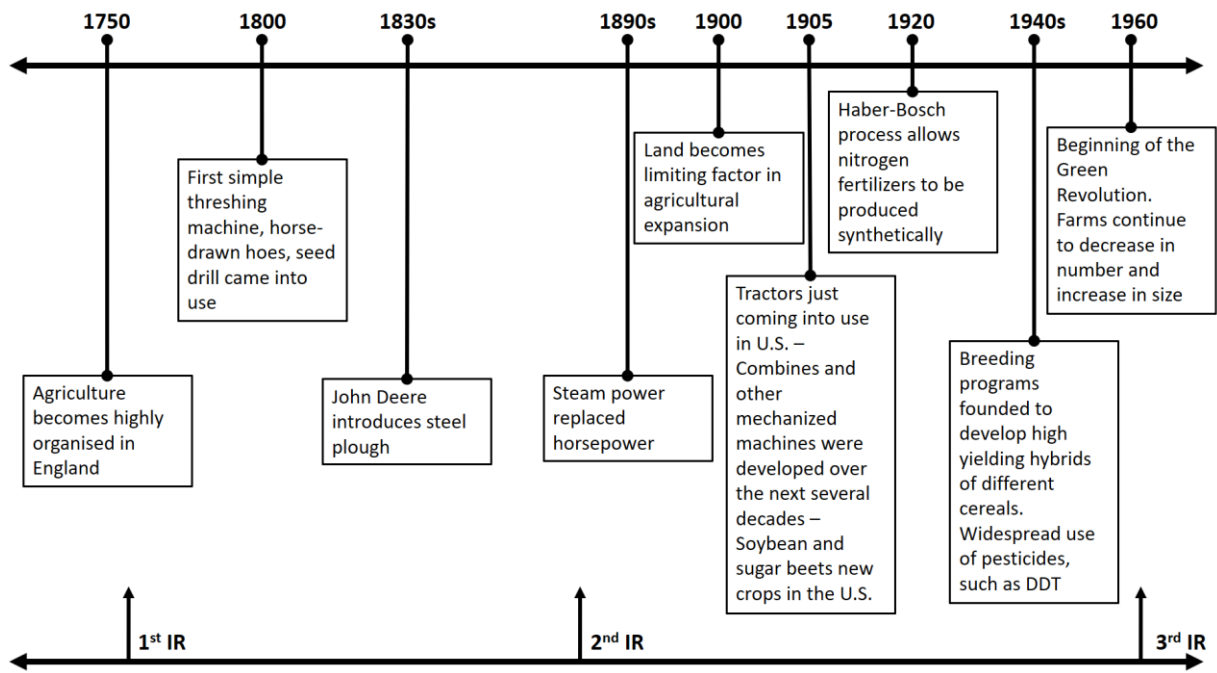


Figure 3: Agricultural timeline 1750 to 1960

## Agriculture in the 3<sup>rd</sup> Industrial Revolution

Often referred to as the computer or digital revolution, the 3rd industrial revolution began in the 1960s, with the development of semiconductors, mainframe computing (1960s), personal computing (1970s and 80s) and the Internet (1990s) as the main drivers. 1960 also saw the world population reaching 3 billion and introduced the era of “industrial” agriculture.

Industrial methods in agriculture became well established in Western nations, with chemical inputs significantly increasing, mechanisation of farming and food production becoming the norm, and raising large numbers of animals confined in crowded indoor facilities common practice. Yields subsequently increased dramatically, along with significant hidden costs. This was also the time the “Green Revolution” was initiated; a planned international effort to eliminate hunger by improving crop performance and increase yields through the introduction of new crops, irrigation, fertilisers, pesticides, mechanisation, increasing technological knowledge, and supplying materials to farmers. The success of the Green Revolution is, however, questionable, because although food production increased by more than 1000% in some places, it didn’t have the same results in all settings. Although it helped curb hunger, it did not eliminate famine, and led to increased costs of production and negative environmental impacts. Consequently, the technology approach does not guarantee a secure food supply and is often not ecologically sustainable. In addition, it did not address people’s lack of resources, nor the distribution of economic power, purchasing power, etc.<sup>9</sup>

Agriculture technologies advanced rapidly in the second half of the 20<sup>th</sup> century, leading into the 21<sup>st</sup>. These developments forever changed the face of agriculture. In 1975 the first twin-rotor system combine was created by Sperry-New Holland, which allowed crops to be cut and separated in one pass over the field. For corn, it not only separated the husk and ears, but shelled the kernels, and chopped the stalks. In 1982 scientists at Monsanto Company became the first in the world to genetically modify a plant cell, and within five years, they planted their first outdoor trials of a genetically modified crop – tomatoes that were resistant to agricultural herbicide, insects, or viruses. 1994 saw the introduction of satellite technology used to advance farming, enabling farmers to see their farms from overhead, allowing for better tracking and planning. Software and mobile devices in the 2000s started helping farmers yielding better harvests. Mobile devices allowed them to stay connected to colleagues whilst out in the field, and having access to data needed while on-the-go, including the ability to place orders for seed or fertiliser at any time or in any place. The advent of big data in 2015 also started revolutionising agricultural potential. Farmers could now use data to help them harness the power of information to make informed decisions and allow them to use resources more sustainably. An example is the Climate Corporation’s Climate FieldView™, a digital platform that brings together data collection, agronomic modelling, and local weather monitoring, which gives farmers a better understanding of their fields. These tools allow farmers to plan for better harvests and make more environmentally conscious decisions.<sup>10</sup>

In this era, agriculture continued to reinvent itself with the increasing challenge of feeding an ever-growing population. However, some challenges farming communities had to deal with include, among others, declining arable land area, prolific pests and diseases, exacerbated by anomalous and sometimes drastic weather patterns induced by climate change; issues juxtaposed by agricultural industrialisation, newer value chains and a lack of actionable information, which collectively make farming a rather challenging occupation. Nevertheless, newer agricultural varieties resistant to certain types of pests, innovations in irrigation technology and improved communication channels, enhanced by advances in information and communication technology, and facilitated by greater use of mobile phones, started serving as mechanisms for redress to these challenges.<sup>11</sup> In 2015, the use of mobile phones for information exchange, such as disease surveillance and pest tracking, has become common practice. Linking knowledge to innovation is also crucial to addressing the information and knowledge gaps in the agriculture sector, thereby further accentuating ICTs very important role in bridging information gaps.<sup>12</sup>

Evidently, with the dramatic advancements in technology, a tipping-point was fast approaching for the dawn of the next industrial revolution. In 2011 the Germany federal government’s 2011 high-tech strategy introduced the term “Industry 4.0”<sup>13</sup>, leading into the term “Fourth



Industrial Revolution” as the main theme for the WEF’s 2016 annual meeting in Davos, Switzerland.<sup>14</sup>

## Agriculture in the 4<sup>th</sup> Industrial Revolution

Not only has the role of information and communication technologies (ICTs) in agriculture grown significantly in recent times in both scale and scope, but the expanding broadband connectivity, increasing deployment of the “internet of things” (IoT), enhanced analytics, affordable devices and innovative applications are further contributing to the digitalisation and digitisation of agriculture.<sup>15</sup> Today, the use of digital technologies in agriculture such as smartphones, tablets, in-field sensors, drones and satellites are widespread, and provide a range of farming solutions such as remote measurement of soil conditions, better water management and livestock and crop monitoring. This enables farmers to plan more effectively and be more efficient, with resultant improved crop yields and animal performance, optimisation of process inputs and labour reduction, all of which increase profitability. Digitalisation also helps improve working conditions for farmers and reduce the environmental impacts of agriculture.<sup>16</sup>

After many years of research in “precision agriculture” there are currently many types of sensors for recording agronomically relevant parameters, as well as numerous farm management systems. Electronically controlled machines are becoming state of the art, in fact, technology is now capable of automating cyber-physical systems by networking between different machines.<sup>17</sup> In addition, inherent to 4IR, developments in communication technologies such as cloud computing and IoT are converging with other advancements such as artificial intelligence (AI), robotic technologies, and big data analysis, which are further driving digital agriculture, or, “Agriculture 4.0.”<sup>18</sup>

It is believed that the fourth agricultural revolution is already on its way, and that the agricultural industry is about to be disrupted and transformed into a high-tech industry. There are numerous innovators spearheading attempts to tap into the growth opportunities embedded in improving yield efficiency, increasing supply chain efficiency, and decreasing complexity along farming’s value chain. Although traditional investor companies are only slowly getting involved, large agrochemical incumbents are already investing heavily in agricultural technology, or as is referred to, “AgTech.” In terms of the agricultural ecosystem, there is increased evidence of innovators active in five major innovation fields, namely<sup>19</sup>:

- 1. Rerouting value chains:** Numerous players are attempting to leapfrog value chain steps via direct-to-consumer delivery, meal kits, food e-commerce and the like to reduce supply chain inefficiency.

2. **Crop efficiency technology:** Examples are start-ups and cross-industry innovators that offer drones, robots, big data and sharing platforms as well as irrigation, soil, and crop technologies to increase effective yield.
3. **Bio-chemicals and bio-energy:** Pursuing the reduction of the ecological footprint, innovators are developing biologically-produced agrochemicals, bio-materials and bio-energy.
4. **Food technology and artificial meat:** Companies are developing plant-based meat and eggs to harness “sustainable protein,” to counter the notion of eight kilograms of grain to produce one kilogram of meat.
5. **Contained and vertical farming:** Newcomer innovations showing potential are smart greenhouses and contained farming.

The fourth agricultural revolution is particularly noticeable in countries such as the USA, Israel, China and India that are pushing the innovation boundaries. It is believed that the investment focus will transition from the mature food e-commerce sector to a more diversified portfolio of innovation fields and targeted value zones.<sup>19</sup> Another country worth mentioning in terms of agricultural innovation and embracing technology in agriculture, is the Netherlands, who, amidst having limited arable land comparable to most other developed countries, is the 2<sup>nd</sup> largest food exporter in the world, after the USA.<sup>20</sup>

Further building on the notion of precision agriculture, agtech holds significant promise to make the farms of the future more productive and efficient, with advancements in specifically seven main categories, namely:<sup>21</sup>

1. Farm management software
2. Precision agriculture and predictive data analytics
3. Sensors that help farmers to collect data and to monitor crop health, weather and soil quality
4. Animal data – software and hardware specifically aimed at better understanding livestock, from breeding patterns to genomics
5. Robotics and drones
6. Smart irrigation
7. Next gen farms, where technology is used to provide alternative farming methods to enable farming in locations and settings that previously couldn't support traditional farming; and marketplaces (technological platforms that connect farmers directly to suppliers or consumers without any middlemen).

With agtech's growing prominence, a useful consideration is the expectations of these technologies' impact on agriculture and how it evolves. One representation for expectations is the Gartner Hype Cycle for emerging technologies, developed by IT research and advisory firm

Gartner. The cycle follows the pattern of people’s expectations when they’re introduced to a new technology, i.e. a new technology is introduced, demanding significant hype; the hype goes beyond the technology's current capabilities; people are disillusioned until the tech climbs out of the through and demonstrates its usefulness. While expectations rise and decline and rise again, the technology is building momentum in the background according to Moore’s Law, implying that technological innovation increases exponentially over time. As far as agtech is concerned, it is considered still in the hype stage, and mostly hasn’t delivered on its technological promise yet, as illustrated by AgFunder's (An online investment platform for AgriFood technologies<sup>22</sup>) adaptation of the Gartner Hype Cycle to include agtech categories below (Figure 4). There is noticeable enthusiasm about numerous technologies, however only at the first iterations. Although real adoption is still to come, it is envisaged that once it does, it will be transformational. Until such time, agtech will continue to attract attention driven by the macro drivers (consumer trends, environmental and resource challenges, increasing populations) demanding technological advancement of agriculture.<sup>23</sup>

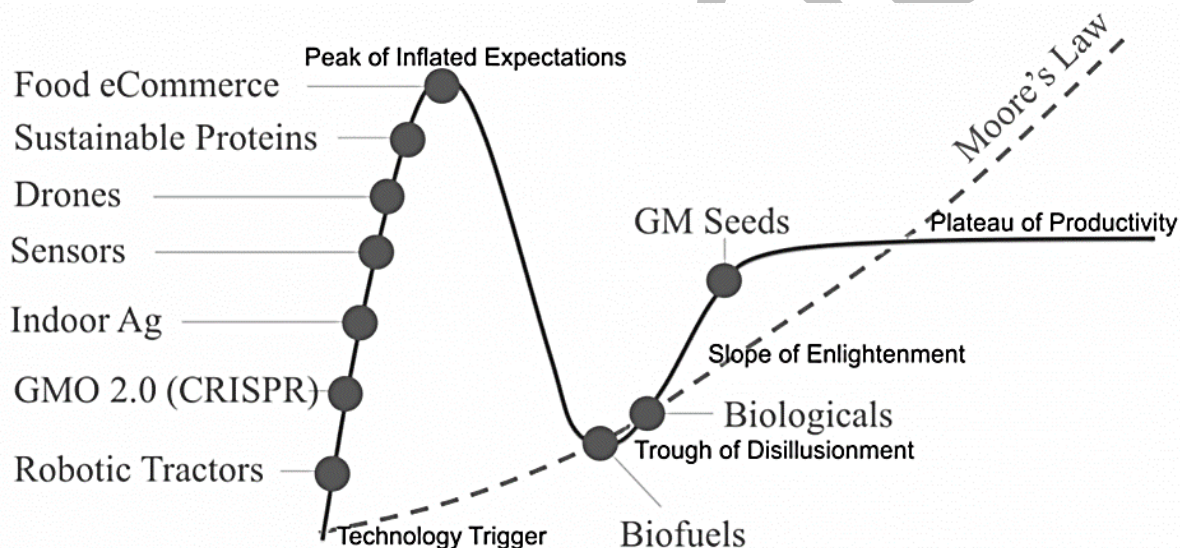


Figure 4: AgFunder's adaptation of the Gartner Hype Cycle to include agtech categories

Although the oldest industry in the world still has some way to go to catch up with the other industries, it is inevitable that agtech adoption will thrive in 4IR as the global demand for agricultural products is rising, whilst simultaneously, consumers, retailers and participants in the value chains are increasing their demands as far as product quality and transparency of production is concerned. Developing and transferring technology alone will not tackle yield gaps or reduce wastage or post-harvest losses. An enabling investment environment should also be established. Farmers are likely to adopt technologies only if there are sound incentives to do so: this calls for well-functioning input and output markets, improved infrastructure, and better finance and risk management tools.<sup>24</sup>

The challenges posed by current and future global food supply will nevertheless continue to thrust agriculture towards technological innovations, but at the same time new technological developments also create new questions. Not everything that is technologically feasible will become reality, hence the importance to assess it in the context of social, economic and political developments around the globe.<sup>25</sup>

## 2. The drivers of agriculture in 4IR

### The point of inference

As observed in document 2, although 4IR is regarded as being driven by extreme automation and connectivity, it is increasingly evident that disruption (resultant from 4IR) does not stem solely from technology, but is also influenced by demographic shifts, globalisation, macroeconomic trends and more. It would, therefore, be insufficient to examine the drivers of 4IR in agriculture only through a technology-lens. Human societies are complex systems, with many different types of players and environmental conditions, and using a partial view as a lens through which to view an entire phenomenon becomes problematic.

To emphasise the complexity, we should be alert to the fact that agriculture does not stand on its own, nor do technological developments take place autonomously; it always interacts with developments in the economy, society and politics. In addition, the food systems of the various countries are intertwined in numerous ways, from the trade in raw materials to final products. A large part of the economic value-add of food is at the farms but in food processing and in retail, and at the end of the food chain is the consumer, whose needs and demands also influence the production and supply of food. On the other hand, companies in the food chain can exert considerable political and social influence, effecting consumer demand. It is therefore a highly complex system and to investigate its future requires many different factors and a large degree of uncertainty must be considered.<sup>25</sup>

A useful summary, indicating the complexity, is found in a recent report by Deloitte, “From Agriculture to AgTech”, where two overarching disruption drivers are presented:<sup>19</sup>

**Disruption driver No. 1** → Ten global megatrends that impact agriculture and intensifying transformation:

1. A growing population
2. Societal and demographic changes
3. Increasing urbanisation
4. Climate change
5. Smart agricultural technologies

6. Biotechnology
7. Servicisation around core products
8. Increasing value chain integration
9. Globalised trade
10. Changing international regulations

**Disruption driver No. 2** → Partly complementary, partly concurrent, industry-specific change accelerators in three categories are amplifying the speed of disruption in agriculture:

1. *New consumer preferences*: the demand for personalised, on-demand products and increasing awareness for health and sustainability.
2. *Emerging technologies*: developing biological tissues, advanced manufacturing technologies, autonomous vehicles, and connected devices.
3. *Changing value chain and firm configurations*: growing trend towards horizontally and/or vertically integrating end-to-end offerings.

The above, is argued, will lead to a major disruption and foretells the millennial shift from family farms to smart “food factories.”<sup>19</sup> The next section attempts to unpack these drivers into a more comprehensive, integrative overview.

## Drivers and megatrends accelerating Agriculture 4.0

Drawing on a previously discussed review of the general megatrends highlighted by a selection of 20 intelligence providers and trend observers, with its twelve commonly-cited megatrends across four dimensions<sup>26</sup>, the table below indicates the drivers and associated megatrends impacting on agriculture.

**Table 1: Drivers and associated megatrends impacting on agriculture**

Driver	Megatrend	Description	Examples relating to agriculture
<b>Technology</b>	Disruptive technology developments	Multiple technology megatrends cited by numerous trend observers, e.g.: <ul style="list-style-type: none"> <li>– Ubiquitous connectivity, Internet of Things</li> <li>– Materials (e.g. smart, nano, bio etc.)</li> <li>– Customisation, personalisation, localisation</li> <li>– Data-driven technologies</li> <li>– Information security and data protection</li> <li>– Virtual world</li> <li>– Artificial intelligence and Robotics</li> <li>– Genomics</li> <li>– Personalised medicine – Etc.</li> </ul>	<ul style="list-style-type: none"> <li>• Farm management software</li> <li>• Precision agriculture and predictive data analytics</li> <li>• Sensors that help farmers to collect data and monitor crop health, weather and soil quality</li> <li>• Software and hardware aimed at better understanding livestock, from breeding patterns to genomics</li> <li>• Robotics and drones</li> <li>• Smart irrigation</li> <li>• Technological platforms that connect farmers directly to suppliers or consumers without any middlemen</li> <li>• New technologies trigger higher yield and cost reductions</li> </ul>
<b>Energy and Environment</b>	Changing energy mix	New energy mixes to address growing demand, dwindling non-renewables,	<ul style="list-style-type: none"> <li>• Energy security that is environmentally and socially sustainable</li> </ul>

		energy security, higher costs (e.g. shale, nuclear, coal, renewables etc.)	<ul style="list-style-type: none"> <li>Renewable energy (wind and solar)</li> <li>Biofuels (avoid diverting food crops and productive land for biofuels)</li> <li>Photovoltaic (PV) energy and durable warmth production</li> </ul>
	Shortage of resources	Shortages of water, food, rare earths, key commodities, including impact of environmental damage	<ul style="list-style-type: none"> <li>Approximately 1.2 billion people live in areas of physical water scarcity</li> <li>Distribution of water seeing decreased flows in basins fed by shrinking glaciers and longer and more frequent dry seasons</li> <li>Of all the water withdrawn for human uses, withdrawals for agriculture represent 70%</li> <li>70% increase in food is needed by 2050 to meet population growth demand</li> <li>Agriculture is a leading cause of loss of global biodiversity due to conversion of natural habitats, such as forests and wetlands, into farmland</li> <li>Diminishing soil nutrition and erosion</li> </ul>
	Climate change	Prevention, adaptation and mitigation to address climate change	<ul style="list-style-type: none"> <li>Greenland and Antarctica are losing 500 cubic km's of ice annually</li> <li>Earth has warmed since 1880 with 10 of the warmest years occurring in the past 12 years</li> <li>Weather manipulation and modification (e.g. cloud seeding; hail gun)</li> <li>Changing weather conditions affect soil quality and crop yields</li> </ul>
<b>Economics and Politics</b>	Knowledge and information society	Prevalence of knowledge as basis for economic value, ubiquitous information, growing personalised education, increasing automation requiring highly skilled workforces	<ul style="list-style-type: none"> <li>Global smartphone penetration to hit 66% in 2018 (developed and developing countries)</li> <li>Mobile devices to account for 73% of internet consumption in 2018</li> <li>59% of internet advertising expenditure will be mobile in 2018<sup>27</sup></li> <li>Farmers wanting to use new technologies need to extend their media competence.</li> <li>Telecommunications infrastructures still inadequate in many rural areas</li> </ul>
	Economic shifts	Economic power of emerging market economies overtaking developed markets, increasing middle class and growing wealth	<ul style="list-style-type: none"> <li>China's share of the world's total GDP is expected to grow from 7.1% in 2000 to 20.7% in 2020</li> <li>By 2030, the middle class is likely to comprise 4.9 billion people, of which 80% will live in what is now considered the developing world</li> </ul>
	Globalisation	Increasingly connected global economy and economic integration	<ul style="list-style-type: none"> <li>Decline in the costs of cross-border trade in farm and other products</li> <li>Reductions in governmental distortions to agricultural production, consumption and trade</li> <li>Farm productivity growth continues to outpace demand growth</li> <li>Diets in emerging economies move towards livestock and horticultural products at the expense of staples<sup>28</sup></li> </ul>
	New normal	Lower interest rates, greater public policy interventions, greater public debt, bigger defence budgets	<ul style="list-style-type: none"> <li>Overall, global growth remains bound by the norms of the post financial crisis era.</li> <li>Low inflation, absence of significant imbalances and supportive monetary policies suggest that recession risk remains low.</li> </ul>

			<ul style="list-style-type: none"> <li>Upside growth potential is held back by high indebtedness (private and/or public), subdued household and corporate confidence, weak credit formation, trivial global trade growth and weakening productivity gains.<sup>29</sup></li> </ul>
	Multi-Polar	Diffusion of power, rising nationalism, shift to networks and coalitions in a multipolar world.	<ul style="list-style-type: none"> <li>Increased complexity of the international system</li> <li>Less stable international order</li> <li>Increased likelihood of destabilisation and crisis</li> <li>New architecture of global finance</li> <li>Increased ability for non-state actors to impact global events</li> <li>Conflicting ideologies / blurring of ideologies<sup>30</sup></li> </ul>
<b>Social and Health</b>	Demographic shift	Population growth, aging societies	<ul style="list-style-type: none"> <li>World's population has almost tripled in 60 years, projected to reach 9.6 billion by 2050</li> <li>Population ageing poised to become a significant social transformation, with implications for nearly all sectors of society (e.g. labour and financial markets, the demand for goods and services, such as housing, transportation and social protection, as well as family structures and intergenerational ties)<sup>31</sup></li> <li>By 2030, the number of youth is projected to have grown by 7%, to nearly 1.3 billion</li> <li>Countries anticipating rapid growth in numbers of youth are among those with very high youth unemployment rates<sup>32</sup></li> </ul>
	Urbanisation and mobility	Growth of mega-cities, smart-cities, need for investment in critical infrastructure for safe, fast, ecologically sound mobility	<ul style="list-style-type: none"> <li>By 2050, 70% of the world population will live in urban areas<sup>33</sup></li> <li>Urbanisation are projected to add 2.5 billion people to the world's urban population by 2050</li> <li>Economic contraction and natural disasters have contributed to population losses in some cities as well</li> <li>As the world continues to urbanise, sustainable development challenges will be increasingly concentrated in cities<sup>34</sup></li> <li>Increasing pressure on agriculture and food production to serve urban expansions</li> </ul>
	Health and wellness demands	Growing expectations for health and wellness, increasing risks of pandemics, burden of aging populations	<ul style="list-style-type: none"> <li>Changing consumer behaviours spurred in part by demographics, evolving healthcare policies and the digital revolution<sup>35</sup></li> <li>Progressive health and wellness consumers are increasingly influential in redefining food culture</li> <li>Health, wellness and sustainability are starting to converge at food retail and food service outlets</li> <li>Consumers managing diabetes look to food and beverage for solutions<sup>36</sup></li> <li>The proportion of the world's population over 60 years from 2000 will double from about 11% to 22%</li> </ul>

The examples of the drivers and megatrends impacting on agriculture listed in the table is by no means complete. It, however, serves to highlight pertinent considerations regarding the future of agriculture. Noticeable from the drivers and megatrends above, is agriculture's pivotal role in the UN's Sustainable Development Goals (SDGs). More specifically, Goal 2 of the SDGs, that aims to end hunger, achieve food security and improved nutrition and promote sustainable agriculture. It subsequently aims to address a fundamental human need, namely access to nutritious, healthy food, and how it can be sustainably secured for everyone.

However, tackling hunger cannot be addressed solely by increasing food production. Well-functioning markets, increased incomes for smallholder farmers, equal access to technology and land, and additional investments all play a role in creating a vibrant and productive agricultural sector that builds food security.<sup>37</sup>

Ironically though, more than enough food is produced to feed everyone in the world, yet close to 800 million are persistently hungry. Because the affordability of food mainly relates to income, ensuring access to food remains one of the key pillars of food security and the wider anti-poverty agenda. Another stark reminder is agriculture's centrality in the food-water-energy nexus. A growing global population with increasing urbanisation and a deteriorating natural resource base implies more people to feed with less water, farmland and rural labour. Satisfying expected increases in water, energy and food needs requires a shift to more sustainable consumption and production approaches, with agriculture and food systems made more efficient and sustainable.<sup>38</sup>

### 3. Challenges and opportunities in agriculture 4.0

#### Agriculture in 4IR challenge-opportunity mix

Despite a significant growth in food production over the past half-century, one of the most important challenges facing society today is how to feed an expected population of some nine billion by the middle of the 20th century. To meet the expected demand for food without significant increases in prices, it has been estimated that 70% to 100% more food need to be produced, considering the growing impacts of climate change, concerns over energy security and regional dietary changes. The goal for the agricultural sector is no longer simply to maximise productivity, but to optimise across a far more complex landscape of production, rural development, environmental, social justice and food consumption outcomes. However, there remain significant challenges to developing national and international policies that support the wide emergence of more sustainable forms of land use and efficient agricultural production. The lack of information flow between scientists, practitioners and policy makers is known to exacerbate the difficulties, despite increased emphasis upon evidence-based policy.<sup>39</sup>

When considering the performance of the agro and food sector in the complex global food system, the degree of uncertainty increases with a wide range of sectors and disciplines being involved. In terms of technological developments, these may be influenced by policy-makers, entrepreneurs and researchers, but also by other developments. In turn technological developments influence other developments, e.g. in food and health, but also in society. That being said, numerous opportunities exist in terms of the application of technology in pursuit of improving efficiencies in agricultural production – technology in this context implying the



systematic application of (exact) scientific knowledge for practical purposes. Examples of technologies holding promise for the future of agriculture include:<sup>25</sup>

3D printing 4D printing Smart materials Robotics Autonomous microrobots Sensor technology Information technology and IT infrastructures Bioinformatics Smart farming Renewable energy	Biorefinery and biofuels Genetics Synthetic biology Protein transition Food design Aquaculture Vertical agriculture Conservation technology Transport technology Weather modification
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However, agriculture is highly dependent on the agricultural equipment, infrastructure and workforce being used. Agricultural equipment consist of mobile and stationary machinery and equipment used for both indoor and outdoor agricultural operations. Modern agricultural equipment provides a range of different options for collecting and analysing process data, but not everyone has digital agricultural equipment, is aware of its benefits, or trusts it sufficiently to use it. Nevertheless, the potentials of digitisation and using data for agriculture are generally recognised. Today, digital technologies can help farmers to meet these requirements and optimise their processes at the same time. But there are a number of obstacles to overcome before these opportunities can be exploited, i.e.:

- The majority of agricultural equipment currently in use is analogue, i.e. not equipped with digital technology and not networked.
- Farmers wanting to use new technologies need to extend their tech-competence.
- Telecommunications infrastructures are inadequate in rural areas.
- Data protection and data sovereignty must be ensured.
- Once collected, data has to be organised and analysed as “big data”.
- Standalone solutions should be avoided.

Conversely, technological solutions to overcome these challenges already exist, such as Bluetooth “beacons”, GPS and RFID systems combined with software, standardisation and interoperability mean legacy machinery can now be digitised. Known as partial digitisation, this is a realistic potential way into Agriculture 4.0 for many farmers.<sup>40</sup>

## Closing thoughts from FAO

In closing the discussion on 4IR and its drivers in the agricultural context, the Food and Agriculture Organisation (FAO) of the UN's "2017 State of Food and Agriculture report" provides valuable insights to inform considerations regarding the future of agriculture. These insights are listed under four main topics, i.e., overarching challenges, leveraging food systems, adjusting farming systems, and, big-picture monitoring.

### **Overarching challenges of ongoing transformations:**

- Industrialisation, the main driver of past transformations, is not occurring in most countries of sub-Saharan Africa and is lagging in South Asia.
- In the decades ahead, sub-Saharan Africa, in particular, will face large increases in its youth population and the challenge of finding them jobs.
- The world's 500 million smallholder farmers risk being left behind in structural and rural transformations.
- Urbanisation, population increases and income growth are driving strong demand for food at a time when agriculture faces exceptional natural-resource constraints and climate change.

### **Leveraging food systems for rural transformation:**

- In late-transforming countries with limited prospects for industrialisation, agro-industry may be an important source of employment for those exiting agriculture.
- Growing demand for food, and the dietary shifts away from staple foods, can present an important opportunity for industrialisation in late-transforming countries.
- Small cities and towns can be conduits in rural transformation, as points of intermediation and agro-industrial development.
- Agro-territorial development that links smaller cities and towns with their rural "catchment areas" can greatly improve urban access to food and opportunities for the rural poor.
- The key to the success of an agro-territorial approach is a balanced mix of infrastructure development and policy interventions across the rural–urban spectrum
- Public goods and services are needed to facilitate business in the food system and along the urban-rural spectrum

### **Farming systems need to adjust:**

- To meet growing food demand, it is necessary to develop more productive and sustainable farming systems.
- Hurdles posed by excessive fragmentation of landholdings need to be overcome.

- Agriculture needs substantial increase in investment to meet the growing demand for food, adjust to changing dietary patterns and make farming systems sustainable.
- Mechanisation and advanced inputs are essential for the transformation of farming systems.

**Monitor the bigger picture:**

- Amid abundance in certain contexts, billions of people still face persistent hunger, poverty, joblessness, environmental degradation, disease and deprivation.
- Economic development of rural areas is as important as that of urban areas in reducing overall levels of poverty
- Understanding the drivers of rural–urban migration, and its cost and benefits, should be high on policy agendas
- It is time to reassess the role of agriculture and rural development in national development strategies
- Territorial approaches should be considered in order to help ensure policy coherence and address local needs
- Fostering rural entrepreneurship and employment diversification, especially for women and youth, requires the development of skills.
- Social protection is crucial to risk management during transformation and for building resilient rural livelihoods.<sup>41</sup>

The belief that ‘bigger is better’ that has come to dominate farming and rendering small-scale operations impractical, is busy changing dramatically with advances in technology expected to disrupt current agribusiness models.<sup>42</sup> Agriculture’s response to 4IR should therefore be integrated and comprehensive, involving the public and private sectors as well as academia and civil society in order to adapt, shape and harness the potential of agricultural disruption.

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