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Building a Climate Change-Resilient Food System in Korea

The Case of Extension and Technology Dissemination Services

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INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

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ABSTRACT

Climate change affects various stages of the food system including production, processing, distribution, and consumption. To cope with this vulnerability, many nations have engaged in a global movement to establish strategies aimed at food security. As in other countries, in the Republic of Korea climate change has had, and will continue to have, a significant influence on the food system, creating many uncertainties. In response, the Korean government and relevant agencies under national strategies have implemented various policy measures and programs to respond to the effects of climate change and strengthen the country's food resiliency. In this paper we examine those strategies, measures, and specific programs, and in particular those that involve agricultural extension and technology dissemination. These various sector-specific or cross-sector strategies have not only counteracted climate change impacts but also improved the incomes of farming households, who have struggled with import competition and low profitability under Korea's generally slowing economy. The Korean government has also implemented extension and tech dissemination projects in and with developing countries with the aim of building resilient food systems in the era of climate change. We find that such programs would benefit from the formation and maintenance of international networks, and moreover, each international program must be preceded by a thorough needs assessment that takes into account the regional context and each project should promote appropriate technologies—that is, technologies customized or particularly suited to the local context.

Keywords: climate-resilient food system, climate change, extension and technology dissemination services, Republic of Korea, smallholder farmers, information and communications technology

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ABBREVIATIONS

AFACI	Asian Food and Agriculture Cooperation Initiative
ATC	agriculture training center
CERES	Crop Estimation through Resource and Environment Synthesis
CSA	Climate smart agriculture
DEEP	Development Experience Exchange Program
GDP	Gross domestic product
GHG	Greenhouse gas
HACCP	Hazard analysis and critical control points
ICT	Information and communication technology
IFPRI	International Food Policy Research Institute
IPCC	Intergovernmental Panel on Climate Change
JARES	Jeonnam Agricultural Research and Extension Services
KAFACI	Korea–Africa Food and Agriculture Cooperation Initiative
KAPEX	Korean Agricultural Policy Experience for Food Security
KMA	Korea Meteorological Administration
KOPIA	Korea Program on International Agriculture
KRW	Korean won
MAFRA	Ministry of Agriculture, Food, and Rural Affairs
MOTIVE	Model of Targeted Impact and Vulnerability Evaluation
NCPMS	National Crop Pest Management System
ODA	official development assistance
RCP	Representative Concentration Pathway
RDA	Rural Development Administration
SNS	social networking service
WTP	willingness to pay

1. Introduction

With the introduction of the Sustainable Development Goals, building the resilience of rural communities, and in particular farmers in vulnerable regions, has become a priority for national and worldwide socioeconomic development. According to Davis, Babu, and Blom (2014), extension and advisory services may be able to rectify the information asymmetry, or knowledge inequality, caused by climate shocks and weather-related disasters by providing or facilitating access to a variety of assets including human, natural, economic/financial, and physical assets, as well as social capital. This report is a case study of how the government of the Republic of Korea is responding to the effects of climate change with policy measures, particularly those related to agricultural extension and technology dissemination services.

Climate change is a global issue that affects the world's food systems in numerous ways. According to the Intergovernmental Panel on Climate Change (IPCC 2001), climate change not only affects average temperatures but also influences extreme climate events, increasing the likelihood of weather-related natural disasters. Indicating that it is not a temporary phenomenon, the IPCC (2013) declared that each of the last three decades has been successively warmer at the Earth's surface than any preceding decade since 1850 and, in the Northern Hemisphere, the duration from 1983 to 2012 was likely the warmest 30-year period of the last 1,400 years. Climate change affects various stages of the food system including production, processing, distribution, and consumption. Hence, to cope with this vulnerability, various countries are involved in a global movement to establish strategies related to food security.

The Republic of Korea (hereinafter referred to as "Korea") is no exception. As in other countries, climate change has had, and will continue to have, a significant influence on the food system in Korea, introducing great uncertainty. To deal with the situation, the Korean government and relevant agencies under national strategies have implemented various policy measures and programs to strengthen food resiliency. For instance, to raise climate change awareness and the adaptive capacity of farmers, the government and its agencies have implemented numerous agricultural extension and technology dissemination services. But still more efforts are required to bring climate change issues into the mainstream and improve accessibility to information for all the potential beneficiaries.

We first examine the status of climate change in the context of Korea and the impact of such change on the country's food system. Next we describe the strategies, policy measures, and detailed programs Korea has implemented to manage climate change impacts and build a climate-resilient food system, focusing on extension and technology dissemination services. We conclude with a discussion of implications for Korea and other developing countries.

2. Climate Change in Korea

Climate Change Trends in Korea

Korea is located in the temperate climate zone of the Far East in the Northern Hemisphere and has four distinct seasons. During the 1981–2010 period, the annual average temperature on the Korean Peninsula (including the Republic of Korea and the Democratic People's Republic of Korea) increased 1.2 degrees Celsius (°C).[1] This rising temperature trend is more obvious during the fall and winter seasons (Table 1).

Table 1: Decadal trend of average temperature on the Korean Peninsula, 1981–2010

Unit value: °C/decade

	Year	**Spring**	**Summer**	**Fall**	**Winter**
Korean Peninsula	0.41**	0.25	0.24	0.49**	0.56**
Republic of Korea	0.36**	0.23	0.11	0.43**	0.57*
Democratic People's Republic of Korea	0.45**	0.28	0.39	0.52**	0.47

Source: KMA (2017).

* $p < 0.1$. ** $p < 0.05$.

Compared with annual precipitation in 1981, by 2010 annual precipitation on the Korean Peninsula had increased by 3.4 percent (77.6 millimeters). But given the fluctuation during the period, we cannot define this as a continuous and significant rising trend, except for the increasing trend during the summer season (55.20 millimeters/10 years).

Table 2: Decadal trend of average precipitation on the Korean Peninsula, 1981–2010

Unit value: millimeters/decade

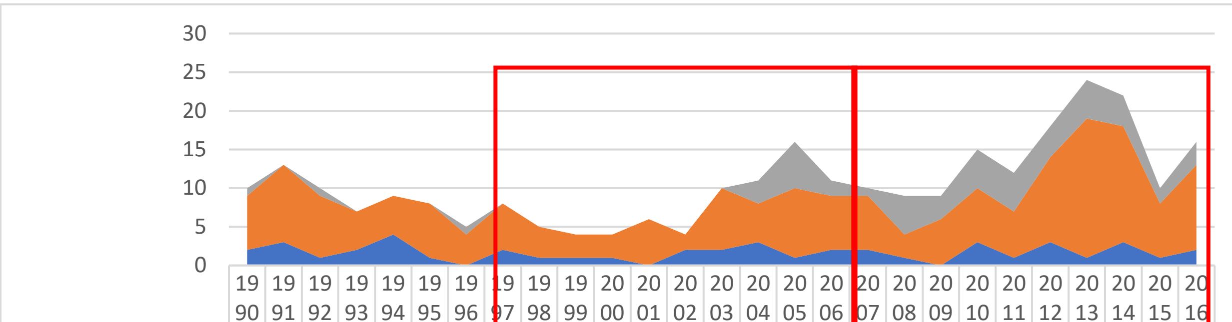
	Year	**Spring**	**Summer**	**Fall**	**Winter**
Korean Peninsula	25.87	10.34	28.07	-7.70	2.20
Republic of Korea	54.28	16.95	46.26	-11.85	1.99
Democratic People's Republic of Korea	-25.19	-3.20	-5.54	-3.24	-1.40

Source: KMA (2017).

[1] Over the 1981–2010 period, the annual average temperature of the Republic of Korea increased by 1.08°C, while that of the Democratic People's Republic of Korea increased by 1.35°C.

After 1990, as the frequency of extreme weather events has increased, the amount of damage has increased accordingly. Whereas from 1997 to 2006, Korea experienced an average of 1.5 typhoons, 5.3 occurrences of heavy rainfall, and 1.1 occurrences of heavy snowfall per year, from 2007 to 2016 the country experienced an annual average of 1.7 typhoons, 9.1 occurrences of heavy rainfall, and 3.7 occurrences of heavy snowfall (Figure 1). As a result of the damage wrought by these natural disasters, approximately 1,050 billion Korean won (KRW) (about 12 percent of national GDP) was spent on average each year from 1991 to 2000, while 2,418 billion KRW (approximately 20 percent of national GDP) was spent each year from 2001 to 2010 (Figure 2).

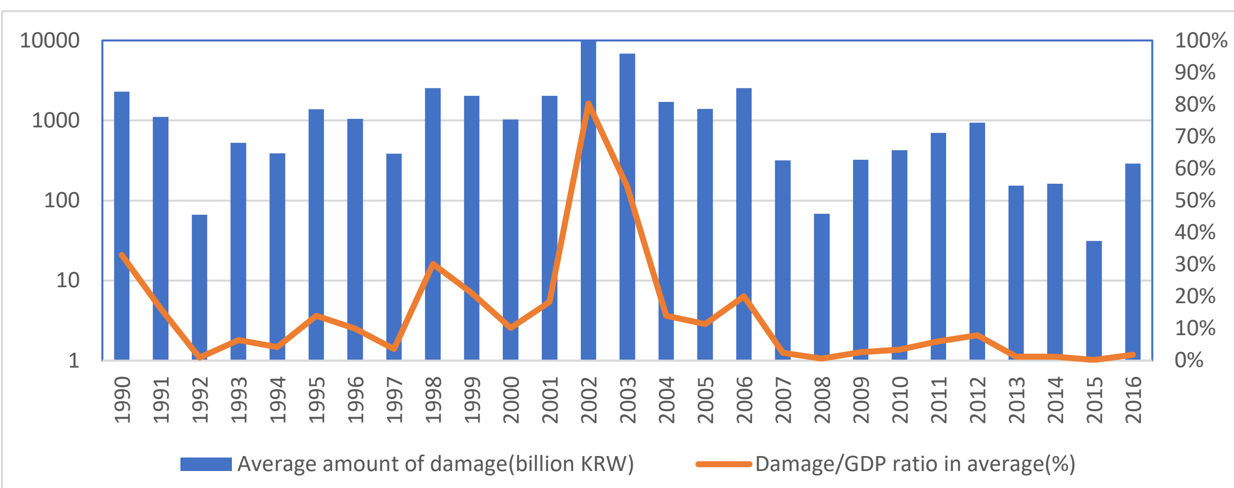
Figure 1: Number of natural disaster occurrences in Korea, 1990–2016



	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Heavy Snowfall	1	0	1	0	0	0	1	0	0	0	0	0	0	0	3	6	2	1	5	3	5	5	4	5	4	2	3
Heavy Rainfall	7	10	8	5	5	7	4	6	4	3	3	6	2	8	5	9	7	7	3	6	7	6	11	18	15	7	11
Typhoon	2	3	1	2	4	1	0	2	1	1	1	0	2	2	3	1	2	2	1	0	3	1	3	1	3	1	2

Source: K Indicator website (http://www.index.go.kr/).

Figure 2: Annual amount of damage caused by natural disasters and the damage-to-GDP ratio, 1990–2016



Source: K Indicator website (http://www.index.go.kr/).

Furthermore, according to the Representative Concentration Pathway (RCP) scenarios suggested in the IPCC's Fifth Assessment Report,[2] Korea might have a higher rate of increase in temperature and precipitation compared with the global average level. According to both RCP 2.6 and 6.0, the increased levels of temperature and precipitation in Korea are projected to exceed the global levels, indicating that Korea will be more exposed to and affected by climate change impacts in the future.

Table 3: Climate change projections for the year 2100 by RCP scenario, Korea and global levels

	Korea	**Global**
RCP 2.6[a]		
Temperature increase (℃)	+1.8℃	+1.3℃
Precipitation increase (%)	+5.5%	+2.4%
RCP 6.0[b]		
Temperature increase (℃)	+3.0℃	+2.7℃
Precipitation increase (%)	+6.8%	+3.6%

Source: KMA (2017).

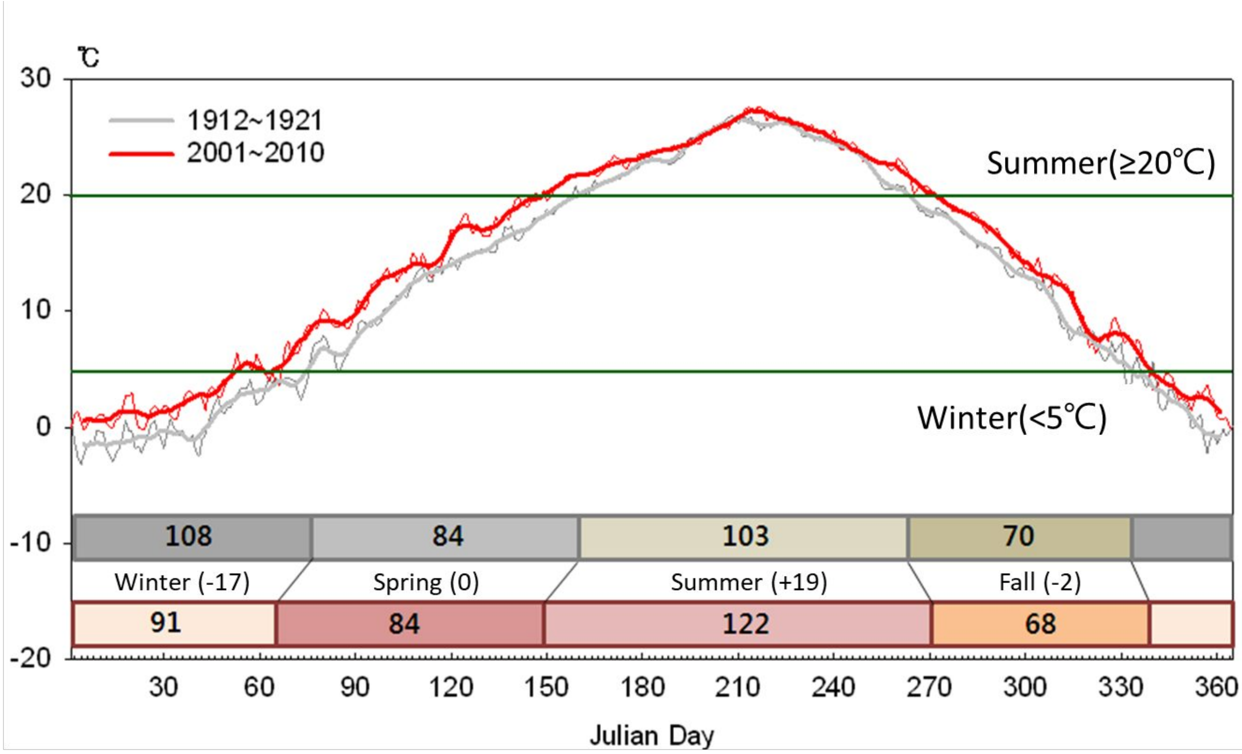
[a] Representative concentration pathway (RCP) 2.6: Climate change scenario that assumes that the human influence of global greenhouse gas (GHG) emissions can be recovered by the Earth itself, which is almost impossible to be attained (atmospheric concentration of CO_2 in the year 2100 = 420 parts per million [ppm]).

[b] RCP 6.0: Climate change scenario that assumes the application of technologies and strategies for reducing GHG emissions to achieve intermediate emission level (atmospheric concentration of CO_2 in the year 2100 = 670 ppm).

The lengths of Korea's seasons have also changed. Compared with the 1910s, Korea now experiences longer summers (+19 days) and shorter winters (-17 days) and falls (-2 days). Also, as Figure 3 shows, spring and summer now arrive earlier while the arrivals of fall and winter are delayed compared with past records.

[2] The IPCC chose these RCPs to represent a broad range of climate outcomes. Four RCPs (RCP 2.6, RCP 4.5, RCP 6.0, and RCP 8.5) were selected and defined by their total radiative forcing (cumulative measure of human emissions of greenhouse gases from all sources expressed in watts per square meter) pathway and level by 2100. (Source: http://sedac.ipcc-data.org/ddc/ar5_scenario_process/RCPs.html).

Figure 3: Lengths of seasons in Korea, 1910s versus 2000s



	Spring	Summer	Fall	Winter
	Starting date of each season			
1912-1921	March 17th	June 9th	September 20th	November 29th
2001-2010	March 6th	May 29th	September 28th	December 5th
Difference (day)	-11	-11	+8	+6

Source: KMA (2011).

Regarding extreme climate indicators, according to the IPCC's global warming projections, the indicators related to extreme cold—such as the numbers of frost days, ice days, and cold wave days—are expected to decrease, while the indicators related to extreme heat—such as the numbers of summer days, heat wave days, and tropical night days—are expected to increase. Table 4 shows the estimated tendencies for several climate indicators in Korea under RCP 2.6 and RCP 6.0.

Table 4: Estimated tendencies of climate indicators in Korea, under RCP 2.6 and RCP 6.0

Indicators	**Current (1981–2010)**	**Early 21C (2021–2040)**		**Mid-21C (2041–2070)**		**Late 21C (2071–2100)**		**Tendency (per decade)**	
RCP scenario		2.6	6.0	2.6	6.0	2.6	6.0	2.6	6.0
Average temperature (℃)	12.5	13.9	13.2	14.2	(13.9)	14.2	(15.2)	0.19	(0.30)
Max. temperature (℃)	18.1	19.4	18.8	19.7	(19.5)	19.7	(20.8)	0.18	(0.30)
Min. temperature (℃)	7.7	9.2	8.5	9.4	(9.1)	9.4	(10.5)	0.19	(0.31)
Daily temperature range (℃)	10.4	10.2	10.3	10.3	(10.4)	10.3	(10.3)	-0.01	(-0.01)
Precipitation (mm)	1,307.7	1,416.8	1,346.0	1,397.1	(1,327.7)	1,393.9	(1,456.9)	9.58	(16.58)
Wind speed (m/s)	2.0	2.0	2.0	2.0	(2.0)	2.0	(2.0)	0.00	(0.00)
Relative humidity (%)	68.6	69.1	68.8	68.8	(68.6)	68.6	(68.9)	0.00	(0.03)
Heat wave (day)	10.1	11.2	11.1	13.4	(15.5)	12.7	(20.8)	0.29	(1.19)
Tropical nights (day)	3.8	7.0	5.5	11.4	(9.8)	9.9	(19.7)	0.68	(1.77)
Summer days (day)	111.4	129.8	(121.6)	137.1	(132.4)	135.8	(151.7)	2.71	(4.48)
Cold wave (day)	6.2	0.0	(4.0)	0.4	(1.6)	0.0	(0.0)	-0.69	(-0.69)
Ice day (day)	8.9	0.0	(3.8)	0.0	(0.0)	0.0	(0.0)	-0.99	(-0.99)
Frost day (day)	99.7	86.7	(91.9)	85.2	(87.5)	85.3	(75.1)	-1.60	(-2.73)
Plant-growing season (day)	272.0	285.7	(282.3)	287.2	(285.9)	286.5	(298.3)	0.96	(0.44)
Maximum length of dry spell (day)	29.5	28.5	(28.6)	30.9	(29.2)	31.2	(30.5)	0.19	(0.11)
Heavy precipitation (day)	2.3	2.5	(2.3)	2.5	(2.5)	2.5	(2.9)	0.02	(0.07)
Max. consecutive 5-day, precipitation (mm)	229.4	237.7	(227.1)	239.1	(254.3)	247.4	(279.7)	2.00	(5.59)
Precipitation intensity (mm/day)	16.3	16.9	(16.4)	17.0	(16.6)	17.1	(17.9)	0.09	(0.18)

Source: KMA (2017).

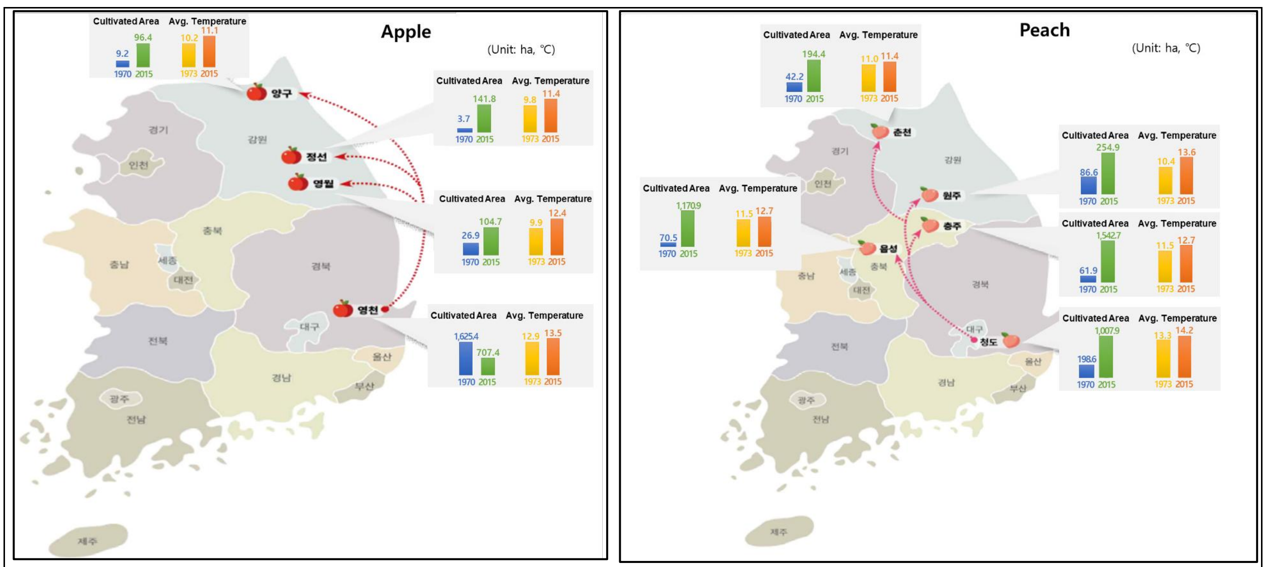
Note: RCP = Representative Concentration Pathway; 21C = 21st century; mm = millimeter; m/s = meters per second.

The preceding indicators and historical records prove that Korea is, and will be, faced with severe climate change impacts, underscoring that effective extension and technology dissemination services should be planned and implemented to raise farmers' awareness and coping capacity, which should create a more resilient food system in Korea.

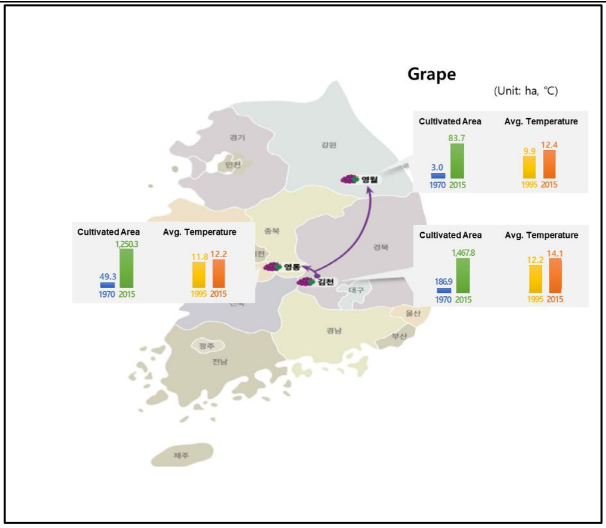
Impacts of Climate Change on the Korean Food System

A partial positive effect of climate change on Korea's agriculture is the introduction of new crop varieties due to an extended cultivation period. On the whole, however, the negative effects outweigh the positive ones (Kim and Im 2016). For instance, from the standpoint of agricultural production, there exist several emerging issues, such as agroclimatic zone shifting, decreased production, and the risk of foreign insects and pests. Suitable agroclimatic zones of major agricultural products in Korea have shifted north as shown below in figure 4 KMA (2018). Furthermore, according to the outlook of future shifting of agroclimatic zones under RCP 8.5, most regions in Korea, except Kangwon Province, will be transformed into subtropical regions and, naturally, the northerly shift of the agroclimatic zones will continue. This trend may constitute a new opportunity or a crisis, but it will cause significant changes in agricultural production in Korea.

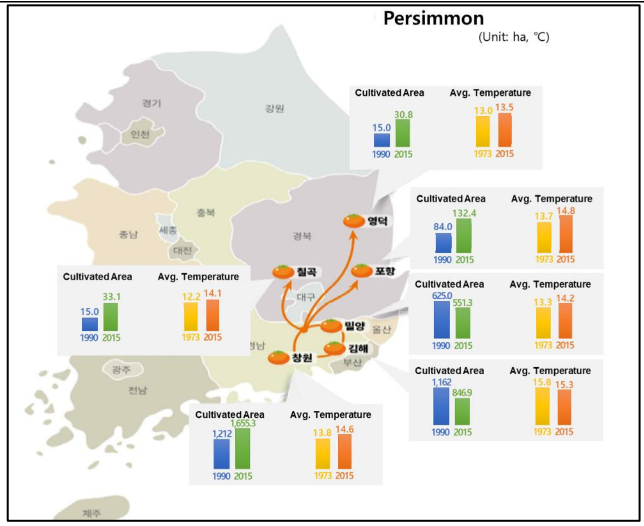
Figure 4: Map of agroclimatic zone shifting, six crops in Korea (1970–2015)



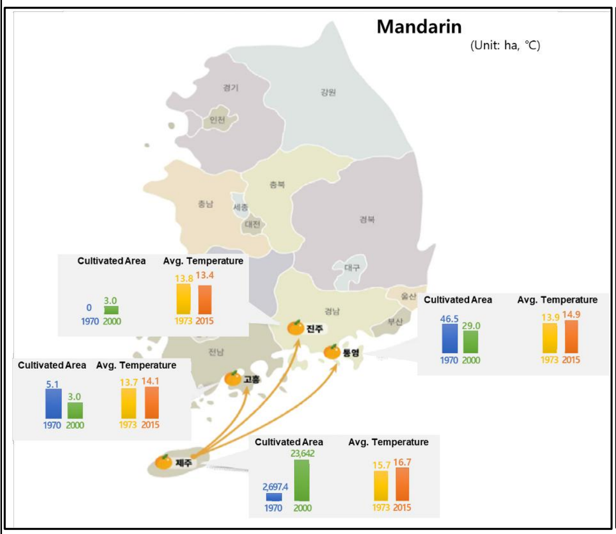
Apple Peach



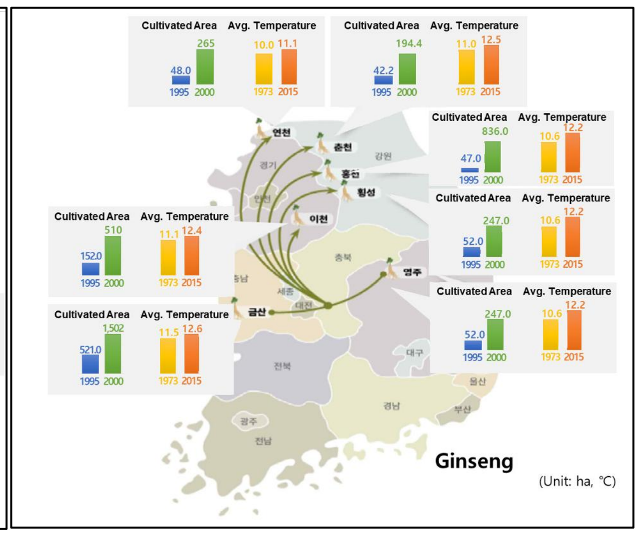
Grape



Persimmon



Mandarin



Ginseng

Source: KMA (2018).

Climate change is affecting Korea's rice production. A model analysis by Kim et al. (2012) reveals reduced yields and area under the IPCC's climate change scenario. According to the results, compared with the baseline, rice production will have fallen by 17.8 percent in 2050 under the RCP 8.5 (Crop Estimation through Resource and Environment Synthesis [CERES]) scenario, with soybean experiencing a 21.2 percent reduction and barley a 13.7 percent reduction under the A2 scenario (CERES). Korea's self-sufficiency ratio will also fall. Under RCP 8.5 (CERES), the estimated self-sufficiency ratio of the rice crop is 55.0 percent in 2050, which means Korea may have to depend on imported rice for almost half of its rice consumption. Considering that the Korean government has traditionally tried to protect the rice cultivation industry to secure the supply of the main staple food in Korea, this projection implies that climate change may trigger severe challenges in food security and sustainability in Korea.

Table 5: Simulation of production and self-sufficiency under climate change: rice, soybean, and barley

		Baseline	2010	2015	2020	2030	2040	2050
Rice: RCP 8.5 (CERES)	Cultivation area (1,000 ha)	917	892	836	825	726	613	501
	Yield (kg/10 ha)	498	482	502	492	473	453	433
	Production (1,000 ton)	4,516	4,295	4,195	4,062	3,429	2,776	2,168
	Import (1,000 ton)	297	327	409	409	970	1,344	1,779
	Self-sufficiency (%)	95.7	83.0	90.4	90.8	77.9	67.4	55.0
Soybean: A2 (CERES)	Cultivation area (1,000 ha)	82	71	73	78	82	85	87.5
	Yield (kg/10 ha)	164	147	165	163	158	154	151
	Production (1,000 ton)	125	105	121	126	131	131	132
	Import (1,000 ton)	1,401	1,473	1,729	1,746	1,765	1,784	1,804
	Self-sufficiency (%)	8.5	6.5	6.5	6.8	6.9	6.9	6.8
Barley A2 (CERES)	Cultivation area (1,000 ha)	47	39	24	21	17	12	8
	Yield (kg/10 ha)	286	211	290	276	258	251	243
	Production (1,000 ton)	129	81	69	59	43	31	19
	Import (1,000 ton)	166	153	196	200	204	204	203
	Self-sufficiency (%)	37.6	26.6	26.2	22.7	17.4	13.0	8.5

Source : Kim et. al (2012).
Note: Baseline data are calculated by the average from 2001 to 2011. RCP = Representative Concentration Pathway; CERES = Crop Estimation through Resource and Environment Synthesis.

Climate change also has affected Korea's livestock and forestry sectors. For instance, higher temperatures decrease livestock productivity and raise the possibility of animal disease and mortality. According to the Ministry of Agriculture, Food, and Rural Affairs (MAFRA 2011b), a rise in temperature from 28℃ to 32℃ will cause a 13.3 percent decrease in swine weight and a 58 percent increase in piglet mortality. With regard to the forestry sector, climate change impacts may change the composition of forest vegetation and increase the possibility of extreme events such as large forest fires and rainfall-triggered landslides. According to MAFRA's projections, if the average annual temperature increases by 2℃, the warm temperate zone will shift toward the Korea's central area, and a 4℃ increase will cause the forest in the southern coastal area to change into a subtropical climate zone.

In addition, as droughts and floods become severe and intense, this presents several difficulties for the water management sector. Korea has faced chronic drought stress during the winter and spring seasons since the 1990s. And typhoons and heavy rains during the summer season have brought continuous damage costs.

Regarding food processing and distribution, a changing climate brings an increased risk of food poisoning and increased food storage costs. According to Jung and Oh (2009), an 1℃ higher average monthly temperature raises the possibility of food poisoning by *Salmonella spp., Vibrio parahaemolyticus, and Staphylococcus aureus* by 47.8 percent, 19.2 percent, and 5.1 percent, respectively.

The addition of uncertainty and risk to the food production, processing, and distribution process that we have discussed in this section would inevitably bring about increases in food prices and inaccessibility, which would limit customers' choices in the market. Considering the low levels of food self-sufficiency in Korea,[3] the unstable trend seen in recent world grain prices could prove to be an extra burden for national food safety.

Climate change also affects the rural society and economy. During the 2007–2011 period, Korea suffered 65 natural disasters that caused 1.1 trillion KRW of damage to the agriculture and fisheries sectors. That cost is expected to increase in the future with the expanding climate change impacts. According to Chae et al.'s (2012) projection, the economic cost to the Korean food industry attributable to climate change is expected to be around 296 billion KRW in 2050 and 613 billion KRW in 2100. Also, if the annual average temperature increases by 1℃, farmland prices would likely decrease by 5.7 to 7.5 percent per hectare and gross agriculture income would likely decrease by 15 to 23 percent (Kim et al. 2009). In short, the impacts of climate change could accelerate and intensify crises experienced by vulnerable and at-risk rural communities.

[3] Except for rice (with a self-sufficiency rate of 104.7 percent), food self-sufficiency rates in Korea have decreased over the past 10 years. In 2016, the grain self-sufficiency rate was 50.9 percent (7.1 percent lower than 1997's rate) while the meat self-sufficiency rate was 68.0 percent (15.8 percent lower than the rate in 1997).

Climate Resilience in Korea's Food System

Although the food system includes the whole process from production to consumption, policy measures and treatments to promote a climate-resilient food system in Korea mainly focus on the production side. For instance, the country has established climate change impact monitoring and forecasting systems for the agriculture and fisheries production sectors. In particular, these systems include climate vulnerability mapping by each region and species, climate impact analysis and agroclimatic zone shifting forecasts for main crops, and the establishment of a real-time monitoring system for marine resources and fishing grounds in 28 coastal areas. Also, to build an accurate and highly utilized production forecast system, governmental agencies and national research institutes have put sustained effort into expanding the number of sample farm households, developing projection models, providing monthly (short-term) and preliminary (mid-term) observation papers on major vegetables, fruits, livestock products, and grains, and holding an annual outlook conference in each region.

In addition to the monitoring systems, efforts to develop and distribute climate-resilient species, facilities, and technologies are ongoing. For instance, species resistant to heat stress and disaster have been developed and distributed to farm households. Also, disaster-resistant standards for agricultural hardware facilities were developed based on accumulated regional climate data. As for climate-resilient infrastructure and facilities, anti-disaster greenhouses and smart farm systems using information and communications technology (ICT) were promoted nationally and disseminated to farmers. In the livestock sector, the country has seen the development of new technologies such as an electronic mapping system to map climate change impacts on livestock farming (2013–), a real-time monitoring system for the livestock farming environment (2012–2015), and climate-resilient technology for stable fodder production (2013–2015), in addition to the implementation of measures for the management and protection of marine production, such as impact analysis on acid oceans and the aquaculture industry (2011–2013) and the development of disease diagnosis and prevention technology for marine creatures. In addition to the aforementioned measures, the practice of intermittent irrigation with lower greenhouse gas (GHG) emissions, carbon-energy-saving infrastructure (including renewable energy facilities), and resource circulation facilities such as manure treatment plants also have been applied as mitigation measures for a resilient food system in Korea. Most of the efforts mentioned above are closely related to Korea's climate smart agriculture (CSA) technology, in the context of climate change adaptiveness, less GHG emissions, and higher productivity.

To manage foreign pests and diseases, a forecasting system of pest occurrences (12 types) was developed (2015) and techniques for the investigation, monitoring, and diagnosis of newly emerged livestock diseases were developed. Also, insurance programs for damages due to natural disasters were promoted for the sustainable risk management of producers.

With these efforts, we have seen some positive outcomes in Korea regarding the climate resilience of the food production sector. First, farmers' awareness about climate change's impacts and their countermeasures has increased. According to Kim et al. (2015), in 2015 82.8 percent of farmers answered that they are aware of climate change impacts, whereas only 76.9 percent had the same answer in 2009. Also, to the question of how climate change affects agriculture, 83.8 percent of the farmers answered that it affected it negatively in 2015, while 73.7 percent answered the same in 2009. Regarding whether farmers are taking counteractions toward the impacts of climate change, 20.1 percent of farmers answered that they are taking, or considering taking, measures to switch their crop to a climate-resilient one, followed by adjusting the sowing and harvesting season (14.1 percent), joining the disaster insurance program (13.7 percent), changing to another crop (13.6 percent), and using climate-adaptive pesticides and weed control (11.0 percent).

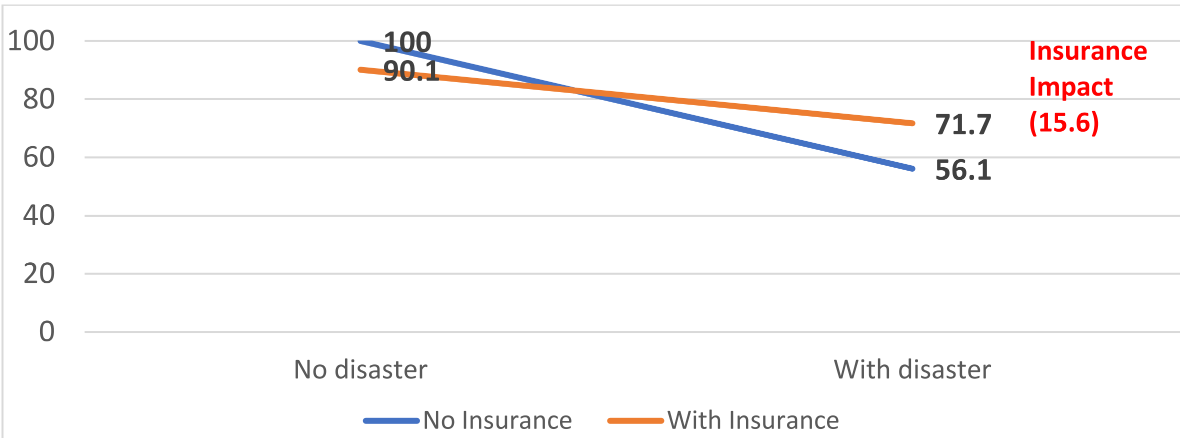
As for use of weather and climate change information, 77.7 percent of the respondents answered that they use climate change information for agricultural activities. Among those, 52.6 percent use information about abnormal weather events while 29.9 percent use information about the long-term trend of rising temperatures and 14.4 percent use information about increased precipitation. But still, 3.1 percent of the total respondents answered that they do not use climate change information because of such reasons as poor accessibility (30.8 percent) and absence of necessary data (30.8 percent).

Regarding crop switching, 51 percent of the respondents answered affirmatively citing that they have had experience of crop switching, and 89.5 percent of those had switched their crop type within the recent 10 years (2006–2015). Their main reason for switching was falling prices caused by the imbalance of market supply and demand (36.9 percent), but other reasons given, such as quality degradation and decreased yield caused by climate change (22.9 percent) and agroclimatic zone shifting (21.6 percent), indicate that around 44.5 percent of the farmers with crop-switching experience used crop switching as a countermeasure to climate change impacts. Also, the survey results show that the (central and regional) governmental supports induced 10.5 percent of farmers to change their crop, which means that the policy measures to disseminate resilient and efficient farming practices were effective at some level. In reality, almost half of all the respondents (45.9 percent) answered that they got the information about crop switching from a nationally operated agency like the Rural Development Administration or a regional agricultural technology center. Furthermore, the farmers who switched their crop had improved their income level in general. An interesting fact is that the farmers who changed their crop type as a countermeasure to climate change impacts had a greater rate of income growth (9.1 percent) compared with the average level of total respondents with crop-switching experience (7.7 percent). Also, this gap is more obvious when comparing groups of farmers who switched their crop before 2010: whereas the rate of income increase among total respondents who switched crops was 16.5 percent, the rate of income increase of the farmers who engaged in climate-resilient switching was 20.6 percent. These results indicate that switching to a climate-resilient crop has a greater positive impact on the rate of income growth compared with the other cases, and this impact can be accelerated with initial supports and investments for crop switching.

On the mitigation side, levels of GHG emissions from the agriculture sector have been reduced generally with CSA practices and climate-resilient infrastructure. For example, intermittent irrigation practices have contributed a 43.8 percent reduction of GHG emissions compared with the continuous flood system in the past. Also, green manure crop production practices have reduced GHG emissions by 65.6 percent compared with past practices. The energy-saving and renewable energy facilities were disseminated with a coverage of 9,804 hectares (2015), which already exceeds the original target mentioned in the national plan. Facilities for manure treatment have also been increased: 114 resource-recycling facilities and 10 energization facilities have been constructed nationwide. But according to Jung et al. (2016), only 36.3 percent of farmers report adopting CSA technology into their crop production. When asked about obstacles preventing adoption of CSA technology, the farmers cited “no merits on the price competitiveness,” “high initial investment cost,” and “more labor input.” But farmers have a positive outlook about the future potential of CSA technologies, considering that 45.9 percent of them said that the profitability of agricultural production with CSA technologies will increase in the future and 71.1 percent said they will adopt the new CSA technologies in the future. When asked about the main priority of the necessary policy measures, farmers answered with “incentive system like direct payment program” (28.6 percent), “initial cost supports” (19.2 percent),” and “sustainable channel for the distribution” (18.9 percent), concerns that are closely related to their answers about the obstacles they faced. We believe this indicates that further policy measures on CSA technologies should focus not only on the development of new technologies but also on the dissemination and promotion of real CSA practices with a proper incentive system.

Regarding the disaster insurance program, around 21.8 percent of the total farm households have joined the insurance program, which is high compared with 13.5 percent in 2011. Kim et al. (2015) formulated pre- and post-comparison charts on the impact of the insurance program derived from the answers of insurance applicants. If total agricultural income is 100 with no disaster, the applicants need to pay the insurance fee (9.9) and have 90.1 as their income. But comparing damage costs under a disaster scenario, the average damage costs the farmers with insurance incur is around 18.4, while the average damage cost for the farmers without insurance is around 43.9. As a result, the income gap under the disaster situation indicates the level of the insurance impact (15.6).

Figure 5: Comparison of relative income with and without insurance and with and without a disaster occurrence



Source: Kim et al. (2015).

Even though 67.8 percent of the insured farmers said that after joining the insurance program, they had less worries about fluctuating crop yields caused by abnormal climate events, 35.3 percent of the total respondents had a negative feeling about the insurance program, while 24.1 percent answered positively. Farmers who had not joined the insurance program answered they had not joined because of the "high insurance fee" (24.3 percent), "uninsurable category of cultivating crops" (21.9 percent), and "no realization about the impact of disaster occurrences" (14.6 percent). This indicates that increasing public relations activities on the impact of insurance and expanding the range of insurable agricultural products should be priorities.

Although the aforementioned measures all have focused on the production aspect, several measures have been geared for a resilient food processing and distribution system. The GHG emissions target management system has adopted 25 food processing enterprises, and it reduced GHG emissions from the enterprises in 2015 by 8.34 percent. In addition, an online market system for agriculture was launched to reduce the number of steps in distribution, and it has made huge progress: in 2009, the system generated a profit of around 5.2 billion KRW, and that increased to more than 2 trillion KRW in 2015.

Regarding measures for quality control during the processing and distribution stages, for instance, the Food Safety and Management System incorporates a hazard analysis and critical control points (HACCP) system and a traceability system[4] for agricultural and livestock products. Also, the Ministry of Food and Drug Safety has distributed a catering safety manual applicable under abnormal weather conditions, such as a heavy rainfall season, to restaurants.

To bring awareness of climate change and its impacts on food security to consumers, the Korean government has for some years now been articulating mid- to long-term national strategies. For instance, MAFRA adopted a low-carbon-certification system for agriculture and livestock products beginning in the year 2012 that provides consumers more information about the carbon footprint of products. Also, various agencies have implemented a stream of education and public relations programs. Lee and Yang (2013) conducted a survey to measure the levels of climate change awareness and willingness to pay (WTP) for food security under a climate change situation. Of the total number of respondents, 71.9 percent said that Korea has a low level of food security and 52.2 percent of consumers said that the targeted food self-sufficiency rate in 2020 (32.0 percent) should be raised (48.9 percent on average). In addition, 90.8 percent of respondents answered that climate change is a serious problem, while 78.7 percent answered that climate change has negative impacts on food security in Korea. Regarding the willingness of extra payment, on average, customers answered that they are willing to pay an additional 1.87 percent in food consumption tax and an additional 1.66 percent in oil tax. The total amounts of WTP calculated are 902 billion KRW (US$801 million) in oil tax and 1,375 billion KRW (US$1,221 million) in food consumption tax, which indicates the potential taxation availability.

As discussed in this section, faced with the challenges of climate change, the Korean government has introduced numerous policy measures and programs. Those measures have been implemented under several national strategies aimed at creating a climate-resilient food system. We will examine those strategies in the following sections.

3. National Strategies for a Climate-Resilient Food System

The Korean government has established and implemented various sector-specific and cross-sector strategies to combat the effects of climate change. Current policy directions and detailed measures to ensure Korea has a climate-resilient agriculture sector and food system are based on four major strategies.

[4] A traceability system for fisheries products is in the process of becoming a mandatory system (2018).

Basic Plan on Climate Change Response in the Agriculture, Forestry, Fisheries, and Food Sectors (2011–2020)

The Ministry of Food, Agriculture, Forestry, and Fisheries[5] established a basic plan for climate change response in the agriculture, forestry, fisheries, and food sectors in 2011. It was the first plan established to react to the impacts of climate change in those sectors, and it has two major goals for mitigation and adaptation:

1. By 2020, reduce 35 percent of GHG emissions from business-as-usual levels and increase by 6 percent the estimated absorption of GHGs by forests.
2. Stabilize supply and demand through prediction of unusual weather events.

Given those two major goals, the plan suggested major policy measures in six subsectors: agriculture, livestock, fisheries, forestry, water management, and food and distribution (Table 6).

Table 6: Policy measures of the Basic Plan on Climate Change Response in Agriculture, Forestry, Fisheries, and Food Sectors (2011–2020) by subsector

Subsector	Measures
Agriculture	Mitigation - Development and distribution of low-carbon agricultural technology - Establishment of energy-saving facilities and renewable energy infrastructure Adaptation - Capacity building for climate change projection - Development of climate-resilient species
Livestock	Mitigation - Dissemination of manure treatment facilities (resource recycling) - Reduction of GHG emissions from intestinal fermentation - Maintenance of optimum level of livestock numbers with the adoption of permission system in livestock industry Adaptation - Development of livestock management and disease control skills under climate change impacts

[5] The Ministry of Food, Agriculture, Forestry, and Fisheries was reorganized into the Ministry of Agriculture, Food, and Rural Affairs (MAFRA) in 2013.

Subsector	Measures
Fisheries	Mitigation - Formation of sea forest and sea farm as a carbon sink - Energization of marine biomass - Low-carbon and energy-saving technology for fisheries industry Adaptation - Projection of future Korean marine environment - Development of new culture species
Forestry	Mitigation - Raising GHG absorption capacity with recovery of damaged forest area, afforestation, tree species renewal, and other measures - Promotion of afforestation program abroad to secure the carbon credit - Activation of forest carbon offset scheme Adaptation - Reorganization of regional forest composition with climate-resilient species - Minimization of damage from forest disasters—landslides, forest fires
Water management	- Conservation of water for agricultural activities and rural areas with multipurpose irrigation and embankment-raising for agricultural reservoir - Small hydraulic power plant using agricultural reservoir
Food and distribution	- Promotion of an efficient distribution system and a green food program

Source: MAFRA (2011a).

To support the sectorial policies shown in Table 6, measures to establish infrastructure responsive to climate change were concurrently set forth. Those measures include the establishment of a climate change response center, adoption of a low-carbon agriculture certification system and initiation of carbon offset projects, golden seed projects (research and development [R&D] project for climate-resilient species), information sharing and campaign for public awareness, and incorporating low-carbon activities into the policy decision-making process.

Mid- to Long-Term Climate Change Response Plan on Agricultural Technology Development (Second Phase, 2014–2023)

This plan was established by the Korean Rural Development Administration under MAFRA to implement countermeasures to cope with the agriculture production crisis. The plan's second phase (2014–2023) follows its first phase (2009–2012) and has been implemented under the vision of "climate-friendly agricultural structure and low carbon agriculture and livestock industry." It consists of four main strategies along with 14 strategic measures.

1. Enhance the ability to project agriculture production trends: continuously monitor the production environment, productivity trends, and agroclimatic zone shifting; conduct a vulnerability assessment regarding biodiversity and pollination system
2. Develop new climate-resilient technologies: adjust the standard analysis method; develop climate-resilient species and climate-driven disease control technologies; observe and exterminate new foreign insects and pests
3. Prevent damage from abnormal climate events: employ disaster mapping (30-to-270-meter level) for drought, heavy rain, and typhoon; achieve nationwide utilization of early warning system in 2020
4. Practice low-carbon agriculture: take advanced measurements of GHG emissions rates in agriculture and livestock sectors; develop new mitigation technologies; use renewable energy and pursue higher energy efficiency

National Climate Change Adaptation Plan (Second Phase, 2016–2020)

A national cross-sector climate change adaptation plan was established under the Framework Act on Low Carbon, Green Growth as a national climate change response strategy. The 2016–2020 phase is the second phase of the five-year rolling plan. The first phase was established in 2010 and revised in 2012; it set forth 67 policy measures in nine sectors. The second phase of this national plan sets forth 20 core policy measures based on an integrated adaptation approach. Table 7 lists the core measures of the plan that are directly or indirectly related to a resilient food system.

Table 7: Policy measures in the Second National Climate Change Adaptation Plan, 2016–2020

Scientific Risk Management
- Multisector, multidimensional observation and forecasting system with an early warning system - Advanced national climate change scenario for more accurate and detailed projection data - Enhanced monitoring of the effects of climate change on the ecosystem - Establishment of the Model of Targeted Impact and Vulnerability Evaluation (MOTIVE) by sector - A customized and integrated information system with information and communications technology
Establishing Safe Society
- Infrastructure management in at-risk regions - Disaster management and damage control
Competitiveness of National Industries
- Enhanced adaptation capacity of industries - Expansion of the adaptation infrastructure - Research and development for adaptation technologies - Promotion of overseas market expansion for adaptation technologies and projects
Sustainable Management of Natural Resources
- Conservation and management of biodiversity - Risk management of climate change impacts on the ecosystem - Natural habitat management and securing a resilient ecosystem
Domestic and International Execution Basis
- Realistic and effective execution of the plan - Enhanced international cooperation - Promotion of regional-level adaptation activities - Public relations and education for climate change adaptation

Source: Government of the Republic of Korea (2016).

Basic Plan on Climate Change Response (First Phase) and 2030 National GHG Emissions Reduction Road Map

The Basic Plan on Climate Change Response is the government's most recent strategy in response to the post-2020 climate regime and the Paris Agreement. This plan not only calls for less GHG emissions but also addresses adaptation, funding resources, technology transfer, capacity building, and transparency. Under the vision of a "low-carbon society with efficient climate change response," the plan articulates seven major cross-sector goals. Among them, the goals and specific measures that bear on a climate-resilient food system are listed below:

1. A society safe from abnormal climate: scientific impact analysis for climate change, construction of climate change–safe society
2. Enhanced international cooperation for the new climate regime: reinforce governmental bargaining power for climate change issues, national response toward the assessment of mitigation contribution
3. Pan-national implementation and participation regarding climate change issues: establish a climate change governance system, formulate a national consensus on climate change response

Along with this basic plan, the Korean government developed the 2030 National GHG Emissions Reduction Road Map. The government declared that 219 million tons of GHG, or 23.7 percent of the total emissions volume, will be reduced domestically in eight subsectors. Among those sectors, the agriculture and livestock sectors will have their GHG emissions reduced by 1 million tons (4.8 percent of total emissions) by 2030.

The four strategies described above briefly summarize the direction of current and future strategies on the national level to build a climate-resilient food system in Korea. In the past, each ministry has had its own strategies and plans with its own priorities. With the adoption of the Basic Plan on Climate Change Response and the 2030 National GHG Emissions Reduction Road Map, Korea now has an integrated and holistic strategy across the line ministries. In other words, Korea can carry out and track its strategies with a common consensus. Even though the line ministries and agencies may have separate plans in the future, they will be managed and discussed under the macro national plan.

Furthermore, in light of the Paris Agreement, additional efforts will be made to reduce GHG emissions under the new climate regime. Since Korea needs to report statistical data on its emissions and attempt to establish and implement mitigation policies in order to meet its nationally determined contribution, additional strategies and policy measures are likely to emerge from each of its sectors.

Lastly, most of the adaptive measures articulated in the national strategies emphasize the development and adoption of climate-resilient crop varieties and technologies. This priority is designed not only to counteract climate change impacts but to improve the incomes of farming households who have struggled to compete with imported commodities and experienced low profit margins with the generally slowing Korean economy. Hence, it can be said that Korea's recent strategies are aimed at environmental and economic sustainability and resilience.

In the next section, we discuss specific cases and examples of policy measures involving agricultural extension and technology dissemination services that Korea has planned and implemented to develop a climate-resilient food system.

4. Agricultural Extension and Technology Dissemination Services for a Climate-Resilient Food System

Agricultural extension and technology dissemination services in Korea fall mainly under the jurisdiction of the Rural Development Administration (RDA, http://www.rda.go.kr/). The RDA has three main functions regarding such services: collection, processing, and dissemination of agricultural technology. Under the central RDA are nine provincial branches of agricultural research and extension service, 158 regional agricultural technology centers, and 728 farmer counseling centers for on-site services implementation.

Agricultural extension and technology dissemination services intended to promote a climate-resilient food system are also designed and implemented within this system. Indeed, issues of climate resilience and adaptation have become major priorities in recent decades with the public's growing interest in and awareness of climate change impacts. For instance, in the Mid- to Long-Term Plan for Agricultural Extension Services (2013–2017), several climate-resilient countermeasures were promulgated under the core goals to raise the competitiveness of Korean agriculture with rapid technology dissemination and to minimize weather–induced damage with the premeasurement of natural disasters. Also, when the RDA declared its 2022 R&D Road Map in 2017, of the 19 main agenda items, three were related to climate change impacts: establishment of basic infrastructure for agricultural science and technology; quality control of and value addition to horticulture products; and development of contemporary and future adaptation technologies.

The recent trends and features of climate-resilient agricultural extension and technology dissemination services in Korea can be characterized by four key focus areas: (1) application of ICT technology; (2) on-site, packaged, and appropriate technologies geared to the regional context; (3) awareness and capacity building of farmers; and (4) networks and partnerships abroad. We discuss each of these, offering several example cases, to elucidate the implications for other developing countries struggling with climate change impact issues.

Application of ICT Technology

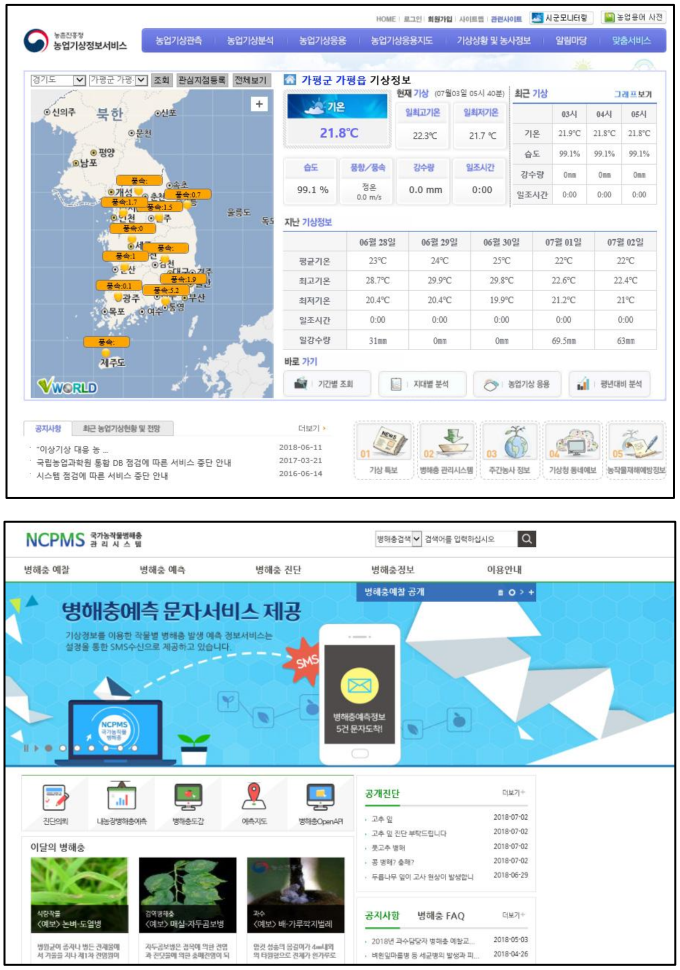
ICT systems are being increasingly embedded in many aspects of our daily lives, and the agriculture and food sectors are not exceptions. Korea is characterized by a high number of Internet and mobile users,[6] and this makes for a favorable environment in which to deliver extension services and disseminate technology. There are several examples of ICT technology being applied for extension and technology

[6] In 2018 the Ministry of Science and ICT reported that 90.3 percent of residents above three years of age used the Internet and 99.5 percent of households had Internet access.

dissemination, such as information sharing systems, climate-resilient facilities and infrastructure equipped with ICT (smart farm system), and a social networking service (SNS) for field reports and networking.

With the application of ICT technology, weather and climate information is more accessible to farmers. In reality, most farmers get their weather and climate information from a smart mobile phone (44.1 percent) or an Internet device (22.5 percent) (Kim et al. 2015). Given that trend, to rapidly share accurate weather information with the public, the RDA has been running its Agricultural Weather Information Service website (http://weather.rda.go.kr/), which provides timely data on basic regional weather indicators such as daily temperature (average, highest, and lowest), precipitation, humidity, daylight hours, and so on. Such predictive data are also presented under the categories of producing region and growing stages of specific agricultural products with the desirable range of weather indicators so that farmers can compare the weather conditions of their own region with the standard. The RDA website also provides a real-time mapping system for special weather reports, disaster situations, agroclimatic zoning, and drought forecasting for upland farm products. In addition to the website, the RDA also runs a National Crop Pest Management System (NCPMS, http://ncpms.rda.go.kr/), which provides an online directory of crop pests with pictures, occurring environment, symptom explanation, and control methods so that farmers can understand and rapidly react to problems. The system also contains a pest forecast mapping system by quarter. This map shows the risk level of pest occurrences for nine major crops as “normal,” “watching,” and “warning” status so that farmers can prepare for a forthcoming pest situation. The system also provides expert consulting and supporting services to farmers. With such services, farmers can seek the advice of experts about their pest-related problems and request a national pest control service. Through both systems, instantaneous disaster-related information and regularly updated news about the farmer’s main crops and farming regions are distributed to the farmers through various channels such as via mobile SMS message or SNS. They are also smartphone mobile applications (apps) that enable farmers to upload pictures of their crop and ask for consulting services more easily.

Figure 6: Agricultural Weather Information Service and NCPMS websites

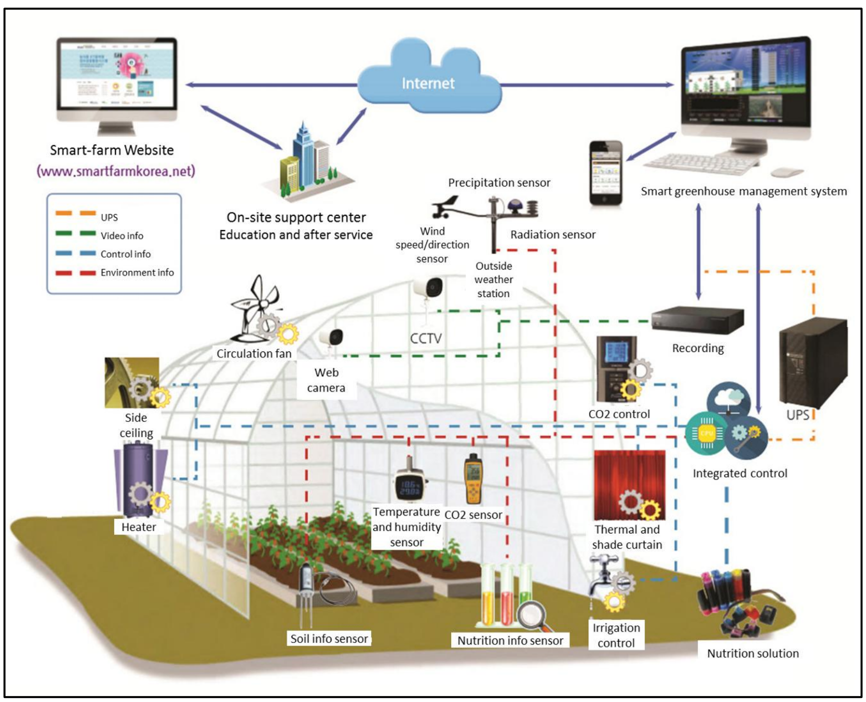


Source: Agricultural Weather Information Service (http://weather.rda.go.kr/); National Crop Pest Management System (http://ncpms.rda.go.kr/).

Beyond the information sharing system, the advancement of ICT enables more sophisticated and automated utilization of farm facilities and infrastructure. With the development of the Internet of things and relevant technologies, Korea has promoted “smart farm” technology, encouraging its adoption in numerous farming environments. This is meaningful not only for the sake of saving labor and increasing productivity but also for the purpose of responding to the effects of climate change as the system is sensitive and can respond quickly to abnormal weather conditions. Smart farm technology is usually applied to the greenhouse cultivation of fruits and vegetables, as well as to field cultivation and livestock farming. How smart farm technology is applied varies based on crop varieties or farm size, the remote-control functions of the temperature, humidity, and nutrient solutions, irrigation, pest occurrences detection, and security systems. Even though the horticultural area using smart farm technology is estimated at only around 1 percent of the total horticultural land in Korea, the Korean government is trying to expand that portion with diverse policy measures. For instance, in 2018 the government announced the Expansion Plan for the Smart Farm System whereby the government would develop and disseminate an innovative model of the smart farm system (Government of the Republic of Korea 2018). This plan mainly aims to establish an industrial infrastructure and ecosystem to expand the smart farm system. The government will establish one of the main projects, the Smart Farm Innovative Valley, in four regions by 2022, including production, distribution, education, and R&D functions of a smart farm system.

MAFRA and subagencies including the RDA have implemented several projects specifically to respond to climate change, such as “plant factories” and a disaster prevention system for livestock farms. A plant factory is a system producing all through the year with full environmental control and atomization of the cultivation process. With these facilities, farmers are more protected from environmental impacts, which will hopefully lead to increased crop productivity and quality. Since the initial investment cost to construct the necessary infrastructure is high and could burden farming households, the government has tried to develop and distribute core technologies through mid- to long-term funding programs. As a result of these efforts, Korea is now transferring or exporting its customized technologies to other developing countries, so that they may catch up to the countries that are leaders in the smart farm technology sector, such as European countries and Japan.

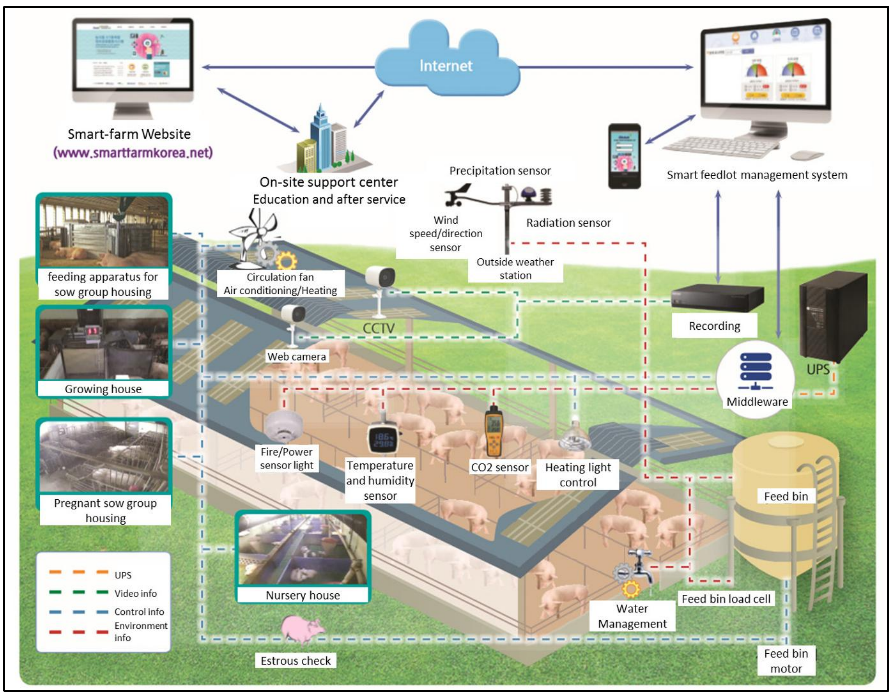
Figure 7: Composition of a smart farm greenhouse



Source: Smartfarm Korea website (http://www.smartfarmkorea.net/).

In the livestock sector, the adoption of smart farm technology can help prevent damage from animal diseases and natural disasters. Feedlots equipped with smart farm technology—in the form of access control and security systems, lightning damage prevention systems, and fire detection systems—are currently in the pilot project stage. Other practical applications of smart farm technology in the pilot stage include monitoring systems for external (temperature, humidity, wind speed, wind direction) and internal (temperature, humidity, blackout, fire) environments; a system for breeding and managing livestock; and a system to supply feed and drinking water. Another pilot project that was planned and implemented used early-detection technology to detect livestock diseases with a thermal imaging camera, and used technology to measure heat and humidity stress indicators to prevent overheating, lessen mortality rates, and increase the productivity and quality of livestock.

Figure 8: Composition of a smart farm feedlot



Source: Smartfarm Korea website (http://www.smartfarmkorea.net/).

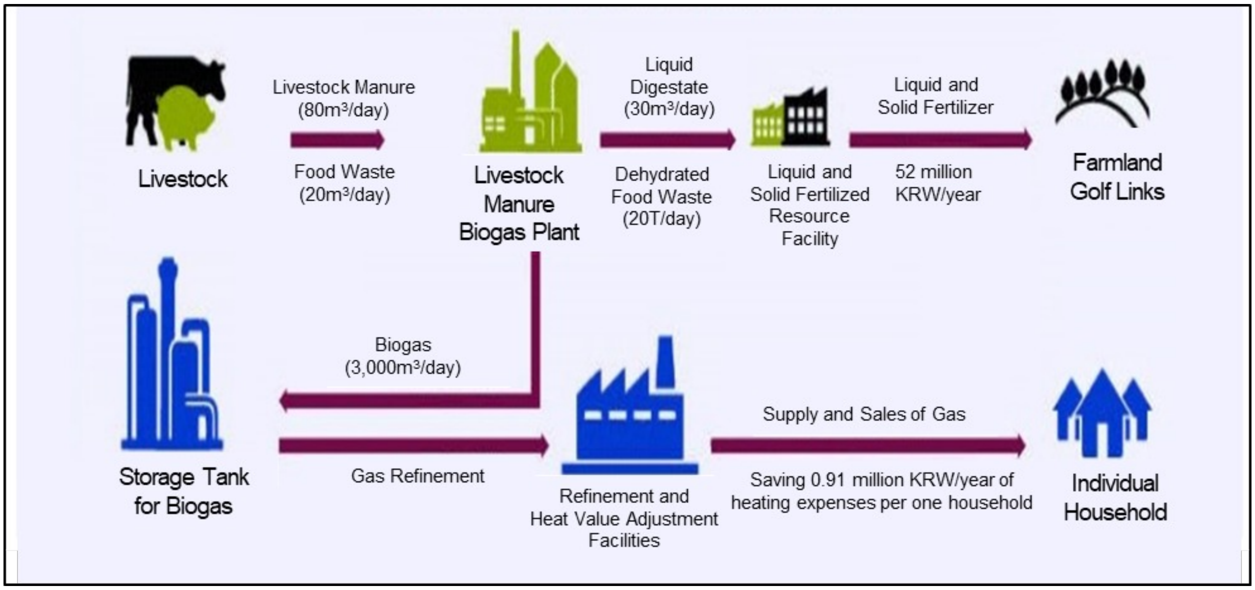
ICT is a critical part of the bottom-up reporting system and farmers' ability to network. With the widening of the SNS network, farmers can report their problems to experts and communicate with each other more easily despite geographical limits. As mentioned earlier, farmers can use the SNS network to ask experts for advice regarding their difficulties, including damage caused by pests or diseases, abnormal weather events, and limited knowledge, and the experts from the RDA or an agricultural technology center in the region can give instant online advice or visit their farm if necessary. The SNS also enables farmers to form a group through quick and prompt communication among themselves. Such a group is usually created and operated within a regional community or cooperative unit among farmers who cultivate the same varieties of crops. Group members can communicate with each other about successful cases, trials and errors, and new information about farming practices and thus raise their resilience to externalities such as climate change impacts.

On-Site, Packaged, and Appropriate Technologies Taking into Account the Regional Context

Although R&D in advanced technologies is important to create a resilient food system, the practical utilization of the technologies in the field is another important issue to be addressed, as the stabilization and settlement measures in accordance with the regional contexts are imperative. The RDA and the regional agricultural technology centers have tried to disseminate new technologies and infrastructure into rural society with less risks and more stability. Especially in recent decades on-site infrastructure has been constructed or upgraded based on farmers' needs and potential interactions with existing facilities. For example, manure treatment on the livestock farms is an important task since, if manure is not treated well, it can cause water and soil pollution with higher carbon emissions, as well as cause a bad odor and a poor hygiene situation, spreading disease via water or air. Diverse solutions have been studied for feasibility with pilot projects and real practices. For instance, livestock manure can be transformed into green fertilizer for crop cultivation. Several pilot projects aim to disseminate the facilities and skills for fertilizer production. For example, in 2018 two pilot projects were initiated for manure treatment and resource circulation. One of them involved the customized production and dissemination of fermented liquid manure fertilizer from pig farms. Facilities, such as a customized processor, storage, and a filtering system for the liquid fertilizer, were supported with a governmental budget and with expert consulting services. The output of this project would be applied to vegetables, fruits, and rice farmland to cultivate ecofriendly agricultural products. The other pilot project addressed the sustainable production of fodder crops with processed-manure fertilizer. With this product, livestock farms can expect to reduce production costs and maintain a stable supply of the fodder crops self-sufficiently and avoid side effects from improper manure treatment.

Another example of a resource circulation and recycling system is called the "energy town" model. Such a system not only processes manure for fertilizer but also generates biogas energy (Figure 9). This began as a government pilot project, and it was a success in the Hongcheon region due to strong participation of community residents. The energy town is now being maintained and has been evaluated as a successful case. According to the Hongcheon Energy Town website, the resource recycling generates an annual profit for the community of around 146 million KRW. Considering that manure treatment facilities are often regarded as unpleasant facilities—the "not-in-my-back-yard phenomenon—this is a remarkable accomplishment that can affect the resilience of the rural community.

Figure 9: Korea's Hongcheon Energy Town: Resource recycling between the livestock and energy sectors



Source: Hongcheon Energy Town website (www.hcenergytown.com/).

An initiative directed at comprehensive and inclusive management of agricultural production consists of distributing packages of relevant technologies to farm households. These technology packages were launched and demonstrated as a pilot project for improved productivity and quality of certain crop varieties or for damage control for unexpected scenarios. A package for counteracting abnormal weather conditions aims to prevent damage from frost, excessive heat, and fruit drop situations and promote the sustainable production of fruits with the technologies of natural and artificial pollination and other environmental controls. This package is in the pilot project stage and has five technologies to prevent frost (frost protection fan), prevent overheating (water spray facilities), prevent fruit drop (windshield screen), increase the seed setting rate (insect vector, artificial pollination), and control the environment (mobile sprinkler). This project is planned to proceed with the cooperative units in the rural community that cultivate the same crop species to disseminate and stabilize the results of pilot project more easily.

An initiative using packages aimed at overheating was designed to solve problems involving low quality, productivity, and photosynthesis rate; the packages are to be applied to at least one crop in each province. Various types of greenhouse-cultivated crops like fruits (strawberry, watermelon, melon, tomato, cucumber, eggplant, pumpkin, bell pepper) and vegetables (chives, lettuce, cabbage, wild herbs and vegetables) are included as the project crops. At least two temperature-reduction technologies—such as cool net, sun-shade, ventilation fan, and fog spray facilities—will be packaged together based on the regional situation and needs analysis.

The energy-saving technologies package is mainly for the improved energy efficiency of heating systems during the winter season. It is developed to reduce costs for farm households and to maximize energy efficiency, which lowers carbon emissions. The package includes such technologies as electronic hot-water boiler, thermal curtain, exhaust air heat pump, and air flow device, and the composition can be varied according to crop type or regional agricultural environment. Considering that most of the heating devices used on rural farms are run by kerosene engines, this new package of technologies with electronic power can be more environmentally friendly when combined with renewable energy projects. According to the Jeonnam Agricultural Research and Extension Services (JARES), when they applied a package of open top–type multilayer thermal curtain and exhaust air heat pump for strawberry greenhouse farming, they had better product quality and lower energy costs (Table 8)**.**

Table 8: Comparison between packages of energy-saving technologies

	Roll-up–type horizontal multilayer thermal curtain + kerosene engine boiler (conventional package)	**Open top–type multilayer thermal curtain + exhaust air heat pump (new package)**
Fruit weight (g)	17.5	18.4
Fruit length (mm)	41.2	42.1
Fruit width (mm)	32.7	32.8
Soluble solid content (°Bx)	8.5	9.2
Quantity (kg/10a)	4,231	4,527
Amount of kerosene fuel consumption (ℓ/10a)	779	-
Amount of electricity consumption (kW/10a)	-	5,966
Energy cost (KRW/10a)	623,200	256,538 (59% cost reduction)

Source: JARES (2017).
Note: g = grams; mm = millimeter;

The appropriate technologies can be classified as alternative, intermediate, low-cost, and community technologies. Discussions about appropriate technology issues are usually focused on vulnerable and fragile communities and how to make their residents more self-resilient with less expensive and less complicated solutions in their own contexts.

Policy measures for the adoption of appropriate technologies started being discussed during Korea's modernization period. But it was more likely to be a process of selection and imitation of technologies from developed countries based on national needs. The government and academia in Korea tried to absorb and internalize the technologies that could be applied to the context of Korean society and the agriculture sector. At that time, climate change issues were not included in the main agenda for national development; improving productivity and self-sufficiency were the core tasks in the agricultural sector in those days. Naturally, the government promoted R&D projects for crop species development, agricultural skills, and agricultural mechanization. Also, due to the massive flow of national community development programs, which was called *samaeul undong* (new village movement), the basic groundwork for agricultural and rural development was established and stabilized rapidly (Lee 2013). As a result, Korea has successfully internalized and caught up with the experiences of frontier countries and tried to develop its own ways to be more sustainable and competitive. As an example, Korea has developed and cultivated diverse species of its own including climate-resilient species. These newly developed species allow farmers not to pay for the loyalty of their crop seeds and to be competitive in the domestic and international markets, which eventually improves the resilience of Korea's food system. Virus diagnosis kits for plant diseases and pests in the field are another successful case. The RDA has developed and disseminated the kits, which can detect 15 types of pests for 10 crop species. This enables farmers to check the diagnosis results within two minutes in the field and move on to the next process to minimize their damage. According to the RDA, during the last 12 years, adoption of the kits saved approximately 500 billion KRW in damage costs. In addition, the import substitution effect of the kits can be measured at around 1.7 billion KRW, which could grow in the future.

But when the discussion is about appropriate technologies in the context of climate change and a resilient food system, it usually implies a slightly different concept. The notion of appropriate technologies in recent discussions is more about innovative and locally available technologies with greater accessibility and sustainability. The application of appropriate technologies for a climate-resilient food system in Korea is still in an early stage. But given the clear political interest and intention to promote appropriate technologies in this sector, domestically and internationally, the forecast for the future is positive.

Several cases can be offered as examples. One of them is an ultralight fabric that prevents damage from abnormal weather events. It is designed for field vegetables such as pepper, eggplant, zucchini, and lettuce and aims to prevent damage from hail, frost, or low temperatures and pest occurrences. Also, the fine ventilation, rainfall permeation, and radiation exposure with its thin layer (less than 18 grams per square meter) make it possible to improve the productivity and growth period of the vegetable. The application of this technology is simple; cover the vegetables in the field with the fabric tunnel (Figure 10). Currently, several farms are involved with pilot projects of this technology, and it is expected to be distributed to other vegetable farms.

Figure 10: Application of the fabric tunnel in a vegetable field

Source: Baek (2018).

Another example of an appropriate technology comes from the water management sector. It is related to a Korean traditional type of water puddle called a *doombeong.* The *doombeong* is a naturally created water puddle in an area that has a higher level of groundwater compared with the surrounding area. In the past, when irrigation systems were not yet established, farmers supplied the water in this puddle to their agricultural field. This traditional irrigation system disappeared when the government-led land consolidation and irrigation program got fully under way.

Figure 11: Traditional doombeongs in rural areas

Source: Kim and Jung (2017).

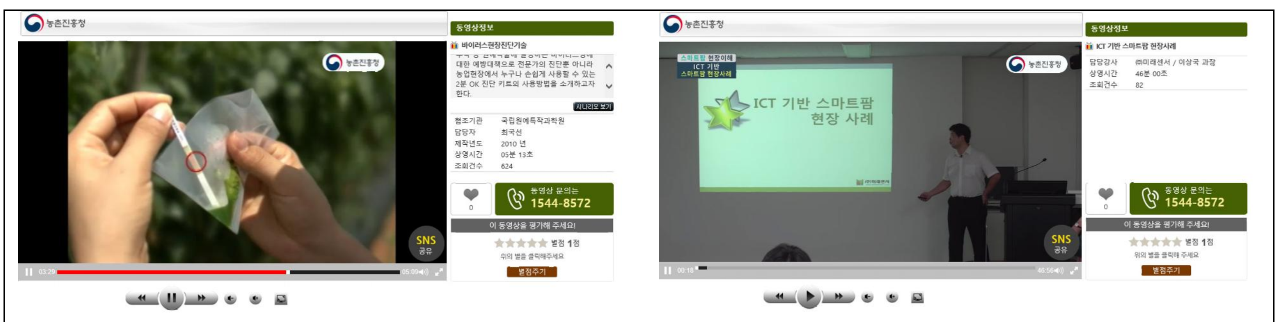
However, in recent decades, in coastal regions where this system remained due to water shortages, the ecological preservation and water control (from flood and drought influences) functions of the *doombeong* system have become apparent. Compared with the paddy land with no access to the *doombeong,* the land near the *doombeong* has more biodiversity, especially in terms of water animals and insects. Also, *doombeongs,* with their absorbing capacity, have worked as a way to store water during the flood and drought seasons. Given this evidence, some regional governments have restored the *doombeong* near farmland not only as a water management facility but as an ecotourism spot in rural areas. Also, they have initiated research projects on the impacts of the *doombeong* to set up a desirable model and stabilize the *doombeong* system in their regions.

Building Awareness and Capacity among Farmers

If we are to cope with the impacts of climate change with better sustainability and resilience, raising the awareness of and building the capacity of farmers is key. Using a variety of methods and channels, the RDA and the regional extension branches have tried to do just that.

The ways to deliver information and raise farmers' awareness and capacity can be divided into three categories. First, government agencies have provided on- and offline materials such as booklets, manuals, video clips, and agro-technology guidelines and reports. The booklets and manuals usually deal with introductory and timely issues such as adoption of new climate-resilient crop varieties and controlling damage from natural disasters and pest occurrence. The video clips, UCC (user-created content) content, and e-learning content make learning about climate-resilient practices more accessible and interesting (Figure 12).

Figure 12: Screenshots of UCC content and e-learning content

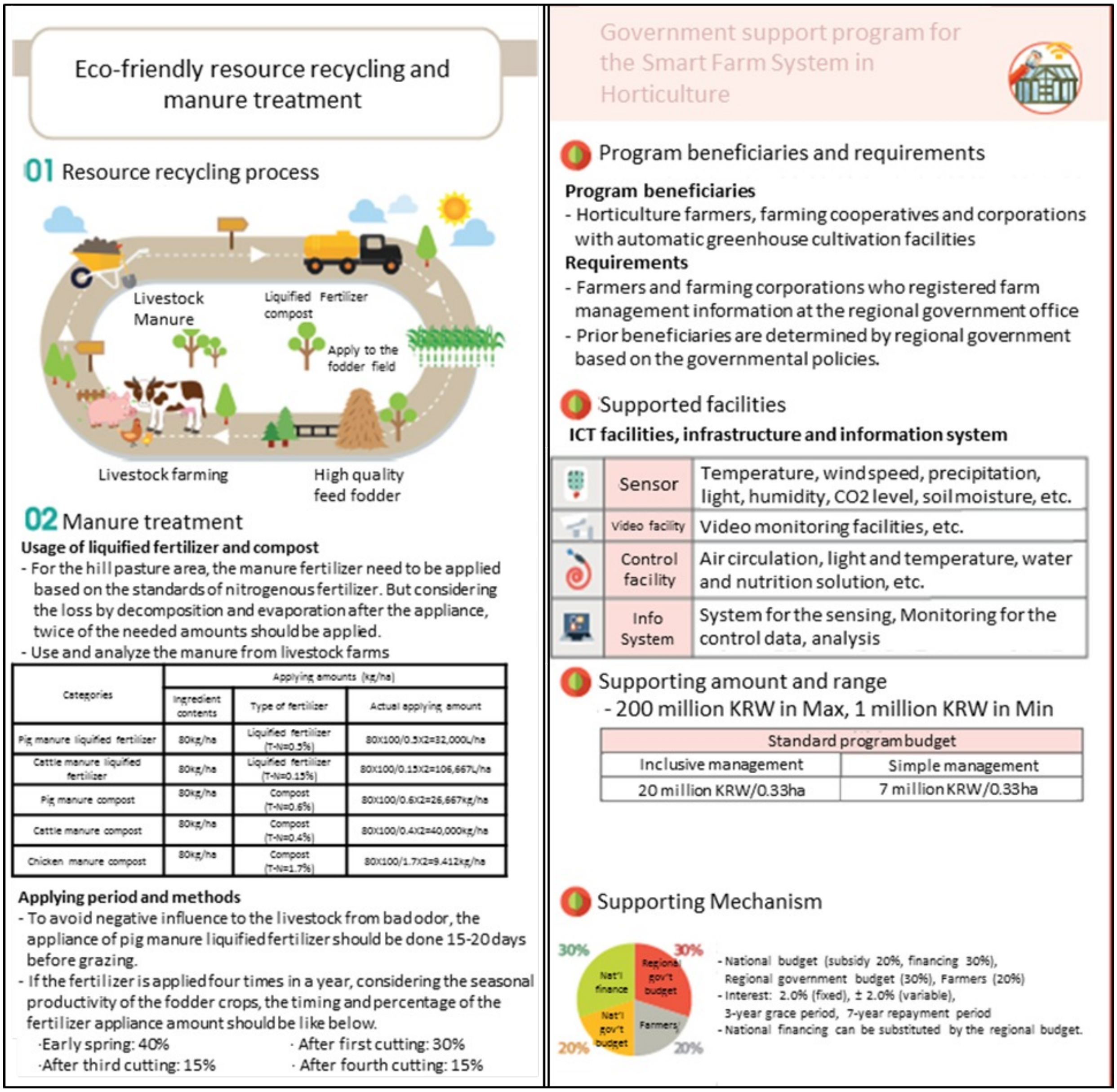


UCC content about on-site virus diagnosis kits **E-learning content about smart farm system**

Source: Nongsaro agricultural technology video clip website (http://www.nongsaro.go.kr/portal/ps/psb/psbo/farmngTchnlgyMvpLst.ps?menuId=PS00069&pageUnit=9).

The agro-technology guidelines and reports are written by experts and published by the RDA. The guidelines usually have content about the current situation, possible solutions, and follow-up information about cultivation of major crops and the farming environment. Regarding the effects of climate change, two guidelines have been published about sustainable crop production under climate change and disaster damage reduction technologies for agricultural infrastructure. Farmers and stakeholders can consult the guidelines for general information on how climate change affects the Korean agriculture sector and their farms. The agro-technology reports, which are more specialized reports, are also published by the RDA and usually deal with profound knowledge or new technologies about the agriculture sector. Two reports have been published specifically about climate change impacts. One is about livestock manure treatment systems (methodology, models, and relevant laws) and the other is about agricultural meteorology (abnormal weather events and natural disasters, weather forecasting system). These reports help farmers widen their professional knowledge based on their specific interests and needs. Besides the learning materials, the RDA, provincial agricultural research and extension service branches, and regional agricultural technology centers have been operating regular education and training curriculums for the farmers. Courses such as an annual farmer education program (called the "New Year Practical Education Course for Farmers"), monthly training courses on demand, and an advanced curriculum for the "farmers college" are provided to raise the awareness and capacity of farmers. To address climate change impacts, they contain topics like adopting commercial climate-resilient varieties, introducing new facilities and technologies to react to climate change impacts, natural disaster prevention, disaster insurance programs, and other new policy measures that affect farm households. Figure 13 is extracted from educational content in the 2017 New Year Practical Education Course for Farmers. One panel is about eco-friendly resource recycling and manure treatment and the other is an introductory explanation of the government support program for the smart farm system in horticulture. Farmers can use these educational and training courses to keep up to date on new information and knowledge about their farm crops and be ready for potential risks including the damage from climate change impacts.

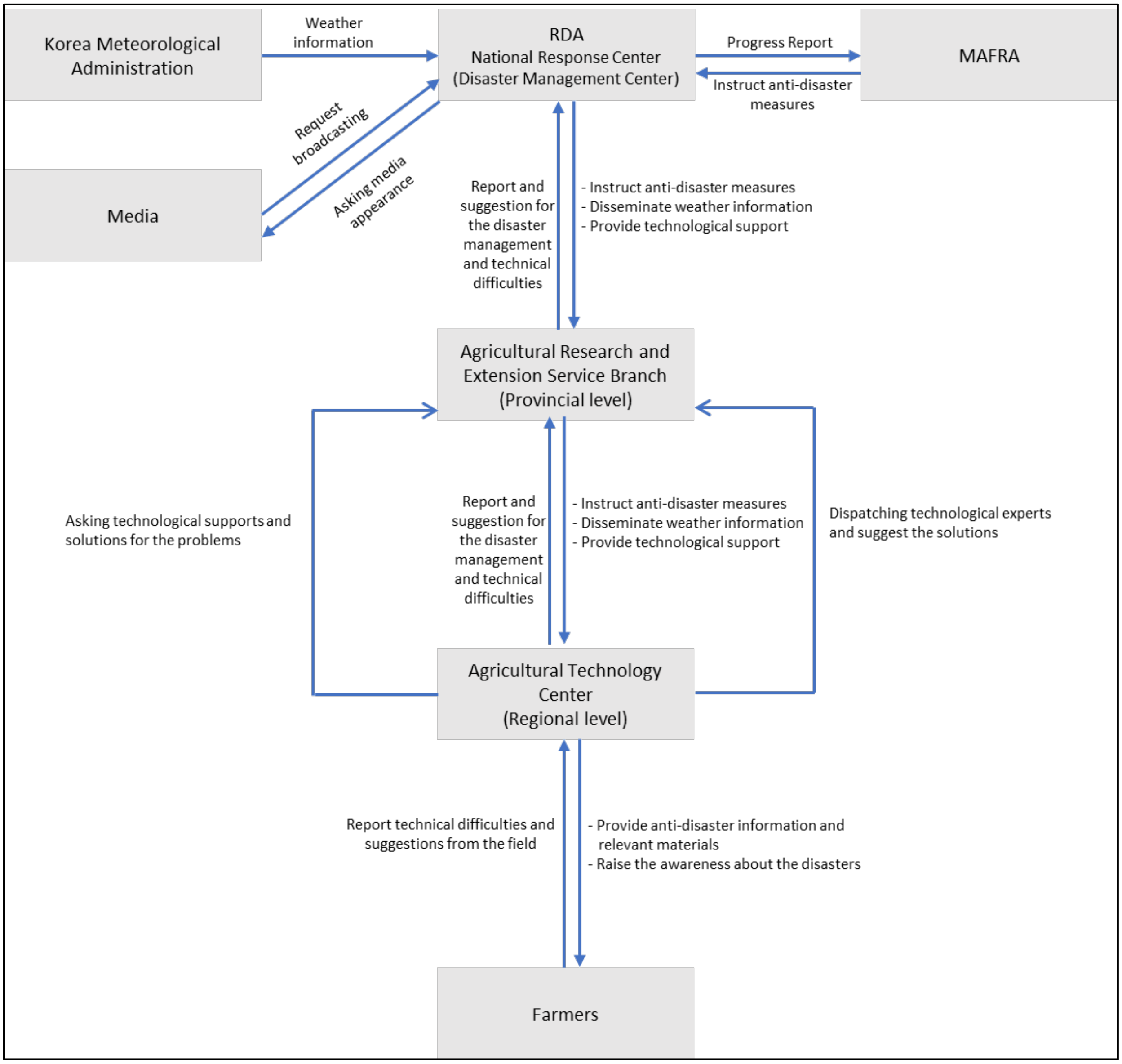
Figure 13: Educational content of 2017 New Year Practical Education Course for Farmers



Source: RDA Rural Human Resource Development Center website (http://hrd.rda.go.kr/).

Lastly, on-site consulting services deliver farmers practical and real-time advice to help them understand their situation and options. As an example of these services, the National Response Center in the agriculture sector is operated at the central and regional levels year round to collect, analyze, disseminate, and react to agricultural data and information. The information is usually about crop cultivation, pests and animal diseases, current agricultural and rural-sector trends, and damage control amidst natural disasters or harvest depression. Based on this information, the center provides policy direction considering current and future issues pertinent to respective regions. Figure 14 shows the structure of the agriculture situation center.

Figure 14: Basic structure of the National Response Center



Source: RDA (2017b).

In a problematic situation such as the occurrence of a natural disaster or an infectious animal disease, this center is changed into a disaster management center. Depending on the seriousness of the situation (ordinary, cautious, alert, severe), the size of the staff and the required tasks may change. If the situation is deemed a serious one, more experts in relevant sectors are dispatched to the center. Once a problematic situation happens, the center follows six steps for problem solving: (1) data collection about the disaster situation; (2) counteractive planning including getting technical support to the damaged regions; (3) on-site technical support and situation analysis; (4) reporting the results of on-site technical support and establishing additional follow-up plans; (5) implementing detailed measures and suggesting policy to the relevant institutions; and (6) providing technical instruction materials and disseminating them to farmers.

In addition to the response center, at the central, regional, and provincial levels, diverse on-site technical supports and consulting services have been implemented based on farmers' needs. The most common and basic method is sending experts to the rural regions for consulting and training services. The central and regional branches dispatch the crop experts and extension officials to provide major information about regional farming practices. In addition to domestic experts, experts from abroad are also invited for a special training session. The contents of this program are customized according to the farmers' needs and recently updated policy measures that can affect farm households. As farmers' interest in climate change impacts has risen, most of the branches include climate change impacts and countermeasures in their content. Considering the farming cycle of the rural area, regional branches usually implement these services in the summer season on an annual basis. Central consulting services, called *sarangbang,* are implemented three to four times by each crop in a year, based on requests from the provincial and regional branches.[7]

In addition to the on-site consulting program, field trips for community leaders are implemented in each region. In such a program, farmers usually visit research institutions, an agricultural technology center, and leading farms in other regions to learn about good farming practices. The community leaders can disseminate the results to their community and try to adopt new technologies or crop varieties to raise the community's resilience. Also, the central and regional branches promote communication among the farm households. This applies not only to the domestic farms but also to international farms all around the world. Among the domestic farms, communication with the leading farms that have gotten advantages from governmental projects or adopted new cultivation technologies can help other farms to raise their productivity and resilience. By talking to farmers in foreign countries, Korean farmers can learn about advanced farming technologies from the developed countries or transfer successful Korean practices to the developing countries. In both cases, farmers learn from one another and find further cooperative opportunities.

[7] The consulting services talked about in this paragraph, from the central and regional branches, are regular and annual consulting services. In an urgent situation like a pest or disaster occurrence, farmers can request on-site consulting services from the regional agricultural technology center and central RDA.

International Networks and Partnerships

Although domestic farm households' climate resilience is regarded as a national priority, international projects to support the climate resilience of rural and agriculture sectors in developing countries are promoted and implemented by numerous public and private institutions.[8] Indeed, the climate change and food resilience issue cannot be perfectly solved with only domestic efforts since it is related to international public goods across nations and generations. Hence international cooperation based on networks and partnerships is very important. Although a few projects focus on climate-resilient agricultural extension and technology dissemination services as the main objective, most of the international agricultural cooperation projects consider environmental factors, including climate change impacts, as a cross-sector issue during the project formation and feasibility study stages. Therefore, in this section, we examine projects with direct and indirect influence on the climate resilience of the recipient countries. The project delivery model with regard to international agricultural extension and technology dissemination services can be divided generally into three types: infrastructure construction, consulting services, and technology transfer.

Supporting infrastructure for climate-resilient extension services usually includes buildings, facilities, agricultural machinery, demonstration farms, and any other hardware components needed to raise farmers' resilience and productivity. But reckless infrastructure support is usually regarded as an inefficient and unsustainable solution by most donor countries or institutions, compared with support in the form of software components, that is, consulting services or technical transfer programs. But with proper guidance and monitoring, this type of support can be effective in forming the foundation of an extension service system for farmers, including training courses, demonstration farming, and pilot projects with new farming practices and technologies. As an example, the Korea Rural Community Corporation constructed an agriculture training center[9] (ATC) in Marracuene District, Maputo Province, Mozambique. This project was designed to reinforce the extension system by establishing an ATC, supplying agricultural machinery and facilities, and providing agricultural training and capacity-building programs to the extension officials and farmers. The first phase of the project, implemented in 2010, supported infrastructure needs, including a main building for training courses and a dormitory, agricultural machinery, and OA facilities. After completion of the first phase, when it became clear that the Mozambique government needed to expand the size and function of the center, the second phase was initiated in 2014 with hardware components including an additional dormitory, a kitchen, storage for food

[8] This paper mentions only the public official development assistance (ODA) projects so as to focus on the "policy measures" of the climate-resilient extension and technology dissemination services. However, many private actors in Korea, including academia, nongovernmental organizations, and other organizations, are actively involved in this area.

[9] The official name of the ATC in Mozambique is Centro de Formação e Extensão Agrária de Marracuene.

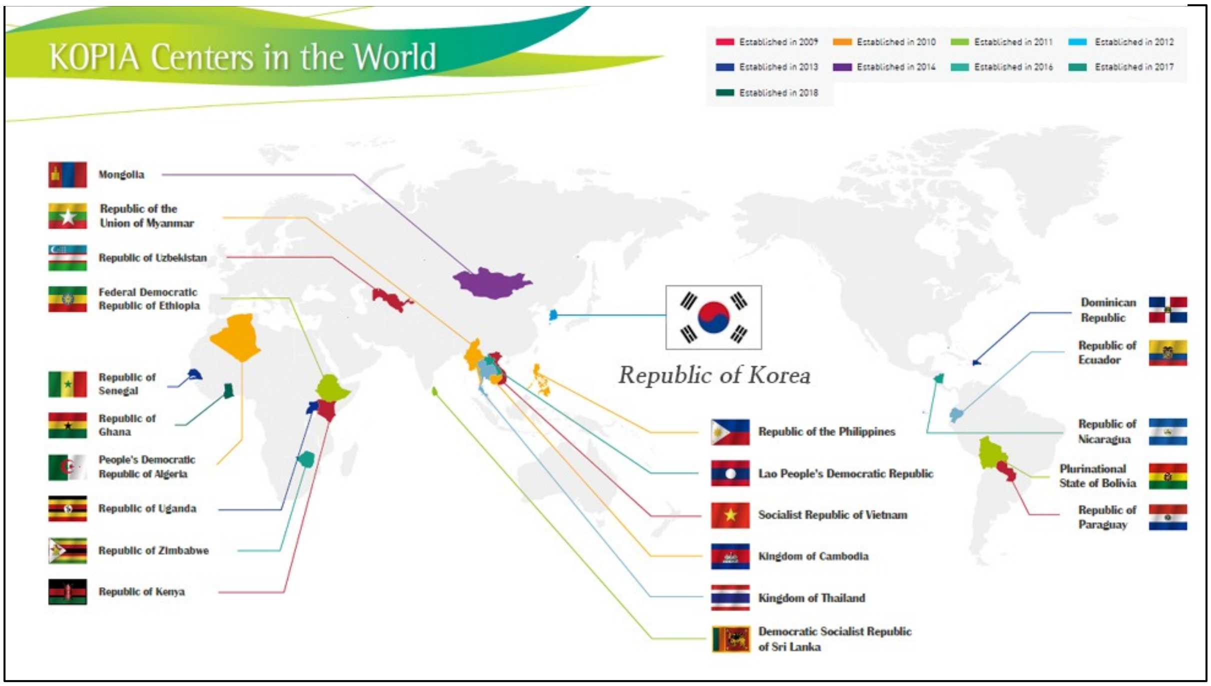
and machinery, a poultry farm and slaughter facilities, demonstrative greenhouse facilities, and so on. Even though these pieces of infrastructure were not mainly countermeasures toward climate change impacts, the project eventually helped extension workers and farmers participate in a training course about the response to climate change impacts and adopt climate-resilient measures such as flood-resistant farming practices and pest control. With the active participation and strong willingness of the recipient country, the project's second phase has been completed and a third phase is in process. The third phase will focus on the modulization and dissemination of the ATC system in other regions or countries with similar contexts.

Korea's consulting arm for developing countries aims to suggest possible developmental solutions and action plans under each nation's context and situation. Compared with the infrastructure supports, the objective of consulting activity is more focused on increasing the sustainability and resilience of the recipients. In the agricultural sector, there are two representative consulting programs in Korea: one is the Korean Agricultural Policy Experience for Food Security (KAPEX) implemented by KREI, and the other is the Development Experience Exchange Program (DEEP) from KOICA. KAPEX is a policy consulting program that supports agricultural policymaking and implementation capacity under a certain demand and topic. Through an annual procedure of joint research, short- to mid-term training programs, and policy workshops, a final report and proposal for a new ODA project is submitted as a program output. DEEP is more likely to be a project-oriented, technical consulting program including a feasibility study, project designing, strategy planning (master planning), and so forth. It is not limited to the agriculture sector, and the duration can vary with the characteristics and depth of the program.

In fact, Korea has not yet planned or implemented a consulting program that specifically deals with agriculture extension and technology dissemination as the main topic or objective. But several cases can be adduced as relevant references. For one, a 2016 KAPEX Mozambique program was implemented under the topic of "enhancing agricultural technology transfer system for smallholder farmers in Mozambique," and based on that consulting program, the Mozambique Ministry of Agriculture and Food Security proposed an extension project. The project is designed to improve the productivity and competitiveness of smallholder farmers through the establishment of a system for innovative promotion and adoption of improved agricultural technologies through improved extension services. As one of the specific activities, it proposed the training of farmers, extension officers, and researchers to establish field demonstrations of productivity enhancements and climate smart agriculture technologies (Zandamela, Nhancale, and Mabasso 2016). This indicates that climate resilience is included as an expected output of the project. In this way, Korea's consulting services can influence recipient countries to realize the priority and necessity of climate-resilient measures.

The RDA is primarily responsible for supporting international technology transfer and dissemination. One example is the Korea Program on International Agriculture (KOPIA) centers, which form the international branch of the RDA in developing countries. The KOPIA centers envision sustainable development and mutual benefits between the Republic of Korea and its partner countries through innovative cooperation in agricultural technology.

Figure 15: KOPIA centers in the world



Source: KOPIA website (http://itcc.rda.go.kr/kopia).

From 2009 to 2018, KOPIA has been launched in 21 developing countries (Figure 15). In each KOPIA center, Korean experts dispatched from the RDA headquarters transfer diverse agricultural technologies based on the needs of the relevant governmental or academic organizations in the recipient country. The centers also implement pilot projects customized to the national agricultural and climate situation. Most of the pilot projects focus on increased and stabilized crop productivity for domestic supply and export. But with the emerging risks associated with climate change, more and more projects are focused on developing and disseminating climate-resilient crop varieties and cultivation technologies. Table 9 lists the technological cooperation projects especially related to resilience to climate change impacts, including disasters and pest occurrences. All of the projects have been implemented based on advanced farming technologies and crop varieties adopted and developed in Korea.

Table 9: KOPIA projects related to climate resilience

Country	Project duration	Project title
Vietnam	8/2012–7/2015	Selection of pest-resistant potato varieties
	8/2012–7/2015	Development of agricultural extension system
	8/2013–7/2017	Survey and research on pest occurrences
	8/2014–7–2017	Development of adaptive vegetable cultivation technologies
	8/2015–7/2018	Development of highland strawberry varieties
Cambodia	8/2013–12/2018	Development and dissemination of adaptive maize varieties
	1/2016–12/2018	Development of rice blast disease control method and disease-resilient rice varieties
Philippines	1/2015–12/2017	Development and dissemination of adaptive rice varieties
Uzbekistan	10/2014–9/2017	Demonstrative farming and dissemination of the fodder crop *Triticosecale*
	1/2017–12/2019	Non-heating greenhouse vegetable demonstrative cultivation
	1/2017–12/2018	Research on agricultural extension organization and its function, and policy for the adoption of advanced agricultural technologies
Kenya	7/2015–6/2018	Development of cultivation technologies for food crops and vegetables (chicken, maize, potato, sweet potato)
Mongolia	5/2014–5/2017 1/2017–12/2019	Demonstrative farming project for the increase in adaptive wheat varieties
Senegal	1/2018–12/2020	Demonstrative farming project to increase farm household income with adaptive onion species
Zimbabwe	12/2016–12/2019	Development of postharvest management machineries for the small-grains production of smallholder farmers
	1/2017–12/2019	Technology development for seed production of potato varieties by meristem culture and hydroponic cultivation
Uganda	2/2018–12/2019	Irrigation and pest control project for the productivity of orange varieties

Source: Compiled by author based on the KOPIA website (http://itcc.rda.go.kr/kopia).

Note: KOPIA = Korea Program on International Agriculture.

Aside from the activities of KOPIA, the RDA has been operating two international partnership groups for technological cooperation: the Asian Food and Agriculture Cooperation Initiative (AFACI) and the Korea–Africa Food and Agriculture Cooperation Initiative (KAFACI). AFACI is composed of 14 member countries, namely, Bangladesh, Bhutan, Cambodia, Lao PDR, Indonesia, Kyrgyzstan, Mongolia, Myanmar, Nepal, Philippines, Sri Lanka, Thailand, Vietnam, and Korea. KAFACI has 20 member countries: Angola, Cameroon, Comoros, Cote d'Ivoire, DR Congo, Ethiopia, Gabon, Ghana, Kenya, Malawi, Morocco, Nigeria, Rwanda, Senegal, Sudan, Tunisia, Uganda, Zambia, Zimbabwe, and Korea. Both networks aim to overcome the agricultural and food challenges facing Asia and Africa by implementing joint pilot projects, training programs, high-level symposiums, and so on. In addition, member countries share agricultural genetic resources freely for research purposes, which enables standardized and integrated management of resources. Regarding resilience to climate change impacts specifically, a pilot project in Zimbabwe serves as an example. The project, named "Production and Dissemination of the Drought Tolerant Corn Hybrids," aims to adopt "Sirdarmaize 133" varieties, disseminate the cultivation technologies to farmers, and eventually raise the productivity and resilience of the region. Inputs such as seeds, fertilizer, and tools were provided to the demonstrative farms, followed by training, monitoring, and on-site instruction by experts. As a result, productivity and corn prices in the project region increased significantly, and many farmers became more interested in adopting new varieties and receiving additional support..

In this section, we discussed specific examples of Korean measures designed to build climate resilience through delivery of agricultural extension services and dissemination of technologies. Based on those policy measures, in our concluding remarks we will discuss implications for Korea and other developing countries.

5. Conclusions and Implications

This paper is written to investigate how the Korean government is supporting a resilient food system in response to the impacts of climate change. As a situation analysis, using records and statistics we first reviewed the climate change trends in Korea and how climate change has affected the resilience of the Korean food system. Next we described Korea's national strategies to create a climate-resilient food system, looking at those strategies' respective priorities. Next, we discussed Korea's agricultural extension and technology dissemination services in the context of building climate-resilient food systems, looking at cases categorized into four types of delivery: (1) application of ICT technology; (2) on-site, packaged, and appropriate technologies adapted to regional contexts; (3) awareness and capacity building of farmers; and (4) building international networks and partnerships.

In this last section, we would like to look at the implications for Korea and other developing countries of the agricultural extension and technology dissemination policy measures the Korean government has implemented in its effort to build a climate-resilient food system. The discussion considers current approaches, what problems are addressed, and how the food system may be improved.

First, regarding the approach that applies ICT technology, including an online weather and climate information system and smart farm technology, farmers' lack of computer skills could be an obstacle to accessing the information system. This is especially true for the older generation, and it may generate an information gap. To address this problem, education programs and training sessions in computer skills should be implemented continuously at the regional level. Also, the database interface to the information system should be made easier to understand and intuitive for sharing information. Other problems may arise regarding the smart farm system. Since the smart farm system is based on hybrid technology that is rapidly transformed and updated, extension officials and farmers in the various regions may have difficulties keeping their knowledge and information about the system up to date. In this regard, the adoption of on-site expert consulting services can help solve the problems the farmers might have and help make action plans for innovative projects with new technologies. If such support is hard to expand to all regions because of budget constraints and number of experts, a detailed manual and guidelines for the application of smart-farm technology can be produced and distributed in Korea's regions. Such a manual could deal with the difficulties that farmers or extension officials frequently present to the expert consultants, or the customized and practical know-how to successfully adapt to a smart farm system. Also, the initial investment cost of the smart farm system can burden farmers. To lower this barrier to entry, the government has directly supported farm households with pilot projects or promoted measures such as "fund of fund" or "crowd funding." But for the sustainable operation of the system, funding sources need to be diversified. For example, as an example of private investment by a domestic food company, we can look at the company Orion. Orion, a private food company in Korea, makes farming contracts with about 500 potato farm households for snack production. Recently the company began a test operation of the smart farm system in its contracted farms to analyze optimum levels of water and fertilizer inputs for better productivity. This could be a win-win strategy for both the farm households and the company since it puts less financial burden on the farmer to adopt smart farm technology and the company can ensure the product's quality even under the impacts of climate change and other negative externalities.

Regarding the approach of delivering on-site, packaged, and appropriate technologies suited to the regional context, besides the advancement of technologies, the willing participation of farmers is critical for the successful settlement of the technology. Especially for the climate change issue, the best technical measures to boost climate resilience and the farmers' actual needs can be in conflict. In this case, plenty of explanation and persuasion should be put into the effort to match farmer needs with climate-resilient measures. In the aforementioned Hongcheon Energy Town case, residents initially hesitated to accept the resource-recycling facility because they thought it was an unpleasant addition to their community. But with persuasion by community leaders the project has had fruitful results. Regarding adoption of appropriate technologies, more policy attention should be paid to promoting and disseminating the appropriate technologies. Currently, the activities regarding the appropriate technologies are promoted by several regional governments sporadically. The country would benefit from a central-level strategy and action plan to promote the adoption of appropriate technologies as one of the countermeasures to the climate change impacts in the agriculture sector. Also, the government should encourage R&D activities and other projects with appropriate technologies both at the central and the regional levels.

In the Korean government's effort to raise the awareness and capacity of farmers, most educational content still focuses on maximizing farm household income with better productivity. Climate change's impacts and the issue of resilience are mentioned as additional issues to be addressed, since farmers' interest in these issues has just started to emerge. Hence learning materials and courses addressing climate change impacts and the resilience issue as their main topics are rarely produced. Therefore the mainstreaming of learning content about climate change impacts should be considered during the initial planning and programing stage of the awareness and capacity-building programs.

Lastly, regarding international networks and partnerships, that there is no international cooperation project focused mainly on climate-resilient extension services is a problem. Considering that agriculture and the food system are critical for developing countries, and that rural areas in developing countries are especially affected by the impacts of climate change, projects to deliver extension services in at-climate-risk regions should be planned and implemented not only for their resilience but for the effective implementation of the ODA projects funded by the Korean government. Table 10 summarizes the points suggested above.

Table 10: Current approaches, problems addressed, and potential paths to improving agricultural extension and technology dissemination services directed toward a climate-resilient food system in Korea

Approaches of agricultural extension and technology dissemination services	**Problems addressed**	**Way to improve the resilient food system**
Application of ICT technology	• Lack of computer skills of the elderly generation in the rural region • Difficulties in keeping the knowledge of extension officials and farmers about climate-related ICT technologies (smart farms) up to date • Initial investment cost burden	• Education programs and training sessions on computer skills; more intuitive, easily accessible database interface • Adoption of on-site expert consulting services; promulgation of manual and guidance on application of smart-farm technology • Diverse funding resources in addition to governmental supports
On-site, packaged, and appropriate technologies geared to the regional context	• Unwillingness of farmers to be involved with the adoption of climate-resilient technologies • Insufficient policies to promote the appropriate technologies	• Match farmers' needs with measures employed to enhance climate change resilience • Policy planning, R&D, and promotion of the appropriate technologies
Awareness and capacity building of farmers	• Lack of learning materials or programs focused on the effects of climate change impact themselves	• Mainstreaming of learning content (toward farm households) about climate change impacts
Networks and partnerships abroad	• Nonexistence of international cooperation projects focused on climate-resilient extension services	• Project planning and implementation focused on extension services in at-climate-risk regions to increase those regions' resilience

Source: Author's compilation

Turning to the implications for developing countries, we will make three points. First, the extension project planners need to do a proper needs assessment under the regional context so that the project gets the best results out of the on-site activities. Extension and technology dissemination services and climate change countermeasures both depend on understanding the regional context, background, community culture, and willingness of residents to "own" the project—a one-size-fits-all solution is inefficient and risks failure. Korea had a learning experience with an ODA project in Mongolia that included creating an animal disease database. It was originally planned to have a web database and mobile application that could share photos and video files of the animal diseases. The original intent of the project was to develop and stabilize an ICT program for the effective management of animal diseases in remote areas. However, a poor understanding of the regional context led to project underperformance. In rural Mongolia, the rate of smart mobile phone use vastly lags behind the rate in Korea, which meant only a few people could access the mobile application for photo and video sharing, and thus the database and mobile app was underused. Clearly, for effective implementation of counteractive programs on a regional level, a needs assessment with a sound understanding of the regional context is imperative. Naturally, this is interrelated with capacity building and empowerment of the regional extension offices and their staffs, because they are already experienced experts with a broad regional network and have an in-depth understanding about the regional context. Thus, supporting and empowering the regional office branches with larger budgets and more staff, as well as cooperating with regional staffs during the project planning and implementation stage, can raise the efficiency and effectiveness of policy measures.

Second, an active international network should be formulated and maintained under a win-win strategy. This includes a network consisting of developed and developing countries, and another network among the developing countries. In the first case, developing countries can learn and benefit from the developed countries' advanced technologies or good practices, while the developed countries can widen their range of R&D activities and international cooperation. In the second case, by sharing their own practices and difficulties, developing countries can create a "South–South" cooperative relationship, which is desirable for the self-reliance of developing countries. In reality, in addition to the cases of AFACI and KAFACI mentioned earlier, diverse kinds of networks have been formulated that jointly create meaningful results.

Lastly, the development community should promote adoption of appropriate technologies. These can be customized technologies from the frontier countries or newly adopted technologies for easier access and adoption. Both should be promoted to expedite catching up. The first can be achieved with technology transfer and joint research programs with developed countries or relevant international organizations. For the second, a micro approach that addresses the "bottom of the pyramid" should be part of the developmental agenda, rather than succumbing to enthusiasm for advanced infrastructure and sophisticated technology. In other words, simple observation and a conceptual shift can help create the technologies that can make a huge impact toward climate resilience. For example, just as the *doombeong* in rural Korea was revived as a new climate-resilient measure, current traditional customs such as rain-harvesting jars or small reservoirs in the field can be developed as appropriate technologies for climate resilience. Therefore, case studies or additional research projects dedicated to producing the best technology model for the case at hand should be promoted and disseminated.

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