Chapter 5
Agricultural 4.0: Its Implementation Toward Future Sustainability

5.1 Introduction

Emerging technologies, which sometimes be disruptive, are growing at an exponential rate advancement and progress in technology deemed crucial particularly if it is related to game-changing technology. The Fourth Industrial Revolution has been a subject of interest among many people, particularly in industries, higher learning institutions, governments and research institutions across the globe. It is basically a concept and development that has fundamentally reshaped the way we live. The development is so fast and important that it could impact the society and economy. Recently, we know how some advancement in technologies had changed our diets, lifestyle, eating habit, and our perception and understanding on some issues in regard to the environment. Revolution is defined as a forcible overthrow of a government. In the context of the Industrial Revolution, it is perceived as the forcible overthrow of a current technology. However, it is not only considered disruptive, but it is also very much strongly integrated with other technologies as well.

5.2 History of Industrial Revolution

The Industrial Revolution, which occurred during the eighteenth and nineteenth centuries, was a period during which predominantly agrarian, rural societies in Europe and America became industrial and urban. Prior to the Industrial Revolution, which began in Britain in the late 1700s, manufacturing was often done in people's homes, using hand tools or basic machines [1]. Industrialization marked a shift to powered, special-purpose machinery, factories, and mass production. The iron and textile industries, along with the development of the steam engine, played central roles in the Industrial Revolution, which also saw improved systems of transportation, communication, and banking. While industrialization brought about

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an increased volume and variety of manufactured goods and an improved standard of living for some, it has also often resulted in grim employment and living conditions for the poor and working classes.

Before the advent of the Industrial Revolution, most people resided in small, rural communities where their daily existences revolved around farming. Life for the average person was difficult, as income was meager, and malnourishment and disease were common. People produced the bulk of their own food, clothing, furniture, and tools. Most manufacturing was done in homes or small, rural shops, using hand tools or simple machines.

A number of factors contributed to Britain's role as the birthplace of the Industrial Revolution [1]. For one, it had great deposits of coal and iron ore, which proved essential for industrialization. Additionally, Britain was a politically stable society, and was the world's leading colonial power at the time, which meant its colonies could serve as a source of raw materials, as well as he a marketplace for manufactured goods.

As the demand for British goods increased, merchants needed more cost-effective methods of production, which led to the rise of mechanization and the factory system. The textile industry, in particular, was transformed by industrialization. Before mechanization and factories, textiles were made mainly in people's homes (giving rise to the term cottage industry), with merchants often providing the raw materials and basic equipment, and then picking up the finished product. Workers set their own schedules under this system, which proved difficult for merchants to regulate and resulted in numerous inefficiencies. In the 1700s, a series of innovations led to ever-increasing productivity, while requiring less human energy. For example, in 1764, Englishman James Hargreaves (1722–1778) invented the spinning jenny, a machine that enabled an individual to produce multiple spools of threads simultaneously [2]. By the time of Hargreaves' death, there were over 20,000 spinning jennys in use across Britain. The spinning jenny was improved upon by British inventor Samuel Compton's (1753–1827) spinning mule, as well as later machines [2]. Another key innovation in textiles, the power loom, which mechanized the process of weaving cloth, was developed in the 1780s by English inventor Edmund Cartwright (1743–1823) [2].

Development in the iron industry also played a central role in the Industrial Revolution. In the early eighteenth century, Englishman Abraham Darby (1678–1717) discovered a cheaper, easier method to produce cast iron, using a coke-fueled (as opposed to charcoal-fired) furnace. In the 1850s, British engineer Henry Bessemer (1813–1898) developed the first inexpensive process for mass-producing steel [1]. Both iron and steel became essential materials, and were used to produce everything from appliances, tools, and machines to ships, buildings, and infrastructure.

The steam engine was also integral to industrialization. In 1712, Englishman Thomas Newcomen (1664–1729) developed the first practical steam engine (which was used primarily to pump water out of mines) [2]. By the 1770s, Scottish inventor James Watt (1736–1819) had improved on Newcomen's work, and the steam engine went on to power machinery, locomotives, and ships during the Industrial Revolution [3].

The transportation industry also underwent significant transformation during the Industrial Revolution. Before the advent of the steam engine, raw materials and finished goods were hauled and distributed via horse-drawn wagons, and by boats along canals and rivers. In the early 1800s, American Robert Fulton (1765–1815) built the first commercially successful steamboat, and by the mid-nineteenth century, steamships were carrying freight across the Atlantic [3]. As steam-powered ships were making their debut, the steam locomotive was also coming into use. In the early 1800s, British engineer Richard Trevithick (1771–1833) constructed the first railway steam locomotive. In 1830, England's Liverpool and Manchester Railway became the first to offer regular, timetabled passenger services. By 1850, Britain had more than 6,000 miles of railroad track. Additionally, in 1820, Scottish engineer John McAdam (1756–1836) developed a new process for road construction. His technique, known as macadam, resulted in roads that were smoother, more durable, and less muddy [2].

Communication became easier during the Industrial Revolution with inventions such as the telegraph. In 1837, William Cooke (1806–1879) and Charles Wheatstone (1802–1875), patented the first commercial electrical telegraph. By 1840, railways were a Cooke–Wheatstone system, in 1866, a telegraph cable was successfully laid across the Atlantic. The Industrial Revolution also saw the rise of banks and industrial financiers, as well as a factory system dependent on owners and managers. A stock exchange was established in London in the 1770s; the New York Stock Exchange was founded in the early 1790s. In 1776, Scottish social philosopher Adam Smith (1723–1790), who is regarded as the founder of modern economics, published "The Wealth of Nations" [1, 2, 3]. In it, he promoted an economic system based on free enterprise, the private ownership of means of production, and lack of government interference.

The Industrial Revolution brought about a greater volume and variety of factory-produced goods and raised the standard of living for many people, particularly for the middle and upper classes. However, life for the poor and working classes continued to be filled with challenges. Wages for those who labored in factories were low, and working conditions could be dangerous and monotonous. Unskilled workers had little job security and were easily replaceable. Children who were part of the labor force often worked long hours and were used for highly hazardous tasks such as cleaning the machinery. In the early 1860s, an estimated one-fifth of the workers in Britain's textile industry were younger than 15. Industrialization also meant that some craftspeople were replaced by machines [3]. Additionally, urban, industrialized areas were unable to keep pace with the flow of arriving workers from the countryside, resulting in inadequate, overcrowded housing and polluted, unsanitary living conditions in which disease was rampant. Conditions for Britain's working class gradually improved by the later part of the nineteenth century, as the government instituted various labor reforms, after which workers gained the right to form trade unions.

The British enacted legislation to prohibit the export of their technology and skilled workers. However, they had little success in this regard. Industrialization spread from Britain to other European countries, including Belgium, France, and

Germany, and eventually to the USA. By the mid-nineteenth century, industrialization was well-established throughout the western part of Europe and America's northeastern region. By the early twentieth century, the USA became the world's leading industrial nation [3].

The First Industrial Revolution in 1748 occurred when mechanical revolution was powered by water and steam. Steam engines are external combustion engines where the working fluid is separated from the combustion products [1]. Thomas Newcomen invented an atmospheric engine in 1712, the first commercial engine that uses piston. During the first Industrial Revolution, the steam engine replaced water and wind power, and becoming the dominant source of energy in the late nineteenth century. James Watt invented a steam engine in 1781 that brought the First Industrial Revolution. Watt introduced a design enhancement based on Thomas Newcoman's separate condenser, which able to give radical improvement on the power and increased efficiency and improved cost effectiveness of the steam engine, as illustrated in Figs. 5.1 and 5.2.

The second revolution took place with the introduction of the conveyor belt, and hence, mass production was made possible. The conveyor belt is a carrying medium of a belt conveyor system. It consists of two or more pulleys with an endless carrying medium, and a conveyor belt that rotates about the pulleys. The pulleys are powered by moving the belt which moves the materials forward. In 1901, Sandvik invented and started the production of steel-conveying belts. The first conveyor belt for the coal mining industry was invented by Richard Sutcliffe. In 1913, Henry Ford introduced the first moving assembly line for mass production which enables a reduced time from 12 h to 30 min to build a car [2]. This has revolutionized the automotive

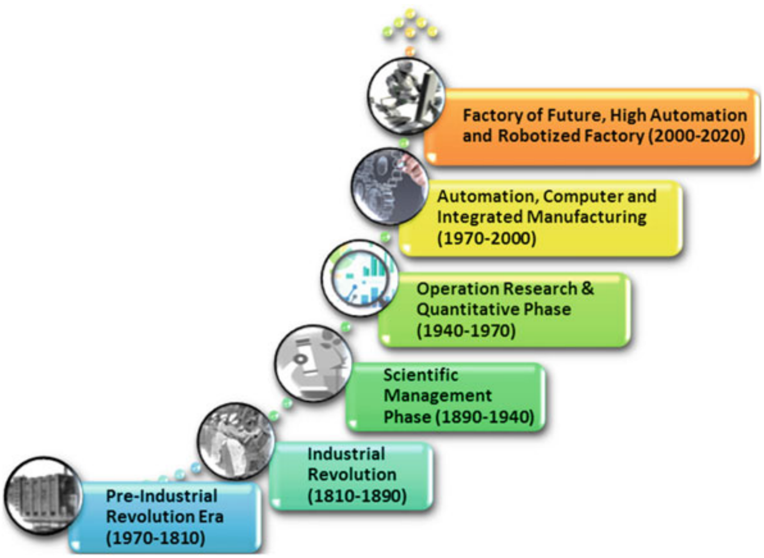

Fig. 5.1 Industrial Revolution history (1970–2020)

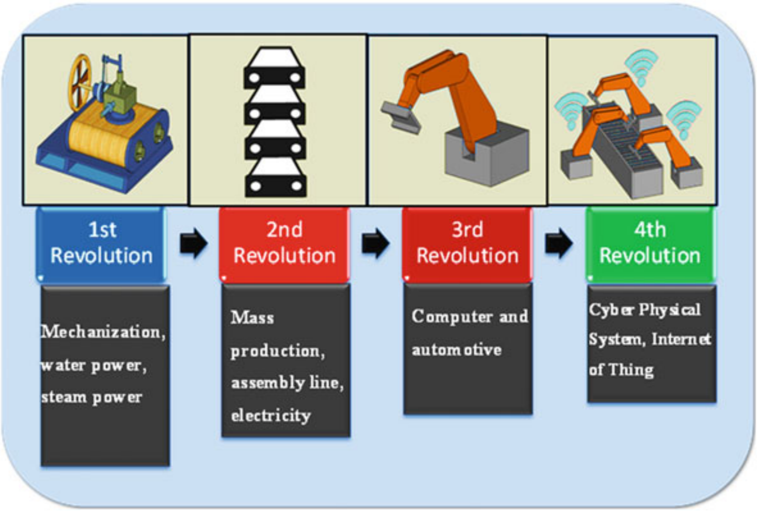

Fig. 5.2 Transformation from industrial 1.0–4.0

industry. The Information Age is a period in human history that is due to the shift of traditional industry that Industrial Revolution brought through industrialization to an economy based on information computerization [3] technology. The digital automation of production by means of electronic and information technology marks the Third Industrial Revolution. On the other hand, the dawn of the Fourth Industrial Revolution began when industry was impacted by the integration of physical and cyber systems, referred to as cyber-physical systems (CPSs). Consequently, the integrated system, production, sustainability, and customer satisfaction formed the intelligent network systems and processes [4]. The Internet of Things (IoT) had greatly changed the landscape of the entire industry. Artificial intelligence which will provide the brain of the entire industry through robotics, self-driven cars, drones, etc., is developed based on industrial needs. New business services are being developed with the intention to improved services for customer satisfaction and to improve productivity and sales by means of connectivity between cyber and physical system. It should be highlighted that the brain of a digital processes is due to advancement of the microelectronics industry. A new phase of robots is currently present in a large number hence, the industry without robotics is almost unconceivable. Robots were designed to execute a dangerous, mass production, and dull tasks, some of each may not be able to be executed by man. They are built to perform some predefined tasks, and their functionality supports business processes [5].

5.3 Disruptive Technology

Disruptive technologies have a great potential impact on economic growth, employment, and inequality by creating the new markets and business practices, revealing the needs for new product infrastructure and different skills of workers. This, in addition, has not only influenced existing firms in established markets; it can also affect the manpower market, workers' wages, and ultimately the distribution of income in the industrial world. The revolutionized communication technologies such as email, the personal computer and laptop, and smartphones have displaced many old products such as typewriters, mainframes, pocket cameras, and GPS devices. New business models are also disrupting entire industries, such as Uber with taxi cabs, Netflix with satellite and cable television, and Skype with telecommunications.

It is believed that the most economically significant technologies over the next decade will be those already well underway in their development, i.e. the mobile Internet, largely placed in the advanced world and rapidly growing in emerging markets; the automation of knowledge work, things such as computerized voices that can handle many customer service calls; the "Internet of Things," such as embedding sensors in physical objects to monitor the flow of products through a factory; and cloud computing. Each of these areas of innovation will contribute an estimated $1 trillion to the world's economy by 2025, even on the low side of their range.

Disruptive technologies can certainly benefit consumers by providing cheaper, more accessible goods or services. Firms that are slow to anticipate or react to disruptive forces might suffer declines in shareholder value and eventually markets. The knock-on effect on manpower markets is more unsettling as workers are often less well-placed to retrain, retool, or relocate, and traditional program of adjustment assistance has proven to be largely ineffective [1].

The 12 areas that exhibit the greatest economic impact and potential to cause disruption by 2025 are: mobile Internet, automation of knowledge work (artificial intelligence), the Internet of Things, cloud technology, advanced robotics, autonomous and near-autonomous vehicles, next generation genomics, energy storage, 3-D printing, advanced materials, advanced oil and gas explorations, and renewable energy [2]. These trends were chosen using four criteria including high rate of technological change, broad potential scope of impact, large economic value affected, and potential for disruptive economic impact. Together, they are estimated to affect trillions of dollars of economic activity and tens of millions of workers.

These disruptive trends are leading in a new era in which digital technologies are meeting or surpassing the capabilities of humans, even in tasks which do not follow a straightforward application of existing rules and were impossible to automate before, such as those involving communication or pattern recognition in uncertain or changing environments. An increase in computer awareness and its capabilities have influenced the need for the processing power of computers to double every two years. This means that there is an exponential growth in computing capability, and that computers of much lower processing power will become cheaper quickly, which then creates the availability of more affordable computers in the market.

By 2025, the mobile Internet, the automation of knowledge work, and the Internet of Things have the potential to deliver an economic value of up to $33 trillion a year worldwide. The estimated range of the impact of dozen technologies is also quite wide, ranging from $14 to $33 trillion by 2025. The technology in renewable energy, advanced oil and gas exploration, and recovery will have a massive effect on the measured impact of those technologies as the energy prices can fluctuate widely.

The optimization of technology will be crucial for total 12 independent, including automation of knowledge work, advanced robotics, next-generation genomics, and Internet of Things, which involves embedding sensors, smart software and communications capability into machines and other physical objects.

The estimation of the transformation of economic growth is important to determine the major forces shaping our technology advancement in the future. Those factors depend on the technological innovations which then turn out to have major economic consequences. The results have some important implications on how we think about innovation. The technologies that will have the greatest impact on the economic potential are the ones that have been evolving for many years in new ways. The technologies that are already in the advanced stage have broad potential impact and could have significant economic impact [3].

For example, in IT technology, computer speed and memory have increased over the past 30 years since the first personal computers were introduced in the market, and fields such as biotechnology are also advancing rapidly. First such as cloud computing and mobile Internet connectivity are not brand-new inventions, as they have existed for years. But the innovations that will flow from those fields, resulting in economic growth, are only the beginning.

Technology advancements have determined a way to put a dollar figure to every technology imaginable all the way out to 2025. Mobile Internet is the single most valuable and disruptive technology we know today by far. With the potential to generate nearly $11 trillion in economic impact, the mobile internet is developing at an alarming rate. (Tables 5.1, 5.2 and 5.3).

In any field, businesses are putting in the same effort trying to mix all these technologies to create profitable revenue. The technologies that have been around for ages and achieved maturity are those that contribute to the real economic benefits of its technology innovation.

Surprisingly, the overwhelming value of mobile Internet is at a very low place given to energy, whether in at a form of fossil fuels or renewables. This is based on

Table 5.1 Top 12 ranking of disruptors technologies [6]

Ranking number	Technology	Potential economic impact ($ trillion)
1	Mobile internet	3.7–10.8
2	Automation of knowledge work	5.2–6.7
3	Internet of Things	2.7–6.2
4	Cloud	1.7–6.2
5	Advanced robotics	1.7–4.5
6	Autonomous and near-autonomous vehicles	0.2–1.9
7	Next-generation genomics	0.7–1.6
8	Energy storage	0.1–0.6
9	3D printing	0.2–0.6
10	Advanced materials	0.2–0.5
11	Advanced oil and gas exploration and recovery	0.1–0.5
12	Renewable energy	0.2–0.3

the significant advancements in an industry that contributes over $1.1 trillion to the economy every year. The impact of technology in this sector is limited by the value of additional output that could cost-effectively be produced. The technology advancement in the field of energy, relative to the economic potential, the renewable energy is the most overhyped technology.

The five technologies that nearly made their list of the most disruptive and impactful technologies are as follows [6]:

1. **Next-generation nuclear**—unlikely to generate a significant impact by 2025;
2. **Fusion power**—unlikely to mature in the report's time frame;
3. **Carbon sequestration**—cost constraints remain high;
4. **Advanced water purification**—more cost-effective approaches are not scalable yet;
5. **Quantum computing**—too much uncertainty about its applicability and impact.

By the time, these disruptive potential technologies exert their influence on the economy in 2025 (Table 5.2); it will be too late for business leaders, policy makers, and stakeholders [7]. They must look ahead, identify the technologies that could affect them, and determine how to shape markets and policies in ways that will serve their main interests. These technologies could fuel a decade of rapid innovation in products, services, business processes, and go-to-market strategies. Companies will have new ways of developing and producing products, organizing their businesses, and reaching consumers and business-to-business customers. Business leaders will need to determine when, how, and whether to take advantage of new technologies and be prepared to move quickly when others use emerging technologies to mount challenges.

Table 5.2 Top six disruptors technologies [6, 8]

Disruptors technology	Effect	Capability
Mobile internet	Increasingly inexpensive and capable mobile computing devices and Internet connectivity	Enabling more efficient delivery of services and opportunities to increase workforce productivity
Automation of knowledge work	Intelligent software systems that can perform knowledge work tasks involving unstructured commands and subtle judgments	A threat to the service sector, especially with voice recognition allowing computers to interact with customers. It will allow for automation of a lot of knowledge work and make it cheaper and more accessible
Internet of Things	Networks of low-cost sensors and actuators for data collection, monitoring, decision making, and process optimization	A positive for industry because it allows companies to manage assets and optimize performance of production process by having improved sensors and remote monitoring
Cloud computing	Use of computer hardware and software resources delivered over a network or the Internet, often as a service	Negates the need for having costly hardware equipment because software and hardware are now accessible remotely over the Internet
Advance robotics	Increasingly capable robots with enhanced senses, and intelligence used to automate tasks or augment humans	It is an obvious threat to manufacturing jobs, but can boost production and reduce costs and also a threat to industries such as health care as some tasks would be able to be performed by robots, and services such as cleaning and maintenance
Autonomous and near-autonomous vehicles	Vehicles that can navigate and operate with reduced or no human intervention. If regulation allows, as early as 2020 autonomous cars, aircraft, and boats can revolutionize transportation	

In the twenty-first century, all business leaders must understand technology. They must develop their own well-informed views of what developments such as cloud computing could do for their enterprises and work to separate hype from reality. Leaders should think carefully about how specific technologies could drive economic impact and disruption in ways that could affect their businesses [8]. Leaders should invest in their own technology knowledge, not to become

Table 5.3 Development characteristics and key features of target country [7, 9, 12]

Country/Target	Development characteristic	Key features
Taiwan **Target**: To promote Taiwan as a hub for Agriculture 4.0	• Agriculture 4.0 • Smart farming devices • Large-scale precision agriculture projects	• Precision farming • Agriculture 4.0 • Drones, robotics • Internet of Things (IoT) • Vertical farms • Artificial intelligence (AI) • Solar energy
Thailand **Target**: Aimed to pull the country out of the middle income trap. (average annual income of farmers from 56,450 baht to 390,000 baht within the next 20 years)	• Thailand 4.0 and Agriculture 4.0 • Reducing inefficiencies, water consumption, fertilizers insecticides, and other chemicals and harmful effects on soil, animals, and people • Give way to foreign investors to make Thailand 4.0 and Agriculture 4.0 more feasible	• Farmers actively improved the qualities of fruit varieties in response to consumer demand • Local firms were able to adapt imported machinery to match local farm conditions and further export the modified versions to other low-income countries • Hired services and rental markets, particularly for combined harvesters, emerged and have since developed into a full-fledged practice that allows farmers to share the costs • Multistakeholder partnership projects • Investment programs that will bring together the non-government organizations, companies, the government, universities, and farmers • Technological transformation that will also provide access to shared information, technology, finances, and markets
Vietnam **Target**: Vietnam has emerged as one of the world's leading exporters of agricultural commodities and is among the top five for aquatic products, rice, coffee, tea, cashews, black pepper, rubber, and cassava	• Agriculture 4.0 • High-tech and clean agricultural projects • Developing high-tech agriculture is an important task and also the inevitable trend of Vietnam's socioeconomic development strategies in the context of deeper international integration	• The development of high-tech agriculture at lower market rates • Preferential loans to high-tech and clean agricultural projects. Interest rates of the loans will be 0.5–1.5% per year lower than other average lending rates

(continued)

Table 5.3 (continued)

Country/Target	Development characteristic	Key features
British **Target**: New patterns of crop rotation and livestock utilization paved the way for better crop yields, a greater diversity of wheat and vegetables, and the ability to support more livestock	• Agriculture 4.0 • The increased availability of farmland • A favorable climate • More livestock • Improved crop yield	• Norfolk four-course crop rotation: fodder crops, particularly turnips and clover, replaced leaving the land fallow • The Dutch improved the Chinese plow so that it could be pulled with fewer oxen or horses • The removal of common rights to establish exclusive ownership of land • Development of a national market free of tariffs, tolls, and customs barriers • Transportation infrastructures, such as improved roads, canals, and later, railways • Land conversion, land drains, and reclamation • Increase in farm size • Selective breeding
India **Target**: Efforts on overcoming language barriers and encouraging collective farming to reduce land fragmentation	• Agriculture 4.0 • Enables farmers to sow right crops at the right location in order to get optimized yield in the limited patch of land • Delivers precise information on the use of agri-inputs leading to a reduction in its wastage and hence resulting in considerable savings and lesser reliance on rural credit • Innovative practices will make the farmers less dependent on rains or will educate them on water-harvesting techniques in case they still rely on rains • Data acquisition for precise data accurate up to the remotest village is available on categories like climate, rainfall, land, soil condition	• At 190 million hectares, India holds second largest agricultural land in the world • Around 800 million of rural population depends on agriculture as their primary source of income and livelihood • Using data science to precisely regulate and optimize the agricultural investment • Management measures in accordance with specific condition of each unit of farmland so as to maximize output and economic benefit while reducing use of resources to protect agricultural ecology

programmers or compulsive Facebook posters, but they should keep abreast of technology trends and pay attention to what their most tech-savvy customers are doing and saying.

No.	Value driver	Description
1	Resource/ processes	• Smart energy consumption • Intelligent lots • Real-time optimization – Productivity increase of 3–5%
2	Asset utilization	• Routing flexibility • Machine flexibility • Remote monitoring and control • Predictive maintenance • Augmented reality for MRO[1.] – 30–50% Reduction of total machine downtime.
3	Labor	• Human–robot collaboration • Remote monitoring and control • Digital performance management • Automation knowledge work – 45–55% increased productivity in technical professions through automation of knowledge work
4	Inventory	• In situ 3D printing • Real-time supply chain optimization. • Batch size 1 – Costs inventory holding decreased by 20–50%
5	Quality	• Statistical process control • Advance process control • Digital quality management • Costs for quality reduced by 10–20%
6	Supply/demand matching	• Data-driven demand prediction • Data-driven design to value – Forecasting accuracy increased to 85%+
7	Time to market	• Customer cocreation/open innovation • Concurrent engineering • Rapid experimentation and simulation – 20–50% reduction in time to market
8	Service/after sales	• Predictive maintenance • Remote maintenance • Virtually guided self-service – 10–40% reduction of maintenance costs

Time is crucial and the world is changing as at the highest speed of the Internet, and technology is continually evolving. Strategies can quickly fall behind, so the rhythm of planning must keep in pace. When technologies have disruptive potential, the stakes are even higher and the range of strategic implications is wider. This is a big red flag against the sole focus by companies on their largest, most established markets and related value propositions. In doing so, companies can miss the ways in which disruptive technologies can jump industry or market boundaries and change the rules of the game.

When necessary, leaders must be prepared to disrupt their own businesses and make the investments necessary for changes (Fig. 5.3): As the past two decades have shown, successful companies repeatedly reinvent themselves to keep up. This will require continuous experimentation and investment. Early investment will probably dilute the profitability of a company's portfolio in the near term, but is ultimately tomorrow's sources of growth that ensures the enterprise's future [7]. Companies that reallocate resources early to capture trends often have higher returns and are more likely to survive in the long term. Failing to reinvent and focusing only on existing markets might open the door for disruptor's potential, particularly at the bottom end of the market.

The democratization of technology is currently advancing, reducing the barriers to entry, and allowing entrepreneurs and other new competitors to disrupt well-established markets and industries. Cloud services make it easier for new companies with little capital to obtain operating infrastructure and access to markets that has taken global companies decades to build. 3D printing goes a step further; it

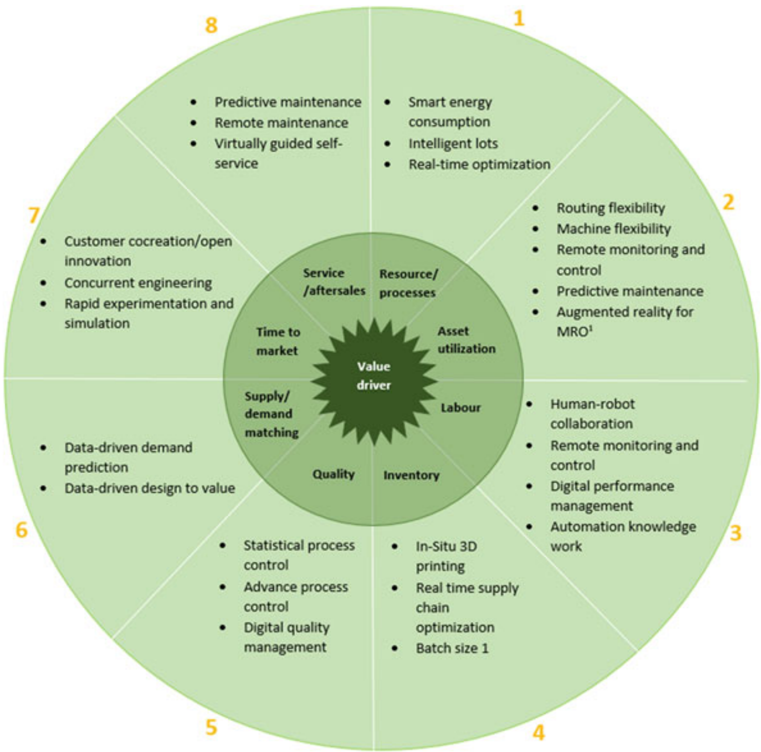

Fig. 5.3 Value driver of disruptive technology [6]

not only opens up markets to competition from entrepreneurs, but it also has the potential to shift value directly to consumers as they learn how to make things that they used to buy [6]. To compete in this environment, companies need deep sources of value or competitive advantage. The prospect of more than two billion new Internet users in developing economies promises both access to new consumers and the threat that those consumers will go into business against you. To survive, companies will need to learn the tricks of the Internet trade and multisided business models such as online advertising or monetizing exhaust data, which need not be reserved for Google and Facebook.

Some of the largest opportunities and challenges for business leaders will arise from new tools that could transform how work is done. With technologies such as advanced robotics and automated knowledge work, companies can potentially have unique opportunities to realize rapid improvements in productivity. These tools could redefine jobs as tasks are augmented by, or transferred to, machines, thus requiring new skills for workforces. Knowledge workers are the foundation of future success, in all sectors of the economy; by 2025, some manufacturers could be hiring more designers and robotics experts than assemblers [7].

Companies that use technology to make knowledge employees more productive will gain a large business model advantages and attract the best talent. Companies will need to have the right people, along with the training systems to keep these workers' skills current. Adopting disruptive technologies entails risks, and managing these risks will be critically important. Internally, organizational effectiveness and cohesion could potentially suffer as some jobs are transformed or eliminated by technology [6]. By working with employees and redesigning jobs to focus on higher value skills and by investing in workforce development, companies can minimize these risks.

External risks include reputational risk and consumer resistance, as well as safety and regulatory issues. For example, new materials may have unforeseen health effects and may pose environmental risks. Autonomous vehicles might not deliver the potential impact we estimate unless the safety of driverless vehicles can be established, consumers accept the idea, and regulators come up with the necessary rules and standards to put these cars and trucks on the road. Business leaders need to strike a careful balance as they adopt new technologies; they must be thoughtful about risk, but they should also manage these risks without stifling potential.

5.3.1 Challenges and Opportunities

The arrival of the Fourth Industrial Revolution, commonly known as Industrial Revolution 4.0 (IR 4.0 or I4.0), will potentially raise the global income and certainly improve the overall quality of life. The well-being and sustainability of human, the main theme of this book, will be the long-term gain, in terms of both efficiency and productivity. Currently, the communication, transportation, and entertainment cost are greatly reduced, and hence, this has affected our lifestyle for the better.

Low growth, volatile energy prices, environmental concerns, and rising expectations from consumers, are some of the challenges the crop production industry is facing today, along with diminishing production profit margins for farmers. To grow food the world needs, crop production systems need innovative solutions to produce more in an environmentally, economically, and socially viable manner.

Research and development in everything from crop development to land usage to pre- and post-harvest crop management will be crucial in providing high-quality, affordable food that protects both natural resources and human health while remaining competitive. Some innovative solutions are already available, and their implementation sometimes made compulsory by law, such as adherence to the Common Agricultural Policy (CAP). But how can we improve access to and use of innovative solutions? What challenges do farmers face as they work to ensure sustainable crop production? Are the existing technologies and tools enough to make crop production sustainable in the long run?

Two main challenges faced by our current food production are to produce food efficiently and safely and contribute to future sustainably. Each day, the world's population grows by 200,000 people, which means many new mouths to feed. The UN estimates that food production will have to be expanded by 70% by 2050. This needed expansion of food production is a daunting challenge, but one that can be met if we make good use of modern technology, and support continued innovation [9].

Agricultural efficiency has already expanded greatly since the 1960s, when the expanded use of new crop protection techniques was accompanied by a huge increase in agricultural capacity. Society is increasingly aware of the dual challenge of feeding a growing population while protecting the environment.

The crop protection practices developed in the 1960s have had a detrimental effect on soil [3]. But different practices can help turn this situation around. The use of cleverly managed, long-term crop rotations, can be used to not only build up soil fertility and health, but also to break cycles of pest outbreaks and disease. One approach to protecting the environment has been organic farming, which is growing in popularity. But organic farming alone may not be able to meet the world's growing food demand. The crop protection industry believes that high-yield pest control can be combined with efficient farming practices to increase future sustainability.

As we know the first industrial revolution relied heavily on human and animals while the arrival of the second revolution had reduces the labor demand and time of production. Since the third and fourth industrial revolutions come with the digitalization era and information age, the blue collar workforce might be reduced greatly, thereby changing the structure of the society. The substitution of automation across the entire economy hence the operating cost and capital investment cost returns might have a new model. Potentially a new rewarding occupation which is health and environment safety and efficient which are to some extent is connected via social media. Some jobs will certainly be vanished.

5.4 Agriculture 4.0

5.4.1 History of Agriculture

The history of agriculture visualized mankind's development and cultivation of producing food, fiber, fuel, and other goods by the systematic raising of plants and animals. Prior to the development of plant cultivation, human beings were hunters and gatherers. The knowledge and skill of learning to care of soil and growth of plants advanced the development of human society, allowing clans and tribes to stay in one location generation after generation. Archeological evidence indicates that such developments occurred 10,000 or more years ago.

Due to agriculture, cities and trade relations between different regions and groups of people developed, further enabling the advancement of human societies and cultures. Agriculture has been an important aspect of economics throughout the centuries prior to and after the Industrial Revolution. The sustainable development of the world's food supplies impacts the long-term survival of the species. There is always a need to ensure that agricultural system is maintain thier green approach with our ecosystem.

By 7000 BCE, sowing and harvesting reached Mesopotamia, in the fertile soil just north of the Persian Gulf, Sumerian ingenuity systematized it and scaled it up. By 6000 BCE [2], farming was entrenched on the banks of the Nile River. During this time, agriculture was developed independently in the Far East, probably in China, with rice as the primary crop [7]. Maize was first domesticated, probably from teosinte, in the Americas around 3000–2700 BCE, though there is some archeological evidence of a much older development. The potato, tomato, pepper, squash, several varieties of bean, and several other plants were also developed in the New World, as was quite extensive terracing of steep hillsides in much of Andean South America. Agriculture was also independently developed on the island of New Guinea.

The reasons for the development of farming may have included climate change, but possibly there were also social reasons such as accumulation of food surplus for competitive gift-giving as in the Pacific Northwest potlatch culture. There was a gradual transition from hunter-gatherer to agricultural economies after a lengthy period during which some crops were deliberately planted and other foods were gathered in the wild. Although localized climate change is the favored explanation for the origins of agriculture in the Levant, the fact that farming was "invented" at least three times elsewhere, and possibly more, suggests that social reasons may have been instrumental.

Full dependency on domestic crops and animals did not occur until the Bronze Age, by which time wild resources contributed a nutritionally insignificant component to the usual diet. If the operative definition of agriculture includes large-scale intensive cultivation of land, monocropping, organized irrigation, and use of a specialized labor forces, the title "inventors of agriculture" would fall to the Sumerians, starting ca. 5,500 BCE. Intensive farming allows for a much greater density of population that can be supported by hunting and gathering, and enables the accumulation of excess products for off-season use, or to sell/barter. The ability of farmers to feed large numbers of people whose activities have nothing to do with material production was the crucial factor in the rise of standing armies. Sumerian agriculture supported a substantial territorial expansion, together with much internecine conflict between cities, making them the first empire builders. Not long after, the Egyptians, powered by farming in the fertile Nile valley, achieved a population density from which enough warriors could be drawn for a territorial expansion more than tripling the Sumerian empire in area. [5]

The invention of a three-field system of crop rotation during the Middle Ages, and the importation of the Chinese-invented moldboard plow, vastly improved agricultural efficiency. After 1492, the world's agricultural patterns were shuffled in the widespread exchange of plants and animals known as the Columbian Exchange [10]. Crops and animals that were previously only known in the Old World were now transplanted to the New World and vice versa. Perhaps most notably, the tomato became a favorite in European cuisine, and maize and potatoes were widely adopted. Other transplanted crops include pineapple, cocoa, and tobacco. In the other direction, several wheat strains quickly took to western hemisphere soils and became a dietary staple even for native North, Central, and South Americans [11].

Agriculture was a key element in the Atlantic slave trade, Triangular trade, and the expansion by European powers into the Americas. In the expanding plantation economy, large plantations produced crops that included sugar, cotton, and indigo, which were heavily dependent upon slave labor.

By the early 1800s, agricultural practices, particularly careful selection of hardy strains and cultivators, had improved so much that yield per land unit was many times that seen in the Middle Ages and before, especially in the largely virgin soils of North and South America. The eighteenth and nineteenth centuries also witnessed the development of glass houses or greenhouses, initially for the protection and cultivation of exotic plants imported to Europe and North America from the tropics. Experiments on plant hybridization in the late 1800s yielded advances in the understanding of plant genetics, and subsequently, the development of hybrid crops. Storage silos and grain elevators appeared in the nineteenth century. However, increasing dependence upon monoculture crops leads to famines and food shortages, the most notable of which is the Irish Potato Famine (1845–1849) [9].

The birth of industrial agriculture coincides with that of the Industrial Revolution. With the rapid rise of mechanization in the late nineteenth and twentieth centuries, particularly in the form of tractor, farming tasks could be performed with a speed and on a scale that was previously impossible. These advances, joined with science-driven innovations in methods and resources, have led to efficiencies enabling certain modern farms in the USA, Argentina, Israel, Germany, and a few other nations to output volumes of high-quality product per land unit at what may be the practical limit. The development of rail and highway networks and the increasing use of container shipping and refrigeration in developed nations have also been essential to the growth of mechanized agriculture, allowing for the economical long-distance shipping of product.

The identification of nitrogen and phosphorus as critical factors in plant growth led to the manufacture of synthetic fertilizers, making it possible for more intensive types of agriculture. The discovery of vitamins and their role in animal nutrition in the first two decades of the twentieth century led to vitamin supplements, which in the 1920s allowed certain livestock to be raised indoors, reducing their exposure to adverse natural elements. The discovery of antibiotics and vaccines facilitated raising livestock in larger numbers by reducing disease. Chemicals developed for use in World War II gave rise to synthetic pesticides. Other applications of scientific research since 1950 in agriculture include gene manipulation and hydroponics [9].

Agricultural production across the world doubled four times between 1820 and 1975. Between 1820 and 1920; between 1920 and 1950; between 1950 and 1965; and again between 1965 and 1975, so as to feed a global population of one billion human beings in 1800 and 6.5 billion in 2002 [6]. During the same period, the number of people involved in farming dropped as the process became more automated. In the 1930s, 24% of the American population worked in agriculture compared to 1.5% in 2002; in 1940, each farm worker supplied 11 consumers, whereas in 2002, each worker supplied 90 consumers [8]. The number of farms has also decreased, and their ownership is more concentrated. In the USA, four companies kill 81% of cows, 73% of sheep, 57% of pigs, and produce 50% of chickens, cited as an example of "vertical integration" by the president of the US National Farmers Union [7].

While industrial agriculture strives to lower costs and increases productivity, the methods of industrial agriculture also have unintended consequences. The degree and significance of these unintended consequences are subject to debate, as is the question of the best way to deal with these consequences [12].

The Green Revolution, the worldwide transformation of agriculture that led to significant, increases in agricultural production between the 1940s and 1960s, occurred as the result of programs of agricultural research, extension, and infrastructural development, instigated and largely funded by the Rockefeller Foundation, along with the Ford Foundation, and other major agencies [9]. The Green Revolution in agriculture helped food production to keep pace with worldwide population growth. The projects within the Green Revolution spread technologies that had already existed, but had not been widely used outside of industrialized nations. These technologies included pesticides, irrigation projects, and synthetic nitrogen fertilizer.

The novel technological development of the Green Revolution was the production of what some referred to as a miracle seeds. Scientists created strains of maize, wheat, and rice that are generally referred to as the high yielding varieties (HYVs). HYVs have an increased nitrogen-absorbing potential compared to other varieties. Since cereals that absorbed extra nitrogen would typically lodge, or fall over before harvest, semidwarfing genes were bred into their genomes. Norin 10 wheat, a variety developed by Orville Vogel from Japanese dwarf wheat varieties, was instrumental in developing Green Revolution wheat cultivators. IR8, the first widely implemented HYV rice to be developed by IRRI, was created through a cross between an Indonesian variety named "Peta" and a Chinese variety named "Dee Geo Woo Gen" [13].

HYVs significantly outperform traditional varieties in the presence of adequate irrigation, pesticides, and fertilizers. In the absence of these inputs, traditional varieties may outperform HYVs. One criticism of HYVs is that they were developed as F1 hybrids, meaning they need to be purchased by a farmer every season rather than saved from previous seasons, thus increasing a farmer's cost of production.

The idea and practice of sustainable agriculture have arisen in response to the problems of industrial agriculture. Sustainable agriculture integrates three main goals: environmental stewardship, farm profitability, and prosperous farming communities. These goals have been defined by a variety of disciplines and may be looked at from the vantage point of the farmer or the consumer.

5.4.2 Fourth Industrial Revolution in Agriculture (Agriculture 4.0)

Industrial agriculture is a modern form of farming that refers to the industrialized production of livestock, poultry, fish, and crops. The methods of industrial agriculture are techno-scientific, economic, and political. They include innovation in agricultural machinery and farming methods, genetic technology, techniques for achieving economies of scale in production, the creation of new markets for consumption, the application of patent protection to genetic information, and global trade. These methods are widespread in developed nations and are increasingly prevalent worldwide.

Agriculture is a conservative industry yet it has been a strong pillar of the economy. However, the agriculture sector is facing some challenges, including food security, climate change such as El Nino, water contamination and scarcity, and high energy demand. Similar to other industries, agriculture is affected by the arrival of the Fourth Industrial Revolution as well. Hence, the implementation of advanced technologies such as sensors, smart farming, vertical farming, smart fertigation systems, green methods of application, and green urea are essential to meet the demand of ever-increasing population. Sustainable development with fundamental yet high-level integration of scientific achievement and modern technologies in sectors of digitalization, biotechnology, and nanophysics hence means that the arrival of IR 4.0 (Fig. 5.4) is expected to have a compelling change in the agriculture industry. When Germany first launches the IR 4.0, it did not anticipate that this would change the entire industry. Some advancement in agriculture based on some country, such as Africa, Vietnam, Nigeria, China, and India, will be reported in the following section.

Fig. 5.4 Impact of Agriculture 4.0

Precision engineering is the highlight of the agricultural industry in the next few years. Taiwan is among the few countries, besides Germany that adopts the agriculture in IR 4.0 [14]. Just like any other business, yield of crops will be the ultimate aim and this can be achieved with greater environment prediction. Predictive monitoring systems, especially those related to soil and weather conditions would be essential for the industry. It is full of potential for future farmers that adopt the right components of Agriculture 4.0, such as IoT, smart sensors, robotics, drones and satellites, hydroponics and aquaponics and solar cells among others. Data analytics is important for Agriculture 4.0, as the data carries important information for farmers. Some startups are offering farmers modern equipment in digital form, software, and innovative tools that could capture, monitor, process, and perform real-time monitoring activities [15]. However, it should be noted that since agriculture is a conservative industry, some farmers are receptive in advanced technology which would actually increase their profit to several folds. A drastic shift in strategies by policy makers and the government, is required to ensure that the middle income model of a country such as Vietnam, Malaysia and Thailand is shifted to a high income nation.

5.5 Summary

Advancement in technology is deemed important particularly if it is related to a game-changing technology. Industrial Revolution 4.0 (IR 4.0 or I4.0) will potentially raise the global income and certainly improve overall quality of life. It has been a subject of interest by many people, particularly in industry, higher learning institution, government and research institutions across the world. Developing high-tech agriculture is an important task in the implementation of Agriculture 4.0 and also inevitable trend in the socioeconomic development strategies in the context of deeper international integration. Data science can be used to systematically regulate and optimize agricultural investments. The estimation of the transformation of economic growth is important to determine the major forces that shape our technology advancement in future. These factors depend on technological innovations which then turn out to have major economic consequences. Agriculture 4.0 creates the new patterns of crop rotation, and livestock utilization that pave the way for better crop yields, a greater diversity of wheat and vegetables, and the ability to support more livestock.

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