Korean Policy Responses for Ensuring Food Security in the time of Climate Change[1]

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INTRODUCTION

Climate change is caused by global warming. It refers to the average increase in global temperature, and has become a megatrend that will lead to significant changes in future society. The UN Intergovernmental Panel on Climate Change (IPCC) offers up substantial scientific evidence supporting this conclusion in its Fifth Report on Climate Change (2014). The effects of climate hange has caused a lot of disasters, such as floods and droughts which became more frequent and intense, land and water more scarce and difficult to access, and increases in agricultural productivity even harder to achieve. These impacts are increasing the risk of food supply in both global and local levels. Without considerable efforts on improving people's climate resilience, it has been estimated that the risk of hunger and malnutrition could increase in the near future.

Current global food supply is now confronted by the challenges of climate change, world population growth, the economic growth of emerging countries (including the BRICs) and increased demand for bioenergy sources, wherein the dominant paradigm is switching from food surplus era to food shortage era (or imbalance). Increasingly frequent incidents of abnormal weather and changes in ecosystems tend to decrease food productivity, while at the same time, the growing population contributes to rising demand for food, resulting in food shortages. Additionally, major countries in the world now use more bioenergy sources. These sources had been suggested as one method of adaptation to climate change. As a consequence, there is a globally increasing demand for biofuels, with maize and sugar cane being the main feedstock. This is a key factor in the rising demand for grains. This is an important problem because biofuel feedstock supply is competing with the demand for food. It is projected that climate change decreases the productivity of the food production system, which again brings about increased competition within the demand for grains. This is a key driver in the threats to food security in terms of both global and local levels.

Food security has to be maintained to cope with instances of food shortages or any sharp rise in food prices. Since the World Food Summit in 1996, the FAO has defined food security as “all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life”. This definition of food security by the FAO provides a systematic framework that food

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security is accomplished “when sufficient food is available, people have access to the food, and that food is well utilized”.

Examples of factors threatening food security include climate change, increased production of biofuels, the introduction of venture funds, and the prevention of food exports by food exporting countries. Of all these factors, climate change has the greatest impact on food security. The fundamental driver of global agflation in 2008, the global grain price rise in 2010, and cabbage price rise in Korea has been caused by abnormal weather under climate change, e.g., droughts, floods, and heavy rainfall.

So far, food security has been an issue in less developed countries, in particular, those countries which have experienced unstable political situations or weather patterns. However, even if developed countries, which had previously not experienced food shortages, are increasingly concerned about sustainable food supply. The report ‘Global Risks 2014 by the World Economic Forum’ defines climate change mitigation and adaptation failure as the fifth global risk, and food crises as the 8th risk among the top 10 global risks (World Economic Forum 2014). In addition, the FAO, the OECD, and the World Bank are now discussing the important issue of climate change and food security. Indeed, when the World Summit on Sustainable Development was held in Rio de Janeiro, Brazil from June 15 to 22, 2012, it reviewed the effort for sustainable development for the past 20 years, by examining the following criteria: climate change, energy, resource efficiency, food security and land use, water shortage, and biodiversity, which serves to illustrate that the key agenda items stressed food security and sustainable agricultural development.

The food obtained from crop production plays an important role in supplying the energy and nutrients necessary for the survival of the human race and therefore securing a stable food supply has been an essential challenge at all times and places. Climate change is expected to continue for a considerable period of time during which time unusual weather phenomena will become both more frequent and intense. In this context, this paper deals with the impacts of climate change on Korean food supply, and the countermeasures conducted by the Korean government in coping with climate change.

SITUATION OF KOREAN FOOD SELF-SUFFICIENCY

Korea has been a large net food importing country in the world for a long time. This reflects largely rapid income growth and changes in dietary patterns and has been facilitated by expansion of agricultural trade liberalization. Thus, Korea is a significant net food importer. With a population of about 50 million and a rapidly growing standard of living, Korea is a very important market for exporters of cereals, including feed grains and livestock products, fruits and processed foods. Imports of agricultural products grew 72 times from US$ 0.5 billion in 1970 to US$ 36.1 billion in 2014. During the same period, export of agricultural products increased from US$ 0.1 billion to US$ 8.2 billion. The agricultural trade deficit has also increased from US$ 0.4 billion in 1970 to US$ 27.9 billion in 2014 (Table 1).

Table 1. Agricultural trade and food self-sufficiency

(Unit: US$ billions, %)

Classification		1970	1980	1990	2000	2014
Import	Nationwide (A)	1.8	21.6	69.8	160.4	525.5
	Agriculture (B)	0.5	3.1	5.4	6.8	36.1
	B/A (%)	27.8	14.4	7.7	4.2	6.8
Export	Nationwide (A)	0.9	17.2	65.4	172.3	572.7
	Agriculture (B)	0.1	1.1	1.1	1.3	8.2
	B/A (%)	11.1%	6.4%	1.7%	0.8%	1.4%
Balance of payment	Nationwide (A)	-0.9	-4.4	-4.4	11.9	47.2
	Agriculture (B)	-0.4	-2	-4.3	-5.5	-27.9
Quantity-based Food self-sufficiency (%)		80.5	56.0	43.1	29.7	24.0

Source: Ministry of Agriculture, Food and Rural Affairs (MAFRA), Statistical Yearbook 2015

Even though, import of agricultural products rose sizably in terms of absolute value, its share in the total national imports has dropped sharply. The share of agricultural products in the total national imports fell to 6.8% in 2014 from 27.8% in 1970. During the same period, the share of agricultural products in Korea's exports also decreased significantly from 11.1% to 1.4%. This is mainly because of the development strategy of industrialization and non-agricultural export-orientation which have been adopted by Korean government since 1960s.

The Korean self-Sufficiency rate in terms of weight for all grains (including feed grains) has continuously dropped since the 1970s. The self-sufficiency rate of grains has fallen from 80.5% in 1970 to 23.6 % in 2014. In 2014, self-sufficiency rate for barley was 24.8%, 0.7% for wheat, 0.8% for corn, and 11.3% for soybeans (Table 2). Rice, the main staple food grain in Korea, has almost reached a self-sufficient level. Average self-sufficiency rate for rice was 95% in the recent three years of 2011~2014. In other words, considerable amounts of most food grains except for rice are imported from oversea markets in Korea.

Table 2. Self-sufficiency of major grain in Korea

(Unit: %)

Classification	**1985**	**1990**	**2000**	**2010**	**2014**
Rice	103.3	108.3	102.9	104.6	95.7
Barley	63.7	97.4	46.9	24.3	24.8
Wheat	0.4	0.1	0.1	0.9	0.7
Corn	4.1	1.9	0.9	0.9	0.8
Soybeans	22.5	20.1	6.8	10.1	11.3
Total for all Grains	48.4	43.1	29.7	27.6	24.0

Source: Ministry of Agriculture, Food and Rural Affairs (MAFRA), Statistical Yearbook 2015

IMPACTS OF CLIMATE CHANGE ON FOOD SUPPLY

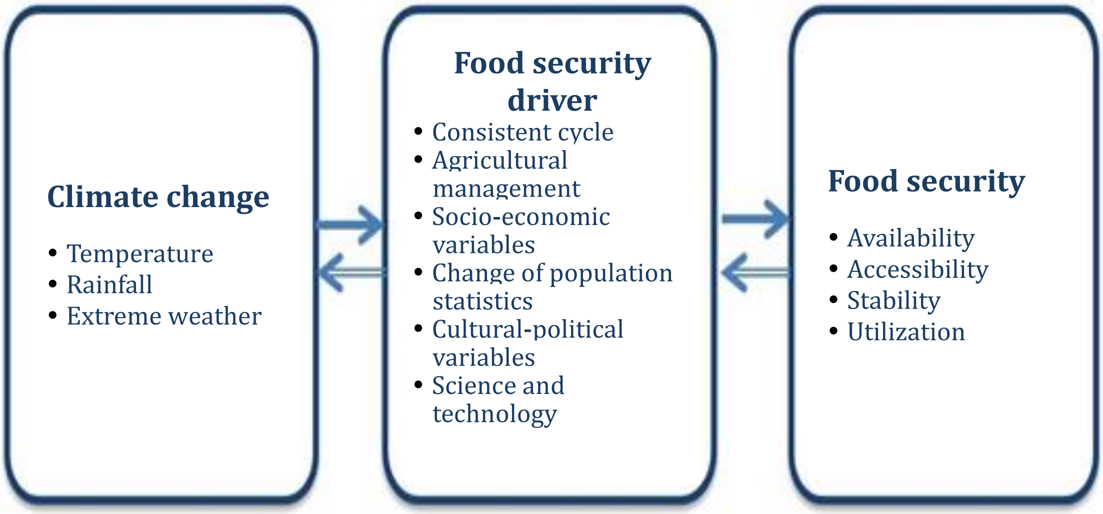
Connection between climate change and food security

The impacts of climate change on food supply are categorized both as a direct impact on Korea's agriculture and as an indirect impact on the changing food production by overseas major crop producers. Climate change similarly impacts Korea's agriculture and overseas agriculture. However, the level and scale of impact depends on each individual country's latitude. Climate change has partly positive effect on Korea's agriculture due to the fact that the cultivation period can be extended to enable new crop varieties to be introduced. However, it has mostly had a significant negative effect due to reductions in usable water, a shortening of crop growth periods due to temperature rises which result in lowering of crop yields and crop quality, a lowering of fruition due to poor pollination brought about by high temperatures, increasing lodged rice and salt damage, and disturbances to the agricultural ecosystem due to revitalized diseases and pests.

Climate change also impacts other countries which produce major crops, the impact varying with the level of temperature rise. Cold high-latitude regions in the northern hemisphere will experience a positive effect, i.e. increased crop production thanks to temperature rise. However, low-latitude regions will have the negative impacts of increased crop stress due to reduced water availability, lower crop yields and quality due to temperature rise, disturbed ecosystems due to increased occurrence of diseases and pests, restricted water for agriculture due to water shortages, and submerged agricultural land in coastal areas due to rise in sea level. In addition, while crops grow well in their native climate conditions, climate change contributes to a northward shift in the crops' northern cultivation limit as well as the ideal land for cultivation. This is also true in other countries besides Korea. The northward shift of land ideal for cultivation can become both a crisis, or an opportunity, depending on the region. It is thus not reasonable to categorize these impacts as either positive or negative.

Because climate change impacts food security it is necessary to understand the link between the factors which cause climate change, and contribute to food security so as to clarify the impacts of climate change on food security (Figure 1). A factor which strongly affects climate change and food security is the biophysical system. The cycle and management of the biophysical system is affected both directly and indirectly by climate, which has components of, for example, socio-economic variables, variables of population statistics, and cultural-political variables. The change of climate variables can affect demand for, and outcomes of, science and technology. The factors affecting climate change also have an effect in four factors of food security, that is, availability, accessibility, stability and utilization, and feedback thereof often returns in the reverse direction.

Fig. 1. Connection between climate change and food security



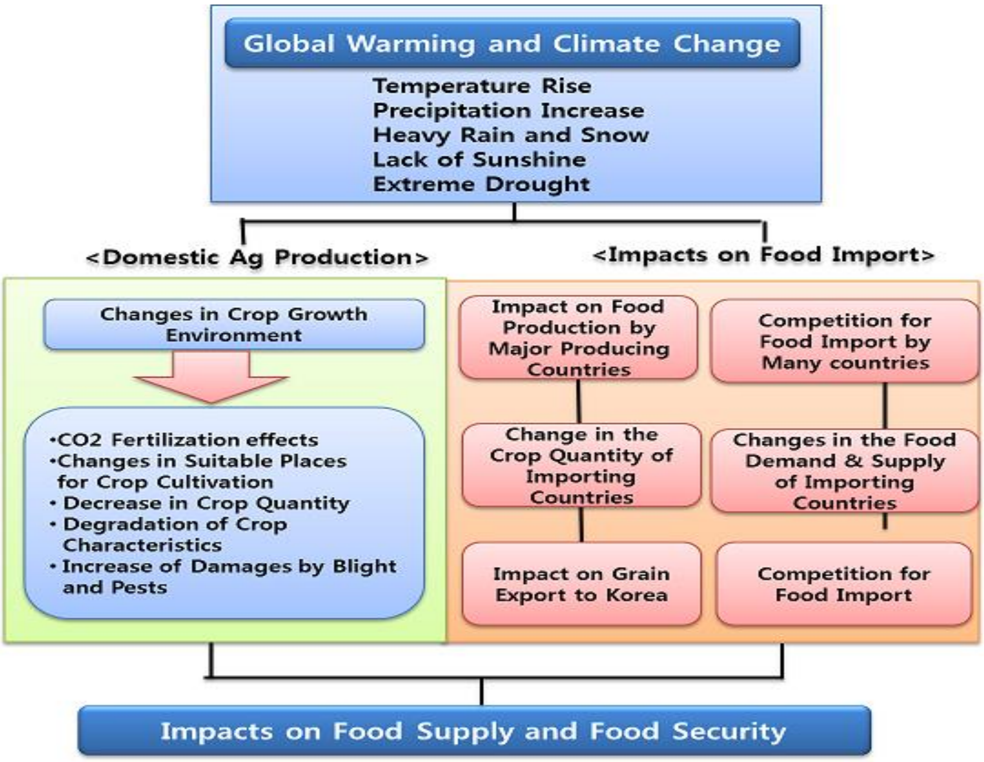
Source: Ziervogel and Ericksen (2010), p.528.

Food accessibility may be affected by extreme weather, for example by droughts and floods. Heat stress may destroy roads. Infrastructure, including roads, may be damaged by frequent flooding, which in turn may affect food distribution. Food utilization may be affected by climate change, depending on the types or volume of usable food, and may bring about far reaching changes in terms of nutrition. A recent investigation has also shown that climate change also directly impacts human health. Bacterial diseases, e.g., malaria, have a tendency to spread to new regions, where they previously did not have a presence, due to global warming. Water-borne diseases, e.g., cholera or dengue fever, also tend to spread due to more frequent flooding.

Approach to Food Supply Analysis

Climate change involves temperature rise and increased rainfall. It also accompanies an increased frequency in the incidence of abnormal weather events, including abnormally heavy rainfall and snowfall, a lack of sunshine and the like. Such climate change negatively impacts Korea's agricultural production, and also on production of major grains in exporting countries. Although the level of impact may vary, climate change impacts carbon dioxide fertilization, the shifting of land ideal for cultivation, negative crop yields and crop quality, and increased damage from pests and diseases. The impact of climate change may differ depending on the region and its latitude, but will certainly have an effect on many major grain export countries and their agricultural production which will inevitably have adverse affect in Korea's ability to import food (Fig. 2).

Fig. 2. Conceptual framework of climate change affecting food supply



Source: Kim, C.G. *et al*. (2013), p. 51

In order to analyze the impact of climate change on food supply, the Korea Agriculture Simulation Model for Climate-Agriculture Relations (SIMCAR) (Kim, C.G. *et al*., 2012) was created. It was envisaged that it would be used in conjunction with the unit yield change of the crop growth model and the agricultural simulation model of the KREI (KASMO).

The unit yield change projected by using the IPCC's climate change scenario was applied to the estimate of unit yields so as analyze the impact on grain supply. The production of rice, the staple grain crop of Korea, was analyzed. The years for the analysis were set as 2020 and 2030 for mid- and long-term impacts, and 2050. In this study, the result obtained by KASMO model simulation with climate change was compared with the KASMO's baseline with no assumption of climate change.

Impacts of Climate Change on Rice Supply and other commodity's production

The RCP (Representative Concentration Pathways) 8.5 scenario was used to estimate the impacts of climate change on rice yield of Korea (Table 3). The RCP8.5 scenario is one of scenarios established in the IPCC's 5th Assessment Report which assumes the continuation of current trends (without reduction) of greenhouse gas emissions.

The rice unit yield was estimated to be 0.7% in 2015, -1.2% in 2020, -5.2% in 2030 and -13.1% in 2050 in comparison with the average yield by using the RCP8.5 scenario.

Table 3. Estimate of rice unit yield under climate change

Unit: kg/10a, %

Scenario	Average unit yield	2015		2020		2030		2050	
		Unit yield	Comparison to average yield	Unit yield	Comparison to average yield	Unit yield	Comparison to average yield	Unit yield	Comparison to average yield
RCP8.5	498.3	501.5	0.7	492.3	-1.2	472.6	-5.2	433.1	- 13.1
Rice Self-sufficiency		92.0%		90.8%		77.9%		55%	

Source: Kim, C.G. *et al*. (2013).

For a precise analysis of impacts of climate change, the Korea Rural Economic Institute established the Korea Agriculture Simulation Model for Climate-Agriculture Relations (SIMCAR) by liking crop growth models and farming simulation models. The analysis of impacts of climate change using SIMCAR shows that the rice self-sufficiency rate as of 2050 will fall to around 50% due to climate change, creating a food security issue where half of rice consumption should rely on imports.

There are a number of climate change impacts on other agricultural products through biological changes such as flowering and heading of crops; quality changes of crops; and changes of major production areas for crops following the northing latitudinal shift of suitable lands for cultivation. The current status of changes in suitable cultivation areas shows that the northern limits for cultivation for winter Chinese cabbages, winter potatoes, rye, apples, peaches, tangerines, and green tea have already gone north considerably. The winter Chinese cabbages and winter potatoes, produced only in Jeju Island until 1985, are now cultivated in Korea’s southern seaboard. Cultivation areas for apples, which were Daegu and Gyeongsangbuk-do, in the past, have been also expanded to include the northern Gyeonggi-do including Paju, Pocheon, and Yeoncheon regions.

The northern limits for cultivation for peaches, tangerines, and green tea moved up to Gyeonggi and Gangwon Provinces from Gyeongsangbuk-do; Geoje, Goheung, and Naju regions from Jeju; and Goseong in Gangwon-do from Boseong and Hadong regions, respectively. In particular, the safe cultivation zones for rye moved from below Chungcheong-do to the middle of Gyeonggi-do.

In 2013, the Rural Development Administration of Korea developed a forecast map for changes in cultivation areas using the “Future Digital Climate Map for Agricultural Use” in order to respond to climate change. The forecast map was developed based on the scenario that climate change continues while crop types and cultivation techniques are maintained, and upcoming changes of cultivation areas for Korea’s major six fruits (apple, pear, peach, grape, sweet persimmon, and tangerine) between 2010 and 2090 were forecast by 10 years in detail.

According to the forecast map, the total cultivation area (suitable cultivation areas and cultivation-capable areas) for apples will continue to decrease, while that for pears, peaches and grapes will inch up until the mid-21st century and start to decrease. The cultivation-capable areas for sweet persimmons and tangerines will increase. Estimates of cultivation-capable areas demonstrate that both suitable cultivation areas and cultivation-capable areas for apples will rapidly decrease compared to those areas over the past 30 years, the cultivation will occur only in parts of Gangwon-do.

In general, a temperature rise of 1℃ translates into the 80 km of northing and a 150m increase in altitude for suitable cultivation areas. Therefore, cultivation for subtropical crops is projected to increase and that for indigenous crops will decrease due to climate change.

COUNTERMEASURES FOR CLIMATE CHANGE

The Korean government prepared a policy foundation that enables inter-department, systemic and consistent implementation of countermeasures for climate change. This is through the enactment of the "Framework Act on Low Carbon, Green Growth" in 2010. It is a five-year plan for the national strategy of low carbon, green growth which is to be established every five years and implemented for the period. In terms of mitigation, Korea sets a national goal of reducing greenhouse gas emissions and carries out necessary measures.

The agricultural sector has been implementing both adaptation and mitigation policies in order to be preemptive to climate change. The following adaptation measures are being carried out in order to enhance agricultural productivity in response to climate change.

First, the R&D projects for development of agricultural green technologies were implemented between 2009 and 2013, reaping excellent outcomes such as development of varieties resistant to high temperature and disasters and selection of excellent resources. In 2014, the "Second-step Mid- and Long-term Plan to Develop Agricultural Technology for Climate Change," slated to end in 2023, was established.

Second, the system that predicts outbreak of plant diseases and insect pests from outside Korea and the technologies that diagnose infectious livestock disease were developed and have been operated.

Third, the early warning system for meteorological disasters was established and has been operated. The system is being operated on a trial basis in order to preemptively respond to climate disasters that would wreak havoc on Korean agriculture. The system provides detailed weather forecast customized for farm households and farms. Together with development of technologies that quantify the level of agricultural meteorological risks for major crops, this early warning service has been expanding nationwide.

Fourth, the agricultural disaster insurance, which functions as a risk-management tool, has been expanded. In order to respond to climate change preemptively, efforts have been made to expand the range of insurance targets and subscribers, thereby creating favorable conditions to farms and achieving economic stability of farm households affected by natural disasters.

Fifth, strategic and effective water management has been carried out. In order to prepare for any future damage incurred by climate change, the repair or renovation of agricultural facilities including irrigation facilities, the construction of new facilities, and the drainage improvement for farmlands prone to floods have been carried out.

Sixth, an increasing number of disaster prevention facilities have been built. Efforts have been made to expand ICT Convergence-type Smart Farms that reduce the input of energy, water, and chemical fertilizers and increase agricultural productivity by providing design standards for crop cultivation facilities which reflect aspects and prospects of climate change.

Policies for reducing greenhouse gas (GHG) generated in the agricultural sector, divided into those for crop and livestock sectors, have been implemented. For the crop sector, the existing method of keeping water fully filled in farming areas was shifted to the method of supplying water only when it is needed, in order to reduce the amount of N_2O. It turned out that this method would reduce greenhouse emissions by 40%. In addition, the use of chemical fertilizers is being minimized by encouraging the use of organic fertilizers.

In the livestock sector, there are policies for using electricity generated through livestock excretion and for increasing the number of facilities that produce composts and liquefied fertilizers. In order to reduce ammonia gases generated during the livestock farming processes, high-quality bulky feeds have been continuously produced and disseminated.

In the horticultural sector, support for new renewable energy facilities including the heating and cooling system using geothermal heat and energy-saving facilities including multi-layered thermal screens have been made in order to reduce the usage of fossil fuels.

The "Low Carbon Certification System for Agricultural and Livestock Products," the Korean version of carbon footprint system, has been introduced to help agricultural enterprises develop capabilities for GHG reduction, thereby achieving reduction goals. The low carbon certification system helps ethical consumers to purchase agricultural produce certified as low carbon products and to participate in the reduction of GHG emissions and the initiative for raising energy efficiency. In addition, the "Voluntary GHG Reduction Program of Agriculture and Rural Areas," the Korean version of carbon offset program, has been implemented. Through this program, the government, after a verification process, either supports trading of certified emissions reductions or purchases them from farmers who voluntarily choose agricultural techniques generating low carbon and achieved the reduction goal. The third verification organization issues certificates of GHG reductions made by farm households in accordance with international standards, and the government purchases the emissions reductions at 10,000 won per ton, providing an income source for farmers while reducing energy costs.

The Korean government plans to carry out in-depth, national-level research and analysis of impacts of climate change on the environment of Korean agriculture and rural areas. The reports on impacts of climate change and vulnerabilities of the Korean agricultural sector and the results of fact-finding investigations, created through collaboration with related research centers, will be released every five years. Those reports are to be utilized as preliminary data for designing policies in order to systematically respond to climate change. In addition, the government plans to establish a "Farm-unit Early Warning System for Meteorological Disasters" by 2018 and provide in advance 12 types of meteorological information (including temperature, precipitation, and wind) for 15 agricultural items. On top of this, soil moisture and soil nutrient amounts of each farm are measured using IOT technologies in order to identify the right time for water supply and fertilizers and to prevent damage from diseases and insect pests.

FUTURE TASKS FOR ESTABLISHING A SOUND FOOD SECURITY WITH CLIMATE CHANGE

Enhancing the Domestic Production Capacity

Key tasks for enhancing the domestic production capacity, which must be undertaken as a matter of priority, include the development and dissemination of climate change adaptation technology, the conservation of farmland and measures to ensure its efficient use, the increasing practice of climate-smart agriculture (achieved by the increasing use of convergence technology) coupled with the modernization of agricultural infrastructure.

First, it is necessary to develop disaster-tolerant varieties which will permit agricultural adaptation to climate change. In particular, it is necessary to develop Japonica rice varieties suited to the subtropical climates of the future. It is also important to develop virus-resistant varieties so as to offset the increased incidence of crops diseases and pests under conditions of climate change, including rice blast disease and rice sheath blight.

Second, customized cultivation technology needs to be developed that will allow agriculture to adapt to climate change. This includes postponing marketing time by rice seeding and transplanting time control, or changes to the cultivation scheme such as direct planting which will ameliorate reductions in rice yields or grain quality.

Third, it is necessary to establish adaptation strategies customized to the needs of each variety of each major crop, taking into consideration Korea's production condition. This will allow for the establishment of a more stable supply base in Korea. The area of farmland, in Korea, shows a tendency of continuing reduction. It is necessary to develop strategies that will preserve 1.5 million ha (0.75 million ha for wet field farming and 0.75 million ha for non-wet field farming), and thus keep farmland use at approximately 120%.

Fourth, it is necessary to make plans that will allow for an increase in feed grain production so as to secure a sufficient food supply. The use of wet fields, which permit double cropping or triple cropping, should be maximized so as to secure feed crops[2] Advanced rice harvesting techniques can reduce damage caused by more frequently occurring, stronger typhoons, diseases and pests. This will allow crop cultivation in wet fields to be maximized. Increases in the production of feed crops will contribute to healthy livestock farming, and lower the nation's dependence on imported feed crops.

Fifth, it is necessary to practice Climate Smart Agriculture based on advanced convergence technology, e.g., information technology (IT), biotechnology (BT), and nano-technology (NT) so as to build a stable food supply basis that can endure the dangers of abnormal weather and uncertainty. In a mid- and long-term period, it is necessary to develop and disseminate advanced convergence technology, e.g., plant factory-based technology which is an intensive highly productive system to practice climate smart agriculture, and photosynthesis technology for increased yields per unit area (Lee, J.M., 2011). It is also necessary to develop technology for incorporating convergence technology, e.g., bioengineering, information and communication, and robot engineering to overcome geographical limitations and significantly improve productivity. Farmers want agricultural technology that can precisely identify climate change variables and/or abnormal weather in advance. These predictions will allow them to stay a step ahead of climate change as opposed to struggling to adapt. To this end, it is necessary to study how to predict changes in regional climate resources so as to allow the construction of an agricultural early warning system.

Lastly, it is necessary to build infrastructure for stable water management because the frequency and intensity of water shortages and droughts is expected to rise as climate change advances. Only 66% of South Korea's 980,000 ha of rice paddy is irrigated and thus capable of enduring a 10-year drought, with most irrigation facilities being at least 30 years old and thus in need of investments in repair and maintenance[3] High-tech equipment is needed for irrigation facilities as this will strengthen the disaster handling capacity to a degree sufficient to cope with abnormal weather.

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[2] Farmers in Jangheung, Jellanamdo harvested rice on August 23, 2012, seeded the field with feed miller in early September, cultivated Italian grass which is a bulky feed crop harvested in April, 2013. This is exemplary triple cropping.

[3] Approximately 88,000ha of rice paddies are actually exposed to regular submergence, and there is always a danger of large-scale submergence due to localized heavy rain because more field crops are cultivated in rice paddies. Therefore, there is an urgent need to repair and reinforce old irrigation facilities, mainly water sources including reservoirs, but also drain facilities and pumping facilities so as to ensure a continuing stable food production adapted to climate change.

Improving Buffering Capacity

Improving buffering capacity will allow the nation to cope with the impacts of climate change. This will necessarily involve enhancing resilience and biodiversity, building a risk management system, securing food storage, both in Korea and in other countries, building overseas food bases, and efficiently using the global grains market.

First, it is necessary to enhance resilience and biodiversity as this will mitigate the impacts of climate change[4] Resilience is the capacity to endure changes and tolerate stress while maintaining the functions and structure of the agricultural ecosystem. It provides a buffer against the impacts sustained by the production sector under conditions of climate change. Resilience enhancers can strengthen sustainable agriculture, improve biodiversity, improve soil fertility and conserve tillage, and practice organic farming. Special attention should be paid to conservation and the management of biodiversity so as to enhance resilience in agriculture. Biodiversity acts like an insurance policy to mitigate impacts on natural resources when large and far reaching changes occur in a wild ecosystem (Cotter and Tirado, 2008).

Second, it is necessary to formulate a plan on how to use cultivated land step by step and a nation-wide emergency food supply plan, for example, always storing high-yield seeds that can be cultivated in emergencies so as to cope with global food crises due to abnormal weather. It is necessary to specify a cultivation area for the cultivation of more wheat, barley, beans and maize in an emergency. This requires a seed store, one built with low temperature storage facilities so as to reduce the possibility of the seeds not germinating after long-term storage.

Third, it is necessary to vigorously establish and strongly enforce a global food storage program while also investing in overseas agricultural development. This will serve to ready the global grains market to cope with the great impact accompanying abnormal weather and so mitigate global grains price volatility. It is necessary to review the method of connecting the international public storage program promoted by '3 Asian counties' in relation to the food storage program with the domestic storage program. It is also necessary to build overseas food bases by positively developing overseas farms so as to secure food. Even under conditions where the use of natural resources is maximized, significant volumes of grains will need to be imported. A strategy for developing overseas farms is thus crucial to ensuring stability in the import of major grains including maize, wheat and soybeans. This will serve to improve food supply capacity.

Improving the Capacity for Policy Countermeasures

Key tasks for improving the capacity for policy countermeasures include refining and further using the climate change impact analysis models, expanding investments in research and development, building a system for vulnerability assessment, strengthening education and training, and providing climate change adaptation centers.

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[4] Agriculture focusing on maintaining biodiversity is the only tried and tested method of securing food production under climate change. Mixed cropping of two or more crops simultaneously on the same piece of land has been proven to enhance adaptation to irregular climate change. The best method to enhance tolerance to stress in a single variety is a new technology for improving varieties which does not need gene modification technology, e.g., MAS (Marker Assisted Selection. This is an effective strategy empirically suggested to enable agriculture to conserve biodiversity to be adapted to climate change (Cotter and Tirado, 2008).

First, it is necessary to develop and use a reliable impact analysis model which can be linked to policy formulation and adjustment; one which would meet the needs of policy makers and allow them to handle food issues on the basis of reliable science. In particular, the accurate identification of food supply and demand is needed for when a food crisis occurs due to abnormal weather. A model should be developed that can estimate the damaged area and reduced unit yields when abnormal weather occurs, identify the domestic grain production capacity that can be implemented by maximizing the use of domestic farmlands through cropping systems, including double cropping, and estimate demand for grains needed on the basis of the population and recommended dietary reference intakes.

Second, there is a need to make investments in studies and establish mid- and long-term R&D plans that can be adapted as climate change advances. R&D should continue to identify the impacts of climate change and predict the state of future agricultural ecosystem and changes in food productivity. Technology development should be divided into studies on how to build a framework for climate change impacts, a climate change monitoring system, vulnerability assessment, and prediction technology to facilitate it. The outcome of technology development should be linked to policy programs. In particular, priority key tasks for building a stable food supply system for adaptation to climate change need to include predictions on the frequency and intensity of abnormal weather occurrences, building an early warning system for predicting agricultural weather changes, building an efficient system for managing agricultural water, and the development of high-yielding varieties resistant to diseases and disasters.

Third, the ideal operation of the stable food supply system adapted to climate change should improve findings from studies, reflect farmers' needs, and provide a 'Center for Climate Change Adaptation in Agriculture (provisional)' so as facilitate the establishment and assessment of policies for adaptation to climate change in a comprehensive manner. The center should be responsible for comprehensive studies and policy program development that links the impacts of climate change with various policy programs developed and assessed by both central government and local governments. This will facilitate the building of a stable food supply system. The center should be responsible for assessing related policies in the future, analyzing the impacts of climate change for each field and item, designing a roadmap for each step of adaptation and mitigation actions and suggesting climate change adaptation actions in each region, based on a vulnerability assessment.

The Ministry of Agriculture, Food and Rural Affairs (MAFRA) should be given the leadership to effectively promote climate change adaptation policies in agriculture, and implement ideal role sharing among related subjects, including research institutions, involved organizations and farmers.

CONCLUSION

Climate change is predicted to continue while having significant or mild impacts on agriculture. Uncertainty about changes in temperature and rainfalls, and frequent abnormal weather in which most countries will experience making precise predictions difficult. However, this will certainly have negative impacts on food security. It is generally accepted that climate change will have significantly greater impacts on agriculture in developing countries, where agricultural conditions are more vulnerable to shocks. Therefore, food security has long been an important issue for the least developed countries. In particular, those countries where both the political situation and the weather are unstable. However, people in developed countries who did not previously exhibit concern about food are now also becoming very concerned about sustainable food supply. Due to the fact that analysis has shown that Korea is situated in a region where climate change negatively impacts agriculture, it is important to establish a special adaptation scheme for food security.

The global situation, in so far as it concerns food supply and demand is quite volatile now. Food supply is not keeping pace with increasing demand for food. The main causes of this include climate change, growing world population, rapid economic growth in emerging countries, as well as demand for biofuels. Korea is in such volatile international conditions, with around 23% of its food supply domestically sourced. From this it is clear that Korea depends greatly on food imports, which implies an extremely vulnerable structure. Furthermore, it seems that climate change is acting to lower the productivity of most food production systems with the effect that food security has worsened. According to the IPCC Fifth Climate Change Assessment Report, major food crop production including wheat, rice and maize will be notably reduced from 2030. This prediction is even more grave, given that the regions in which the aforementioned major grains are produced would experience significant negative impacts of climate change.

The global community is bent on integrating food security with climate change, while at the same time preparing adaptation measures that will enhance the resilience of the food system. Such action is needed in order to find a breakthrough that will solve the issue of food and thus tackle the negative impacts of climate change. Korea also has urgent food issues due to climate change. These issues mainly arise from the rising frequency, and intensity of, abnormal weather, the need to shift crop cultivation limits further north, heavy snowfall in winter, abnormally low temperatures and hail in spring, a lack of sunshine in summer, stronger typhoons and heavier rainfall, drought and the more frequent occurrence of diseases and pests. If special action is not taken to increase food production by using domestic natural resources that can be adapted to climate change, a significant reduction of yields is unavoidable, and more food will need to be imported to offset the situation. In the future, the global grains market will propel food production to be notably increased unless innovative technology is deployed. Even if it should be so, expanding population will continue to contribute to rising demand for food. In this scenario, food price rises are inevitable. Sharp food price rise in the global grains market will inevitably result in even more serious food problems in developing countries. This will bring about increasing malnutrition, more hungry people, and wider gaps between rich and poor, the fed and the hungry, which will further highlight food supply as a global issue. Due to the fact that grains as food source is competing against its use as a biofuel input, the energy issue will have a great impact on the food issue. This may worsen the future battle over grains.

In this context, an important task is to find an answer to the questions of where Korea is currently positioned and what Korea should do. An in-depth review should be conducted into the possibility of buying food with funds at any time in the future, and importing a large volume of food. In this context, the importance of food security is thus understandable in connection with climate change.

In summary, the changing circumstances, both globally and in Korea, the issue of food security under conditions of climate change requires a switching of paradigms in terms of political action. The stable supply of food, adapted to climate change, requires that step-by-step positive actions to control national risks be taken. In particular, it is necessary to enforce the following strategies in each field so as to continue to ensure a stable food supply system. That is, analyze the impacts of climate change on food supply; develop and disseminate climate change adaptation technology; maximize the use of food production potential by using domestic natural resources; build a national food integration system in consideration of self-supply and independent supply; practice smart agriculture by using convergence technology including IT·BT·NT; and build a risk management system to tackle the uncertainty of climate change. Because improving systems for carrying out a variety of key programs will necessarily entail significant amounts of budget expenditure, there is a pressing need to obtain the understanding and support of all institutions concerned. These involved institutions would necessarily include policy makers, farmer groups and involved industries. This would facilitate organic cooperation and ideally role sharing.

It is expected that the nature of the policies that need to be prioritized and promoted, given the constraints of budget, organization and information will be addressed in future research. Also, in order for the solutions to key challenges to work properly in the field such that policy outcomes be maximized, a consortium of research in the related fields of agriculture, agricultural meteorology and agricultural economics should be created in preparation for the specific action programs for each field. Furthermore, follow-up studies should be conducted to verify the expenses required for developing reliable climate change impact assessment models and the effectiveness of the enforced policies. This field research can be used to prepare effective measures in the struggle to build a stable food supply system.

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