Chapter 10

Bio-industrial Agricultural Production Networks and Robustness Against Disasters: Roles of Information and Communications Technology in Industrial Agricultural Production in the Republic of Korea

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CHAPTER 10

BIO-INDUSTRIAL AGRICULTURAL PRODUCTION NETWORKS AND ROBUSTNESS AGAINST DISASTERS: THE ROLES OF INFORMATION AND COMMUNICATIONS TECHNOLOGY IN INDUSTRIAL AGRICULTURAL PRODUCTION IN THE REPUBLIC OF KOREA

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Introduction

Over the past 150 years, the global average surface temperature has increased by 0.76°C (IPCC, 2007) and has caused greater climatic volatility such as changed precipitation patterns or increased frequency and intensity of extreme weather events including typhoons, heavy rainfalls, floodings, and droughts. Although the agricultural sector continually adapts to climate change through changes in crop rotations, planting times, genetic selection, fertiliser management, pest management, water management, and shifts in areas of crop production, it needs effective information on important environment factors that can be used for warning and preventing adverse impacts of climate change. In particular, industrial agricultural production requires monitoring for a secure production and control of food safety standards.

In 2015, there were 1,237,000 farm, forest, and fishery households in the Republic of Korea with 2,924,000 dependent persons (Statistics Korea, 2016). Compared to the previous agricultural census in 2010, this was a reduction of 7.6% in the number of households and a 16.4% reduction in the number of the primary sector population. Out of 10,027 ha of total land area, 1,711 ha are used for cultivation and food production (KREI, 2015). The average Korean farm size is 1.4 ha, very small compared to those of

other highly industrialised countries. The income of the agricultural population is less than 80% of the national average. The farming population is ageing, with 37.8% over 65 years old in 2015.

Information and communications technology (ICT) has played a role in supply chain management but is increasingly being included in farm management. Farmers can use ICTs to match cropping practices with climatic trends, use inputs and resourses environmentally and sustainably, and cope with threats to productivity. Indeed, ICT is gaining momentum as part of sustainable development, and environmental and climate change strategies. To achieve sustainable agricultural production, it can be used as a method in increasing crop yields, reducing water consumption, and increasing profits. ICT has been implemented in several risk areas in developing and developed countries although it has limited accessibility to poor farmers because of cost (WB, 2011). Many countries have strategies and targets to improve, develop, and optimise the use of this technology by reducing its accessibility limitations.

In this article, we deal with scenarios of climate change and significant impacts of natural disasters on Korea's agricultural production by focusing on the implementation of ICT.

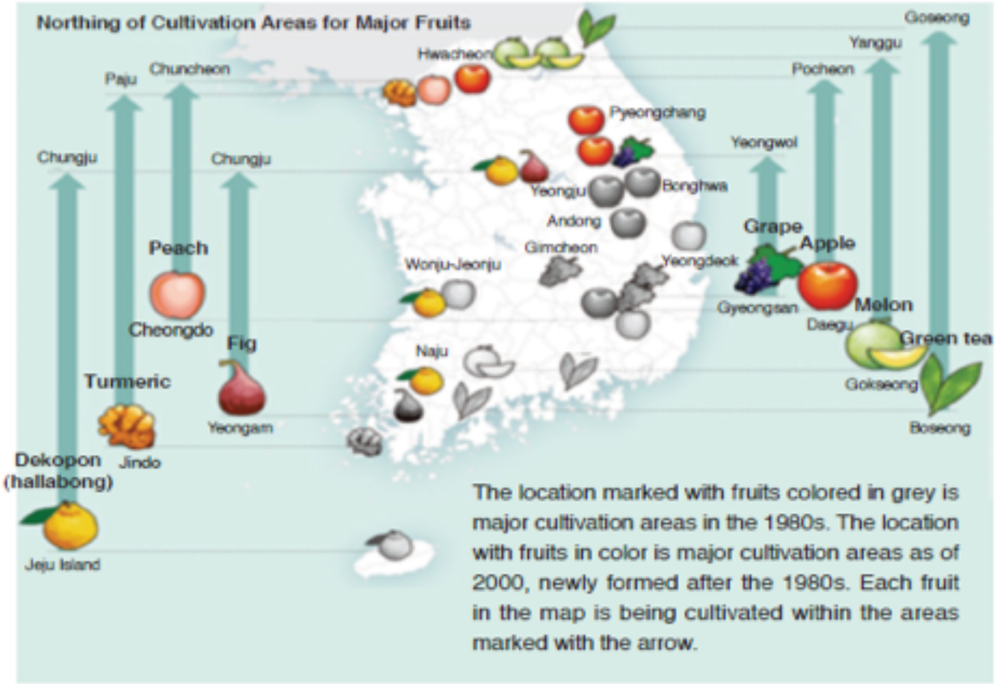
Scenarios on Climate Change and Occurrence of Disasters

According to the projections of Korea Meteorological Administration based on observation data accumulated over 30 years, the temperature in Korea will continuously increase until 2100. For instance, the current annual average temperature of the southern part of Jeju Island, located in the subtropical climate zone, is 16.7°C.

Climate change will affect major production areas. In 2013, the Future Digital Climate Map for Agriculture Use forecast changes in Korea's cultivation areas (Figure 1). Rice production, for instance, will fall to around 18.3% in 2050 due to increasing high temperature (KREI, 2015).

The total areas for apple cultivation will continuously decrease, while those for pear, peach, and grape will remain until the mid-21st century before they start to decrease. Conversely, cultivation-capable areas for sweet persimmon, tangerine, and subtropical crops will increase.

Figure 1: Changes in Suitable Cultivation Areas for Major Crops as Induced by Climate Change

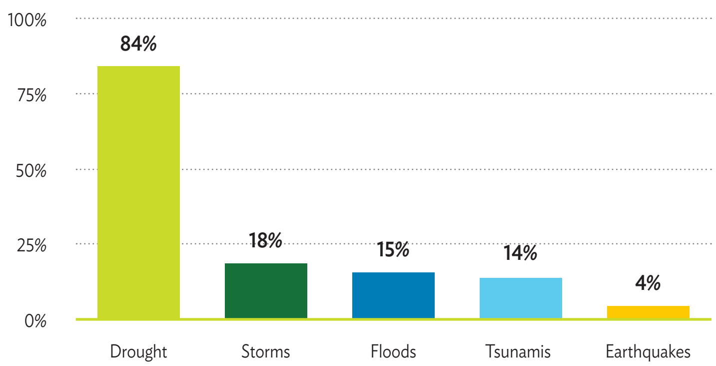


Source: Rural Development Administration, 2015.

Loss and Damage to Agricultural Production

Over the last three decades, there has been a rising trend in the occurrence of natural disasters worldwide, particularly climatological events such as droughts, hydrological events like floods, and meteorological events such as storms. The increase in weather-related events is of significant concern to the agriculture sector given its dependence on climate (FAO, 2015b).

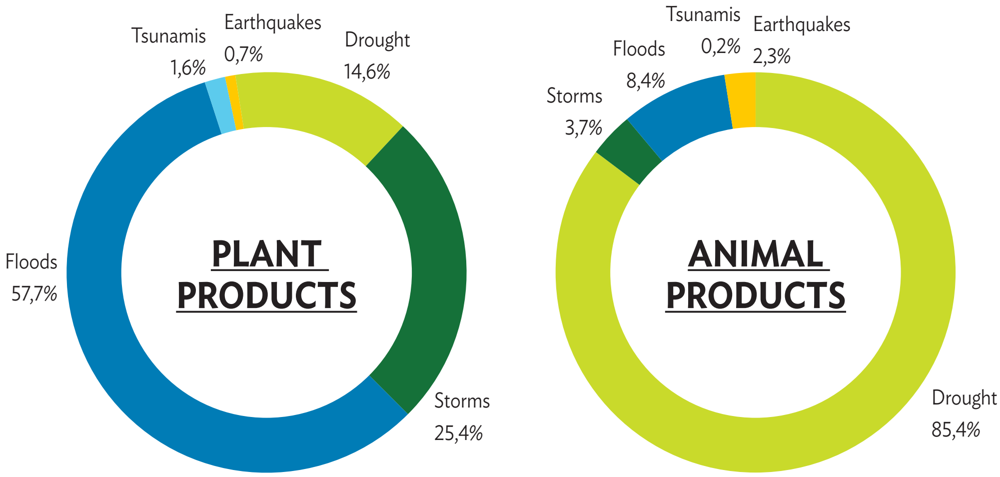
Figure 2: Kinds of Natural Disasters



Source: FAO, 2015b

The Food and Agriculture Organization (FAO) (2015a) found that from 2003 to 2013, natural hazards and disasters in developing countries affected more than 1.9 billion people and caused over US$494 billion in estimated damage. Moreover, FAO's findings show that the 78 disasters caused a total of US$30 billion in loss and damage to the agriculture sector. As illustrated in Figure 3, the relationship between drought and agriculture is particularly important as 84% of the loss and damage caused by droughts is to agriculture (FAO, 2015b). Moreover, total loss and damage to the crop sub-sector amounted to about US$13 billion, almost 60% of which were caused by floods, followed by storms with 25%. Livestock is the second most affected sub-sector, accounting for US$11 billion or 36%. A total of 67 developing countries were affected by at least one medium to large natural disaster between 2003 and 2013, causing crop and livestock production losses amounting to US$70 billion. Damage and loss to crop and livestock production caused by droughts and floods amounted to 44% and 39%, respectively (FAO, 2015a).

Figure 3: Loss and Damage to Agriculture Subsectors by Type of Hazard



Source: FAO, 2015b

Different types of disasters have different impacts on each subsector, as illustrated in Figure 4. Crops tend to be most affected by floods and storms, accounting for an estimated 83% of economic impact on the sub-sector. Livestock is overwhelmingly affected by droughts, causing nearly 86% of all loss and damage to the sub-sector (FAO, 2015b).

Understanding these differences is critical in the formulation of policies and practices at national, sub-national, and community levels. Disaggregated sub-sectoral data on disaster impact are needed to support the implementation of innovative risk management

tools, such as weather risk insurance schemes for agriculture and rural livelihoods. Systematic and coherent data availability will facilitate the design of insurance schemes, which would help further diversify risk-mitigation strategies.

The Republic of Korea is seriously affected by climate change such as changes in temperature, rainfall patterns, increase in extreme weather events including floods and droughts, and occurence of easily spreading diseases which affect agricultural production and people's livelihoods. Natural disasters have significantly contributed to unstable domestic agricultural production and food supply in the country. Natural disasters in Korea increased from 48 cases in 1910 to 190 cases in 1990.

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Natural Disasters	Range of Years	Impacts
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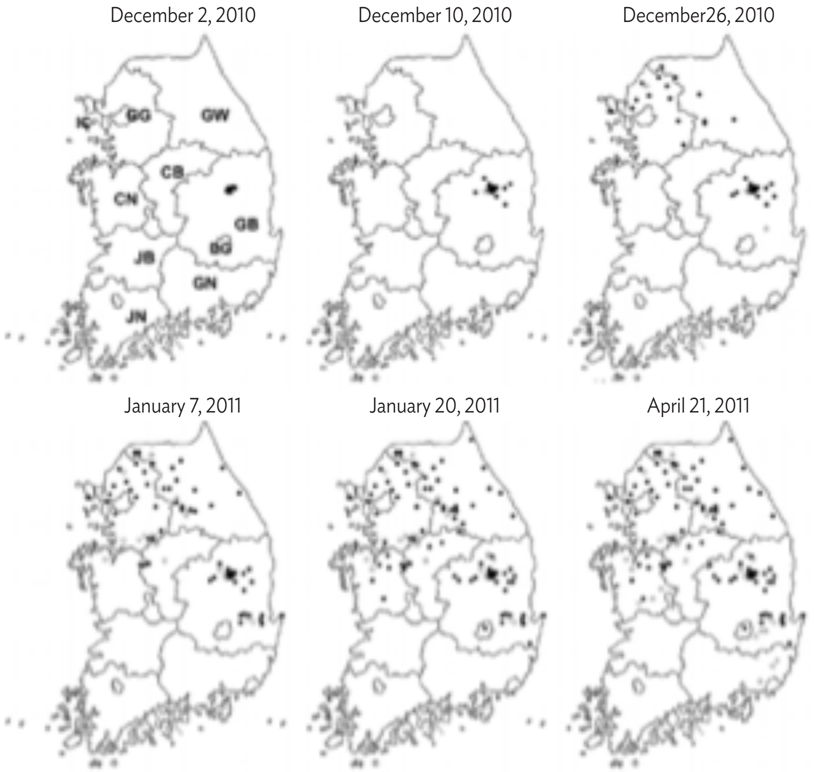
Typhoons	1981–2012	Rainfall and wind
Foot-and-mouth disease	November 2010–April 2011	Effect on livestock
Winter storms in East Asia	May 2009–February 2010	Blizzard and heavy snow

Source: Wikipedia, 2016.

An outbreak of foot-and-mouth disease (FMD) in Korea in November 2010–April 2011 seriously affected the country's food supply chain which could not respond to domestic consumption demand. The economic losses amounted to approximately US$1.7 billion. Consequently, market prices of meat were increased to control and manage the situation while at the same time introducing the use of technologies, improved breeds, and more intensive production systems, and consequently taking market opportunities at local, national, and international levels. The government imposed quarantines and initiated a vaccination campaign that targeted nine million swines and three million heads of cattle while culling 2.2 million livestock. The overall cost of this effort was estimated at US$1.6 billion. After vaccination and culling were implemented, the number of daily FMD cases decreased gradually. Amongst cattle, the number of FMD cases began to decrease 40 days after the initial outbreak (12 days after the first cattle vaccinations). In swines, the number decreased 60 days after (18 days after the first swine vaccinations) (Park et al., 2013) (online Technical Appendix Figure 5).

Figure 5: **Progress of Foot-and-mouth Disease Transmission Throughout Korea During 2010–2011 Outbreak**



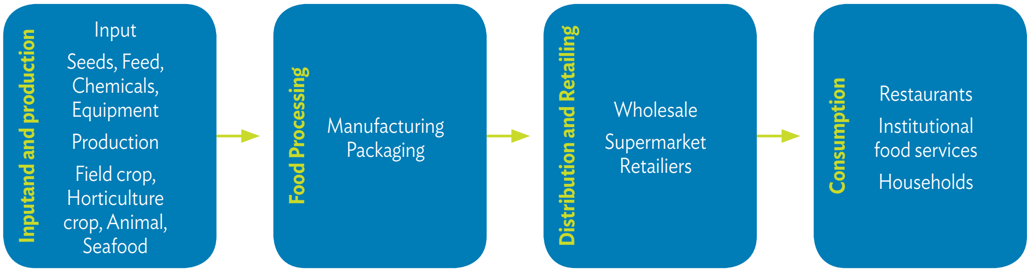
Note: Circles indicate swine cases in index farms; black dots, cases in cattle. A timeline of case detection is provided in online Technical Appendix.
Source: wwwnc.cdc.gov/EID/article/19/4/1- 1320-Techapp1.pdf .

Impacts to Food Supply Chain of Loss of Agricultural Production

The industrial system for agricultural production network is created to provide sustainable food security and to ensure a healthy life for present and future generations. However, recent climate change situations have created various impacts on agricultural production networks especially on initial farm-level production networks. More than 80% of loss and damage was caused by droughts and floods (FAO, 2015b), mainly involving reduction and loss of crops and livestock. For food supply chain (Figure 6), insufficient raw materials and price variables affect industrial agricultural production, which needs increased investment to be able to provide raw materials into food supply chain to be transformed as agriculture products in food processing for delivery to retailers or supermarkets. At the same time, a producer in food processing must realize return profit to his investment by determining proper prices for the consumer. For instance, cereal prices in Southeast Asia are likely to rise up to 30% if mean temperatures change in the range of 5.5oC (Easterling, 2007) which will lead to a decline in crop yields. This issue can be a reason to import

(Ministry of Agriculture, Food and Rural Affairs 2015). The rice farms are of small scales at 1.19 ha in average. Therefore, its food self-sufficiency rate is very low. (KREI, 2015).

Figure 6: Food Supply Chain – Linear Model

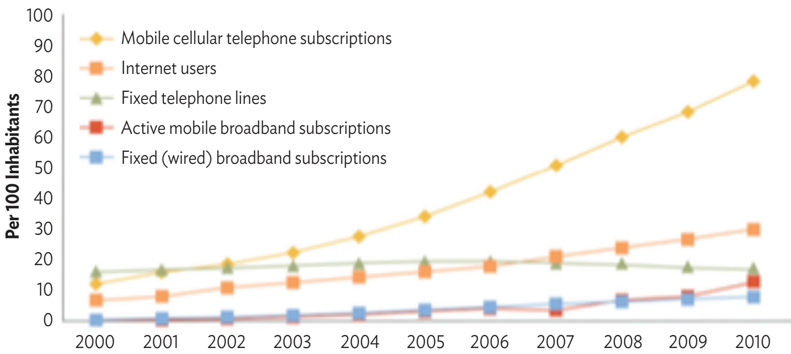


Source: Berti and Mulligan, 2015.

Implications of Using ICT in Agriculture Sector

ICT intervention for the agricultural value chain is on pricing service where commodity price information is provided to customers on a regular basis. Such service offers advantages such as price transparency and improved negotiating leverage for the often disempowered seller (farmer). Furthermore, crisis management helps prevent crop losses and raise productivity. Alert systems enable farmers to react quickly before disasters occur, including weather conditions and diseases. For long-term productivity and risk management information services, ICT does not replace work of agents but it can help add an extension to agents for better services. For example, extension agents may be very knowledgeable in their field, but may be receiving training on the latest techniques only once a year. ICT can provide extension agents access to virtual libraries and the internet to research new ideas and techniques. ICT can also help extension agents be more productive by enabling them to serve more beneficiary farmers at once. This can be done with fewer visits to the field and more interaction with beneficiaries through the ICT platform, such as via distance learning or day-to-day monitoring and advice using personal mobile phones.

Figure 7: Global Development, 2000–2010



Source: International Telecommunications Union's world Telecommunication/ICT indicators base 2016.

An ICT is any device, tool, or application that permits the exchange or collection of data through interaction or transmission. Development of this technology, especially mobile network, is continually increased to make useful information more widely available (Figure 7).

Roles of ICT Network in Agricultural Production

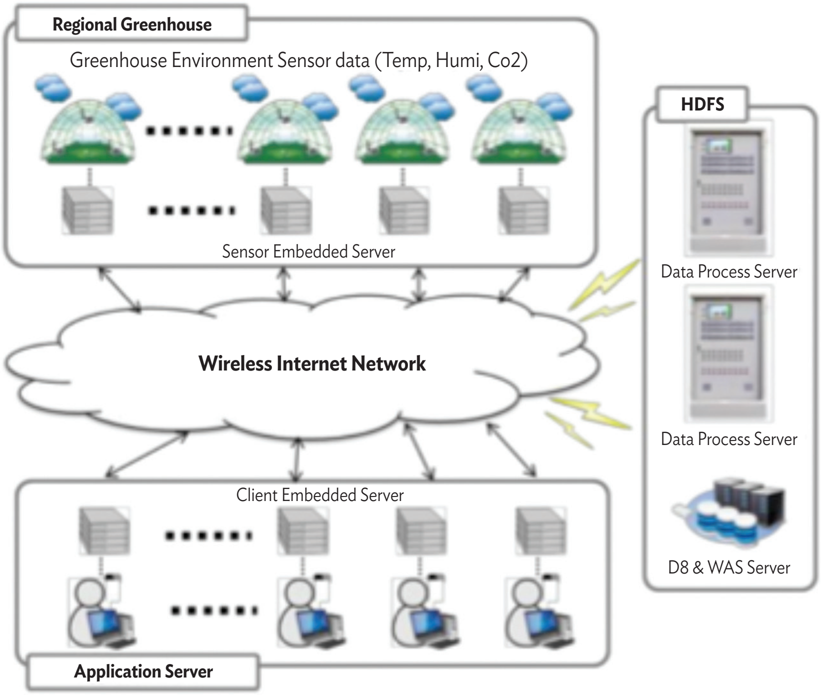
As ICT plays very important role in increasing agricultural production, priority should be given to this technology. ICT, combined with agriculture, has a big impact on productivity and can help countries against vulnerability to natural disasters, help farmers improve their productivity, and minimise risk.

Data-based Collecting System

The green environmental data consulting system to improve crop quality is presented in Figure 8. As described by Kim and Yoe (2015), the system is categorised into areas of data collecting, data saving and processing, and data analysis including visualisation.

In the data collecting area, environmental sensors gather greenhouse environmental information data that affect growth and development of greenhouse crops in each region such as temperature, humidity, illumination, carbon dioxide, etc. Collected data are managed by the embedded server and transmitted to greenhouses in each of the regions. The data saving and processing area consist of servers installed in each greenhouse, and in Hadoop Distributed File System, which stores and handles big data collected from the greenhouses in each of the regions. The data analysis and visualisation area works with a Web application that monitors a greenhouse environment in each of the regions while checking crop quality at the same time. The servers in greenhouses receive and process environment data in real time, and maximise storage and processing functions of HDFS. Environmental data from HDFS undergo separate storage and processing work. Through the Web application programme, a user is given regional environmental data information to enable him to, for example, understand proper temperatures for his crops.

Figure 8: Data Collection System



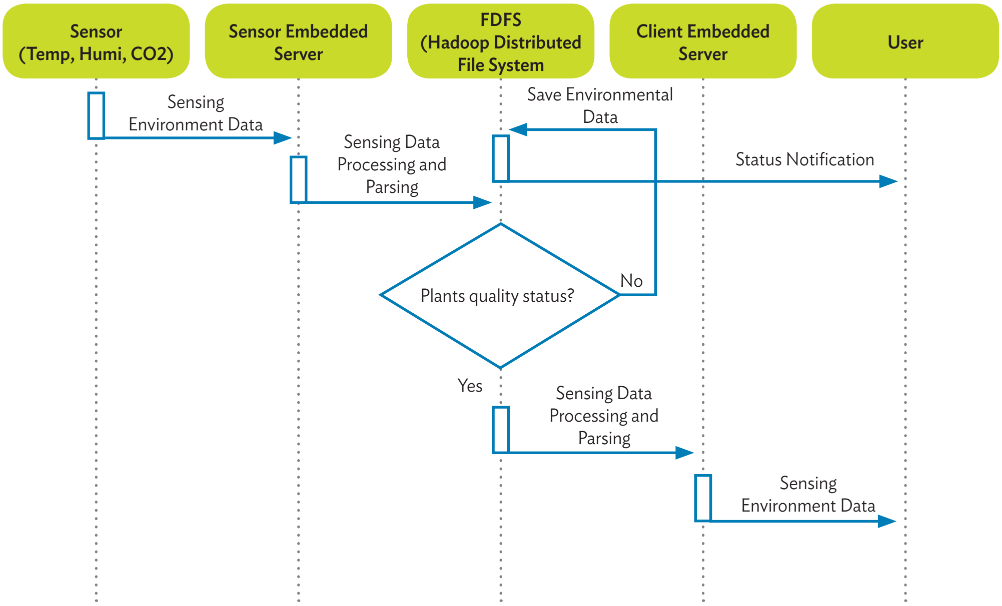
Source: Kim and Yoe, 2015.

Achieving Farming Practices

Plant factories and greenhouses are increasing in Korea due to climate changes such as unexpected heavy snow, heavy rains, and typhoons. Abnormally high and low temperatures and droughts often happen, causing shortage of food and rise in its prices. By providing suitable environmental condition, growth management can be performed using robot ICT. A plant factory using robotics produces crops of high added value in a planned way.

A flow chart of the proposed system is presented in Figure 9. Data collected by greenhouse environmental sensors are transmitted to servers in greenhouses, where they are processed before sending to HDFS. HDFS checks and analyses environmental information and conditions of crops and sends out results. When crops are in good condition as analysed, data are saved in the system. When crops look most satisfactory, the data are transmitted to a client server. The server delivers environmental data information to a user after properly processing the information to the latter's interface. The user takes care of one's greenhouse based on the transmitted data and again saves new data gathered in the greenhouse in HDFS (Kim and Yoe, 2015).

Figure 9: Flow Chart of the System Process



Source: Kim and Yoe, 2015.

Applied ICT and Smart Farm Development in Korea

The Korean smart farm project being promoted by Rural Development Administration aims to achieve optimum growth environment in horticulture and livestock production. The smart farm is an automatically controlled environment of greenhouses and animal houses using a combination of technology and information communication for agricultural management through remote control. Also, depending on the project, DEMETER would be used as climate model ensemble and to forecast seasonal climates. According to a study by the Ministry of Agriculture, Food and Rural Affairs, average production rose by 25% while production cost decreased by 27.2% after the introduction of smart farming. The ministry has vowed to invest W107.5 billion in research and development related to smart farming until 2021.

Korea aims to pursue the following technologies to reduce the vulnerability of agriculture: robot-based technology for agricultural and livestock production, state-of-the-art intelligent precision technology, eco-friendly smart plant factory technology, and integrated intelligent control system for agricultural irrigation.

Still, more innovations in technology for agriculture are urgently needed. The integration of agriculture technology is also likely to address the challenges of ageing farmers and attracting youth into the industry.

Summary

Climate change poses extreme risk to the potential of agricultural areas especially in tropical and subtropical regions. Although warming is projected to affect more areas of high latitudes than those of low latitudes, small increases of temperature in low-latitude areas may have a greater impact possibly because agriculture in these regions is already marginal. The increasing frequency of disaster events signifies climate change. In the last couple of decades, 78 natural disasters cost the agriculture sector of developing countries US$30 billion, with droughts causing the most loss and damage. Loss and damage to the food supply by disasters affect food supply chains that transform agriculture products into processed food for delivery to retailers or supermarkets.

Industrial agriculture relates to the development of technological innovations to increase productivity. Because it is seriously affected by climate change, it must seek several technologies to add efficiency such as the ICT system which plays role in overcoming losses by providing relevant and timely information and agricultural services, mapping agro-biodiversity in multiple cropping systems, forecasting disasters, and predicting yields. Yet, even if ICT plays a significant role in agricultural value chains, it has its limitations because of the high investments needed for it and the lack of experience of smallholder farms.

Discussion for Future Works

Protection from natural disaster events must consist of early warning systems through mobile devices and the Internet. It should provide detailed weather forecast for household and industrial farms. It should improve global and regional databases and information systems based on national data. The methodology for assessing impacts of natural disasters should be improved to better capture their full extent in agriculture and its subsectors, food value chains, food security, the environment, natural resources associated with the sector, and national economies. Precision is critical in formulating well-tailored policies and investments in the sector. Moreover, the agricultural disaster insurance, which functions as a risk-management tool in creating favourable farm conditions and achieving economic stability of household farms affected by natural disasters, should be revised for smart farms to reduce the high investment required.

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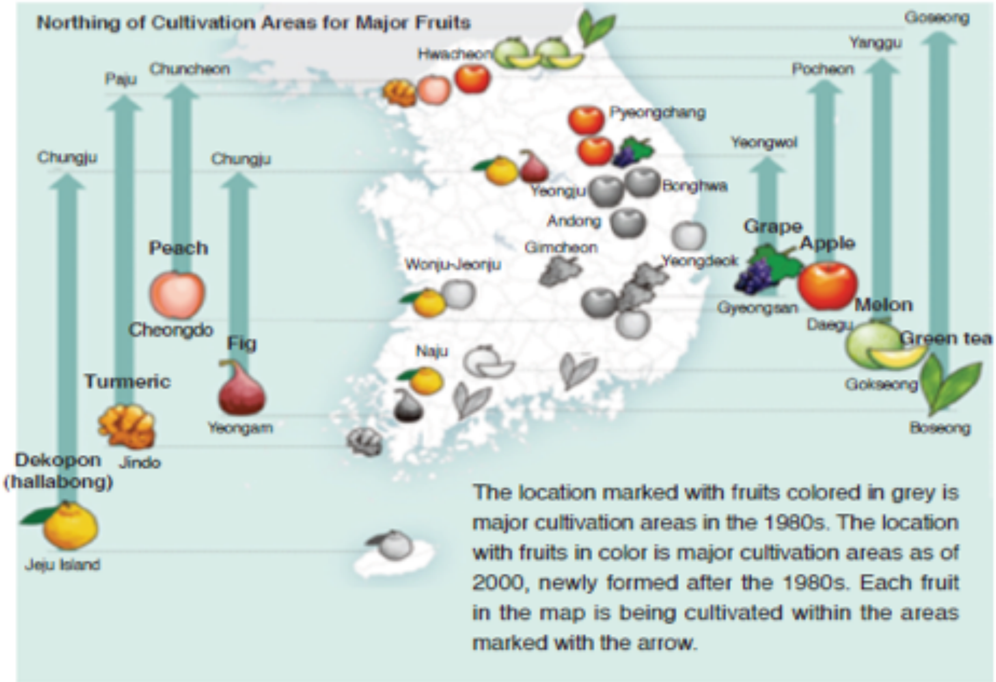

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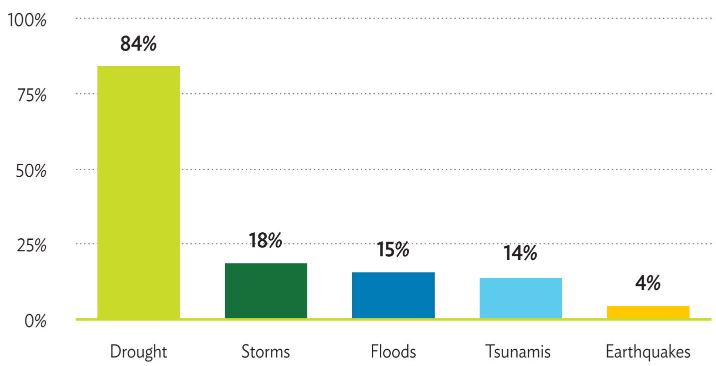

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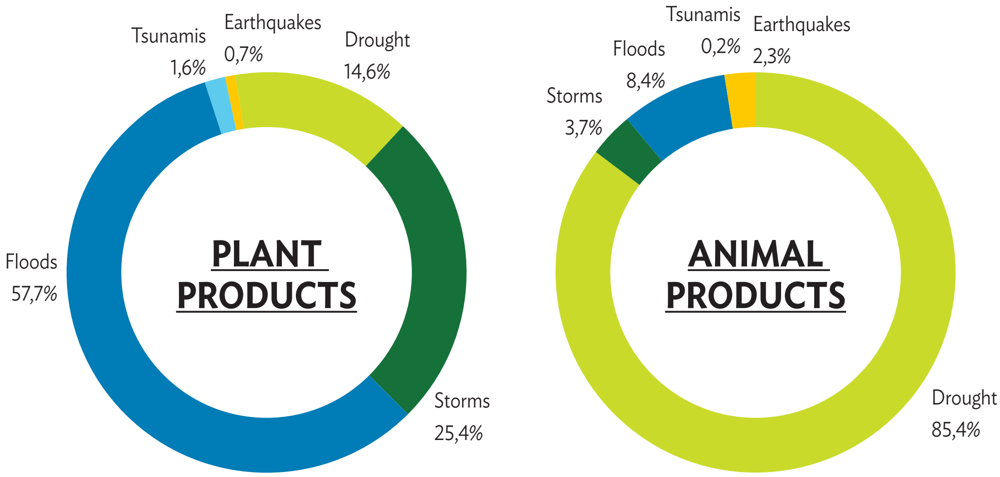

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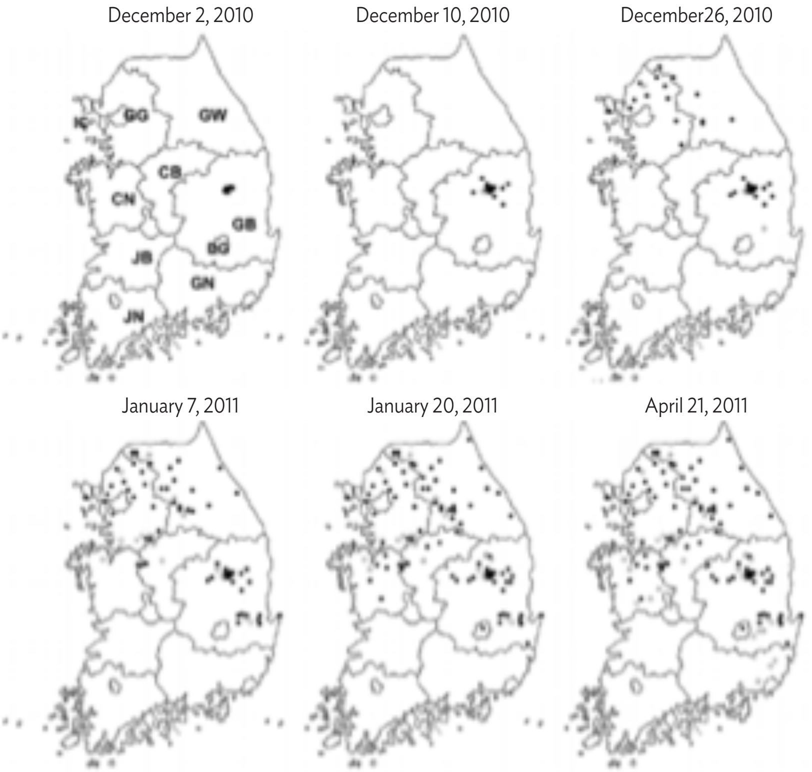

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The industrial system for agricultural production network is created to provide sustainable food security and to ensure a healthy life for present and future generations. However, recent climate change situations have created various impacts on agricultural production networks especially on initial farm-level production networks. More than 80% of loss and damage was caused by droughts and floods (FAO, 2015b), mainly involving reduction and loss of crops and livestock. For food supply chain (Figure 6), insufficient raw materials and price variables affect industrial agricultural production, which needs increased investment to be able to provide raw materials into food supply chain to be transformed as agriculture products in food processing for delivery to retailers or supermarkets. At the same time, a producer in food processing must realize return profit to his investment by determining proper prices for the consumer. For instance, cereal prices in Southeast Asia are likely to rise up to 30% if mean temperatures change in the range of 5.5oC (Easterling, 2007) which will lead to a decline in crop yields. This issue can be a reason to import

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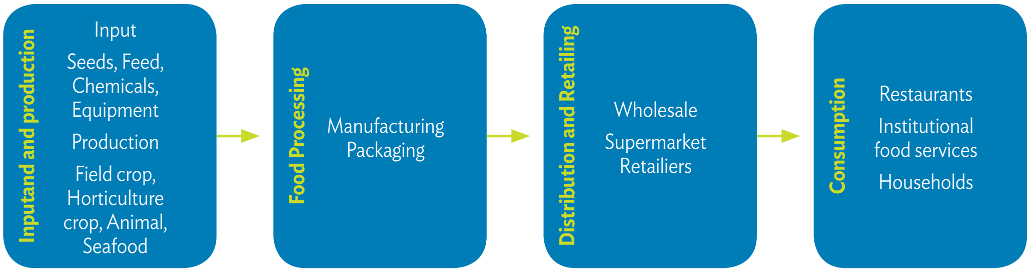

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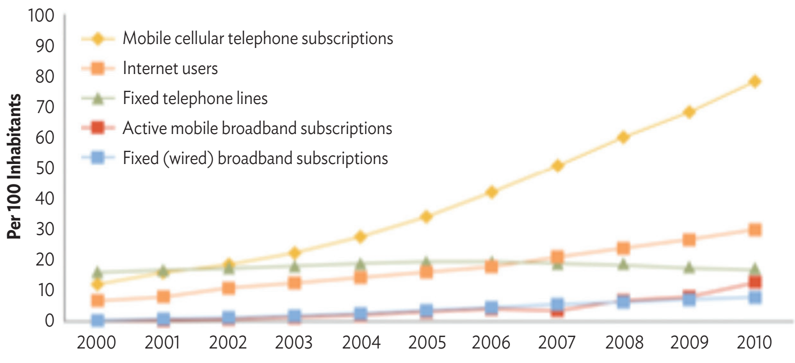

Source: International Telecommunications Union's world Telecommunication/ICT indicators base 2016.

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As ICT plays very important role in increasing agricultural production, priority should be given to this technology. ICT, combined with agriculture, has a big impact on productivity and can help countries against vulnerability to natural disasters, help farmers improve their productivity, and minimise risk.

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The green environmental data consulting system to improve crop quality is presented in Figure 8. As described by Kim and Yoe (2015), the system is categorised into areas of data collecting, data saving and processing, and data analysis including visualisation.

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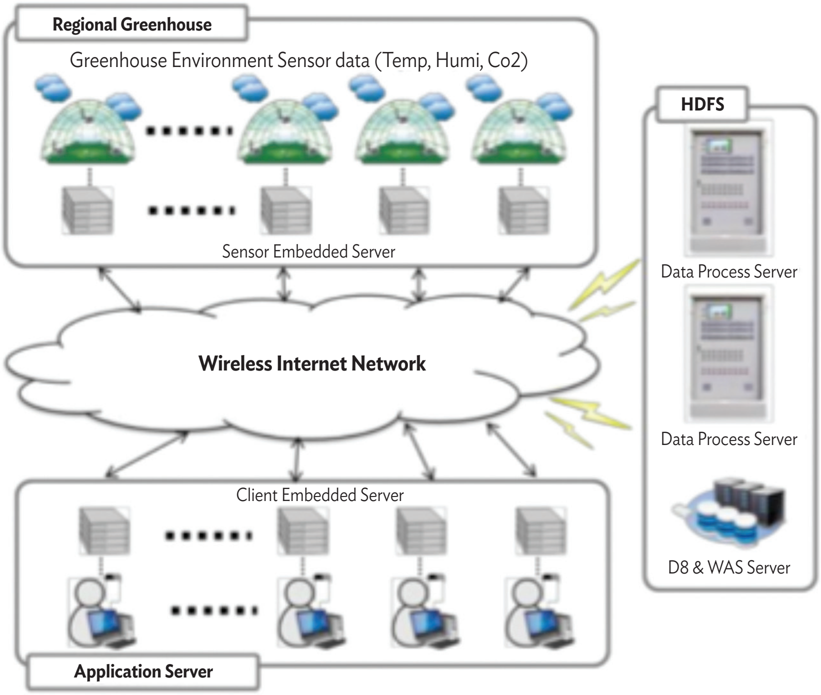

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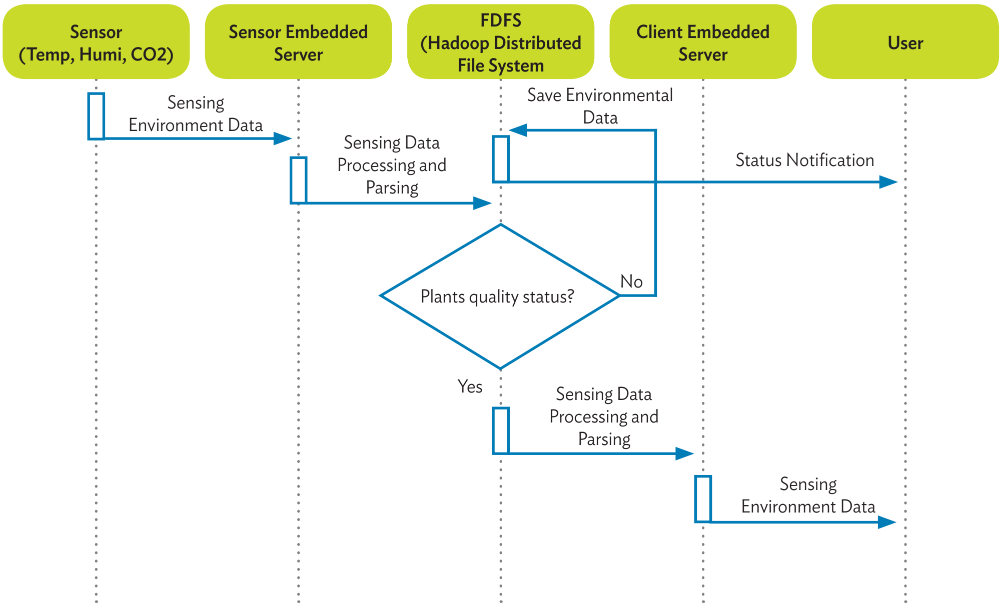

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Industrial agriculture relates to the development of technological innovations to increase productivity. Because it is seriously affected by climate change, it must seek several technologies to add efficiency such as the ICT system which plays role in overcoming losses by providing relevant and timely information and agricultural services, mapping agro-biodiversity in multiple cropping systems, forecasting disasters, and predicting yields. Yet, even if ICT plays a significant role in agricultural value chains, it has its limitations because of the high investments needed for it and the lack of experience of smallholder farms.

Discussion for Future Works

Protection from natural disaster events must consist of early warning systems through mobile devices and the Internet. It should provide detailed weather forecast for household and industrial farms. It should improve global and regional databases and information systems based on national data. The methodology for assessing impacts of natural disasters should be improved to better capture their full extent in agriculture and its subsectors, food value chains, food security, the environment, natural resources associated with the sector, and national economies. Precision is critical in formulating well-tailored policies and investments in the sector. Moreover, the agricultural disaster insurance, which functions as a risk-management tool in creating favourable farm conditions and achieving economic stability of household farms affected by natural disasters, should be revised for smart farms to reduce the high investment required.

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CHAPTER 10

BIO-INDUSTRIAL AGRICULTURAL PRODUCTION NETWORKS AND ROBUSTNESS AGAINST DISASTERS: THE ROLES OF INFORMATION AND COMMUNICATIONS TECHNOLOGY IN INDUSTRIAL AGRICULTURAL PRODUCTION IN THE REPUBLIC OF KOREA

Hyeon Tae Kim, Malinee Phonsuwan, Byeong Eun Moon, Waqas Qasim
Department of Bio-industrial Machinery Engineering, Gyeongsang National University, Korea

Introduction

Over the past 150 years, the global average surface temperature has increased by 0.76°C (IPCC, 2007) and has caused greater climatic volatility such as changed precipitation patterns or increased frequency and intensity of extreme weather events including typhoons, heavy rainfalls, floodings, and droughts. Although the agricultural sector continually adapts to climate change through changes in crop rotations, planting times, genetic selection, fertiliser management, pest management, water management, and shifts in areas of crop production, it needs effective information on important environment factors that can be used for warning and preventing adverse impacts of climate change. In particular, industrial agricultural production requires monitoring for a secure production and control of food safety standards.

In 2015, there were 1,237,000 farm, forest, and fishery households in the Republic of Korea with 2,924,000 dependent persons (Statistics Korea, 2016). Compared to the previous agricultural census in 2010, this was a reduction of 7.6% in the number of households and a 16.4% reduction in the number of the primary sector population. Out of 10,027 ha of total land area, 1,711 ha are used for cultivation and food production (KREI, 2015). The average Korean farm size is 1.4 ha, very small compared to those of

other highly industrialised countries. The income of the agricultural population is less than 80% of the national average. The farming population is ageing, with 37.8% over 65 years old in 2015.

Information and communications technology (ICT) has played a role in supply chain management but is increasingly being included in farm management. Farmers can use ICTs to match cropping practices with climatic trends, use inputs and resourses environmentally and sustainably, and cope with threats to productivity. Indeed, ICT is gaining momentum as part of sustainable development, and environmental and climate change strategies. To achieve sustainable agricultural production, it can be used as a method in increasing crop yields, reducing water consumption, and increasing profits. ICT has been implemented in several risk areas in developing and developed countries although it has limited accessibility to poor farmers because of cost (WB, 2011). Many countries have strategies and targets to improve, develop, and optimise the use of this technology by reducing its accessibility limitations.

In this article, we deal with scenarios of climate change and significant impacts of natural disasters on Korea's agricultural production by focusing on the implementation of ICT.

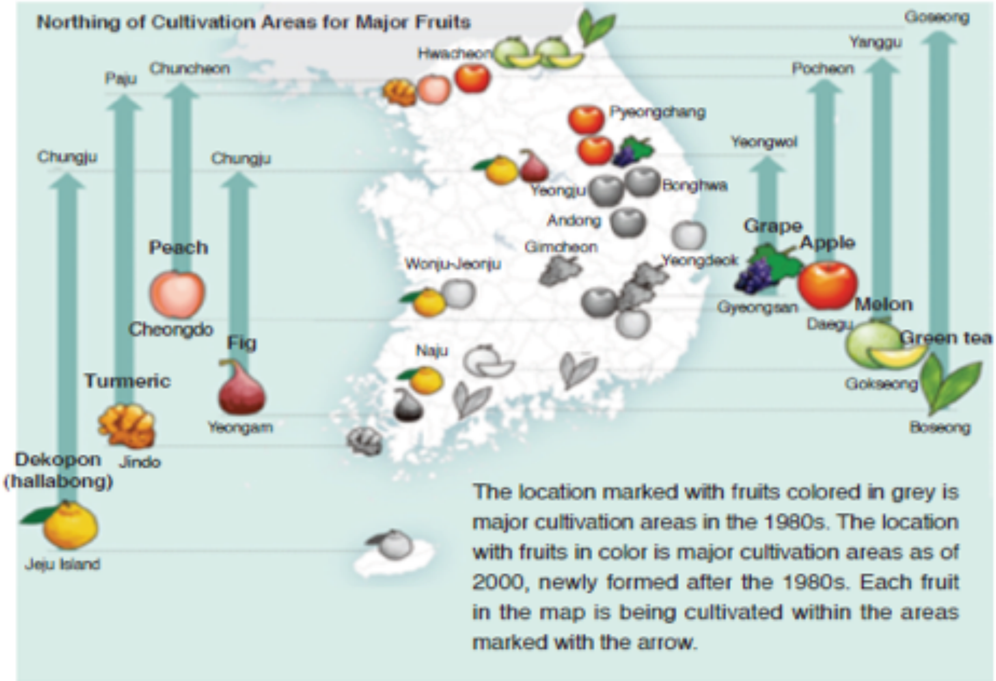
Scenarios on Climate Change and Occurrence of Disasters

According to the projections of Korea Meteorological Administration based on observation data accumulated over 30 years, the temperature in Korea will continuously increase until 2100. For instance, the current annual average temperature of the southern part of Jeju Island, located in the subtropical climate zone, is 16.7°C.

Climate change will affect major production areas. In 2013, the Future Digital Climate Map for Agriculture Use forecast changes in Korea's cultivation areas (Figure 1). Rice production, for instance, will fall to around 18.3% in 2050 due to increasing high temperature (KREI, 2015).

The total areas for apple cultivation will continuously decrease, while those for pear, peach, and grape will remain until the mid-21st century before they start to decrease. Conversely, cultivation-capable areas for sweet persimmon, tangerine, and subtropical crops will increase.

Figure 1: Changes in Suitable Cultivation Areas for Major Crops as Induced by Climate Change

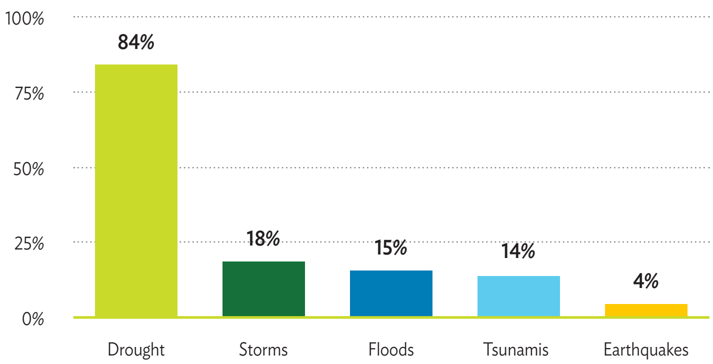


Source: Rural Development Administration, 2015.

Loss and Damage to Agricultural Production

Over the last three decades, there has been a rising trend in the occurrence of natural disasters worldwide, particularly climatological events such as droughts, hydrological events like floods, and meteorological events such as storms. The increase in weather-related events is of significant concern to the agriculture sector given its dependence on climate (FAO, 2015b).

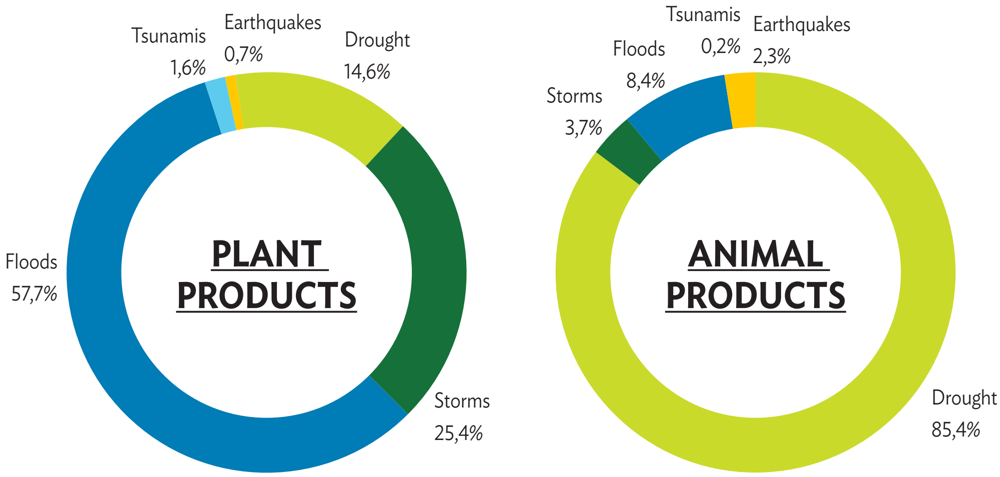
Figure 2: Kinds of Natural Disasters



Source: FAO, 2015b

The Food and Agriculture Organization (FAO) (2015a) found that from 2003 to 2013, natural hazards and disasters in developing countries affected more than 1.9 billion people and caused over US$494 billion in estimated damage. Moreover, FAO's findings show that the 78 disasters caused a total of US$30 billion in loss and damage to the agriculture sector. As illustrated in Figure 3, the relationship between drought and agriculture is particularly important as 84% of the loss and damage caused by droughts is to agriculture (FAO, 2015b). Moreover, total loss and damage to the crop sub-sector amounted to about US$13 billion, almost 60% of which were caused by floods, followed by storms with 25%. Livestock is the second most affected sub-sector, accounting for US$11 billion or 36%. A total of 67 developing countries were affected by at least one medium to large natural disaster between 2003 and 2013, causing crop and livestock production losses amounting to US$70 billion. Damage and loss to crop and livestock production caused by droughts and floods amounted to 44% and 39%, respectively (FAO, 2015a).

Figure 3: Loss and Damage to Agriculture Subsectors by Type of Hazard



Source: FAO, 2015b

Different types of disasters have different impacts on each subsector, as illustrated in Figure 4. Crops tend to be most affected by floods and storms, accounting for an estimated 83% of economic impact on the sub-sector. Livestock is overwhelmingly affected by droughts, causing nearly 86% of all loss and damage to the sub-sector (FAO, 2015b).

Understanding these differences is critical in the formulation of policies and practices at national, sub-national, and community levels. Disaggregated sub-sectoral data on disaster impact are needed to support the implementation of innovative risk management

tools, such as weather risk insurance schemes for agriculture and rural livelihoods. Systematic and coherent data availability will facilitate the design of insurance schemes, which would help further diversify risk-mitigation strategies.

The Republic of Korea is seriously affected by climate change such as changes in temperature, rainfall patterns, increase in extreme weather events including floods and droughts, and occurence of easily spreading diseases which affect agricultural production and people's livelihoods. Natural disasters have significantly contributed to unstable domestic agricultural production and food supply in the country. Natural disasters in Korea increased from 48 cases in 1910 to 190 cases in 1990.

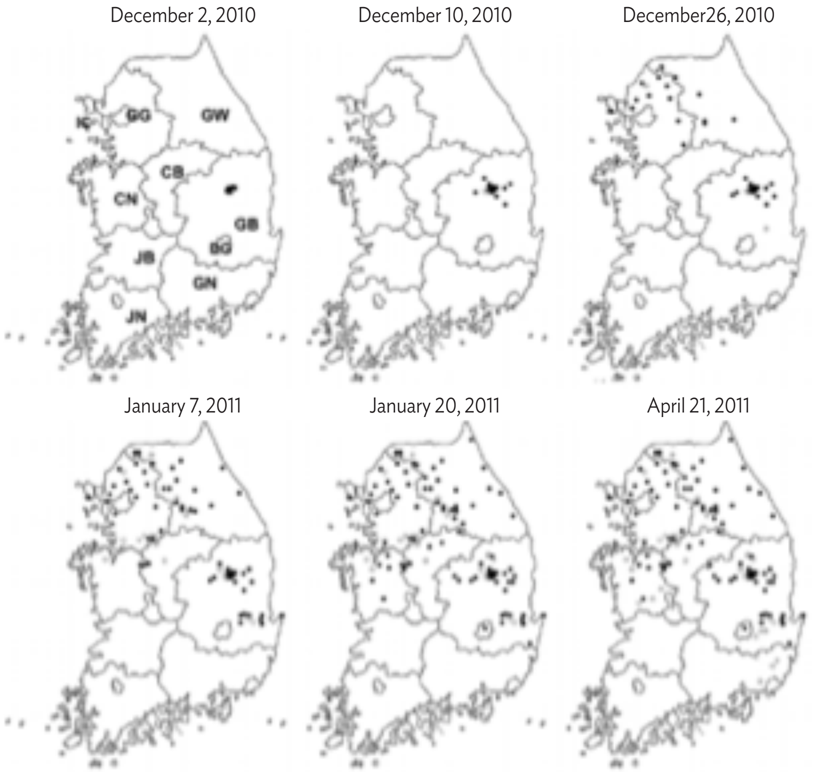
Table 1: Natural Disasters in Korea (1981–2016)

Natural Disasters	Range of Years	Impacts
East Asia cold wave	January 2016	Temperatures in Seoul fell to -18°C (0°F), the lowest in 15 years.
Drought in Korea	June 2015	Soyang Lake completely evaporated
Typhoon Chan-hom	2015	Rainfall and wind
Korea floods	July 2011, August 2014	Heavy rainfall, flash floods, and landslides
Typhoons	1981–2012	Rainfall and wind
Foot-and-mouth disease	November 2010–April 2011	Effect on livestock
Winter storms in East Asia	May 2009–February 2010	Blizzard and heavy snow

Source: Wikipedia, 2016.

An outbreak of foot-and-mouth disease (FMD) in Korea in November 2010–April 2011 seriously affected the country's food supply chain which could not respond to domestic consumption demand. The economic losses amounted to approximately US$1.7 billion. Consequently, market prices of meat were increased to control and manage the situation while at the same time introducing the use of technologies, improved breeds, and more intensive production systems, and consequently taking market opportunities at local, national, and international levels. The government imposed quarantines and initiated a vaccination campaign that targeted nine million swines and three million heads of cattle while culling 2.2 million livestock. The overall cost of this effort was estimated at US$1.6 billion. After vaccination and culling were implemented, the number of daily FMD cases decreased gradually. Amongst cattle, the number of FMD cases began to decrease 40 days after the initial outbreak (12 days after the first cattle vaccinations). In swines, the number decreased 60 days after (18 days after the first swine vaccinations) (Park et al., 2013) (online Technical Appendix Figure 5).

Figure 5: **Progress of Foot-and-mouth Disease Transmission Throughout Korea During 2010–2011 Outbreak**



Note: Circles indicate swine cases in index farms; black dots, cases in cattle. A timeline of case detection is provided in online Technical Appendix.
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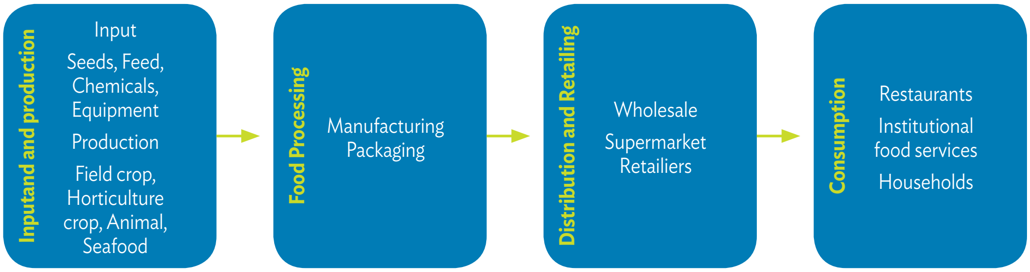

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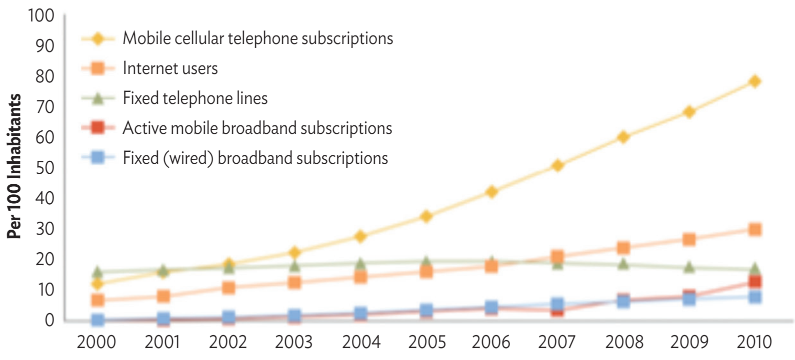

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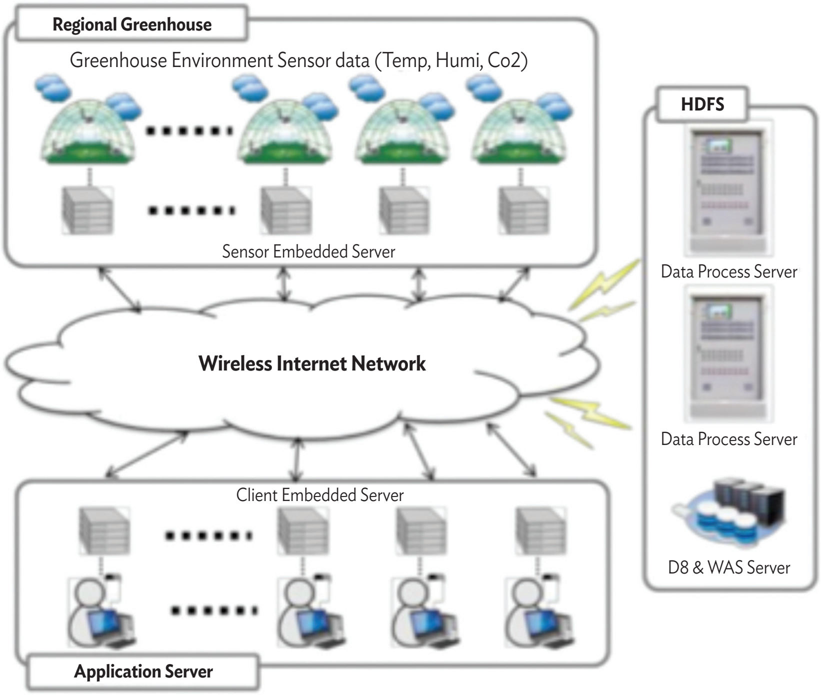

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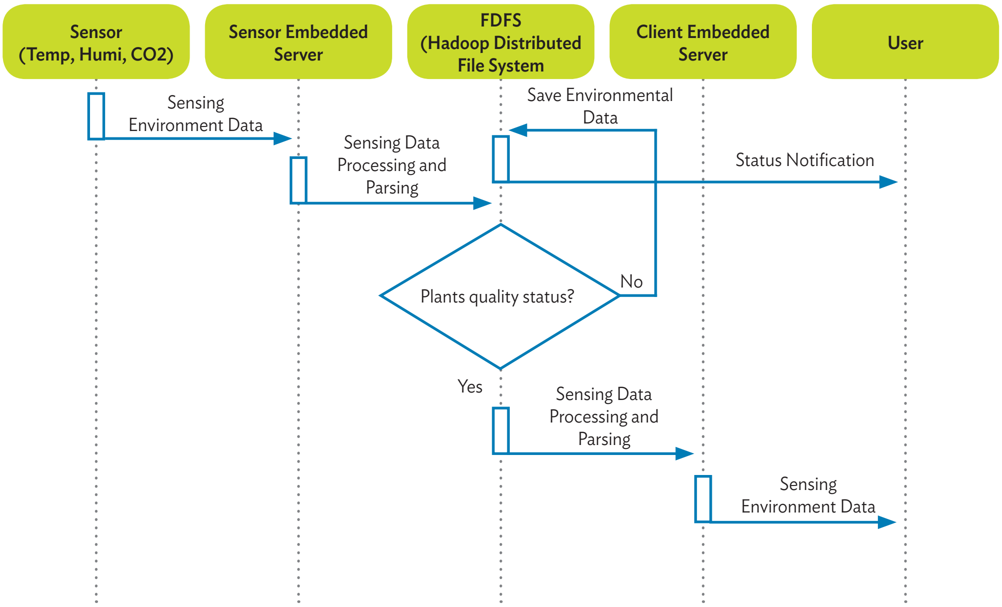

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