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연구노트

Implementation of Agrometeorological Early Warning System for Weather Risk Management in South Korea

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ABSTRACT

The purpose of the farmstead-specific early warning service system for weather risk management is to develop custom-made risk management recommendations for individual farms threatened by climate change and its variability. This system quantifies weather conditions into a "weather risk index" that is customized to crop and its growth stage. When the risk reaches the stage where it can cause any damage to the crops, the system is activated and the corresponding warning messages are delivered to the farmer's mobile phone. The messages are sent with proper recommendations that farmers can utilize to protect their crops against potential damage. Currently, the technology necessary to make the warning system more practical has been developed, including technology for forecasting real-time weather conditions, scaling down of weather data to the individual farm level and risk assessments of specific crops. Furthermore, the scientific know-how has already been integrated into a web-based warning system (http://new.agmet.kr). The system is provided to volunteer farmers with direct, one-on-one weather data and disaster warnings along with relevant recommendations. In 2016, an operational system was established in a rural catchment (1,500 km^2) in the Seomjin river basin.

Key words: *Agrometeorology, Early Warning Service, Farmstead-Specific, Weather Risk Management*

1. Background

Climate change and extreme weather can cause increased weather hazards and natural disasters, posing a serious threat to humanity. In response to this, government organizations similar to the National Emergency Management in Korea are being operated around the world. Globally the United Nations (UN) established the UN International Strategy for Disaster Reduction (UNISDR) to encourage inter-governmental cooperation as a means to reduce disasters (UNISDR, 2001).

Disaster management is generally divided into crisis management and risk management. As it is impossible to avoid weather crisis such as storm and torrential rainfall, the focus is on post-analysis and recovery after a disaster. Risk management, on the other hand, puts emphasis on prevention and protection through prediction and preparation (Wilhite *et al.*, 2000). The UNISDR adopted a framework for action from 2005 to 2015, focusing on prevention and preparedness (UNISDR, 2005). To this end, it emphasizes the implementation of an early warning service system for identification of potential risks.

A disaster occurrence and its size depend on the probability and strength of weather risk and vulnerability of the exposed targets (human and plant community). An early warning system is one of effective tools that can contribute to the reduction of vulnerability. Around the world, government units have already developed early warning systems that cater to their own purposes such as urban settings, agricultural environments and forests, and the provision of related services. Recently, climate change has made the dependency of agriculture to weather more critical. Climate change has increased the frequency of weather extremes, led to serious damages to the agricultural sector in some region. While climate extremes occur at a variety of levels, alleviating their damaging effects is only possible at a limited scale.

In this context, the Agrometeorological Early Warning Systems are effective, only when the systems are firmly built based on accurate and site-specific agricultural information.

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However, the existing systems often lack site-specific data on adverse weather events. The particular circumstances of farmlands are generally neglected in the system. Furthermore, the mechanisms do not consider the 'chronic long term effects' of adverse weather events or the combined effects of two or more weather elements.

In this regard, the National Institute of Agricultural Sciences (NAS) under the Rural Development Administration (RDA) in South Korea has designed a risk management framework for individual farmstead that is threatened by the detrimental impacts of climate change and its variability.

2. Changes and Needs

The early warning system started with the Global Information and Early Warning System (GIEWS) established by the Food and Agriculture Organization (FAO) in 1975 to respond to the global food crisis in the early 1970s. The goals of GIEWS is to reduce suffering from famine by collecting accurate data on the supply and demand of food in various venues such as continents, nations and areas, and deliver them to the corresponding policy makers at the right time (FAO GIEWS, 2017).

Another example of these systems is the Famine Early Warning Systems Network (FEWS NET) established by United States Agency for International Development (USAID) and United States Department of Agriculture (USDA). It predicts the status of supply and demand in specific areas or nations, and issues a warning report in advance to prepare for any forecasted food shortage (FEWS, 2017).

Unlike aforementioned systems, the early warning system for weather risk management in agriculture sector needs to be designed and serviced on an individual site (field, farmstead) level. It is also required to predict faster, improved information accuracy and delivery methods (the Internet and mobile phone), provide the right information to the right people at the right time at the right place, and personalize information (with countermeasures) (Gunasekera, 2004; Jagtap and Li, 2004; Stone *et al.*, 2004).

3. Fundamental Concept

The purpose of the Early Warning System for weather risk management in agricultural sector is to develop custom-made risk management recommendations for individual farmstead threatened by climate change and its variability. This service system quantifies weather conditions into a "weather risk index" that is customized to the crop and its phenology (growth stages).

When the risk reaches the condition that can cause any damage to the crops, the Early Warning System is activated and the warning messages are delivered to the farmer's mobile phone. The messages are sent with proper recommendations that farmers can utilize to protect their crops against potential damage. The early warning system has been developed, based on comprehensive technology including the scaling down of weather information to the field level and crop specific risk assessments for operational service. The system has been integrated into a cloud based service system.

4. Current Implementation

A framework has been developed to make the early warning system for weather risk management more practical since 2014, by integrating several techniques including forecasting real-time weather conditions, scaling down of weather data to the individual farm level and weather risk assessments of specific crops. Furthermore, the scientific know-how has been integrated into a web-based warning system (Fig. 1). The detailed framework is as follow.

4.1 Scaling Down of Weather Data at Field (Farm) Level

The surface air temperature data at 06:00 (day minimum) and 15:00 (day maximum) provided by the Korean Meteorological Administration (KMA) through the Korean Local Analysis and Prediction System (KLAPS) and digital forecast with 5 km grid unit were used as the background temperature. These data are corrected to detailed distribution map with a spatial resolution of 30m based on Inverse Distance Weighted method (IDW) for spatial interpolation considering various terrain effects (altitude, lapse rate, cold air accumulation, cold pool, advection etc.) (Chung *et al.*, 2006; Chung *et al.*, 2009; Kim and Yun, 2011; Kim et al, 2012; Kim and Yun, 2014;

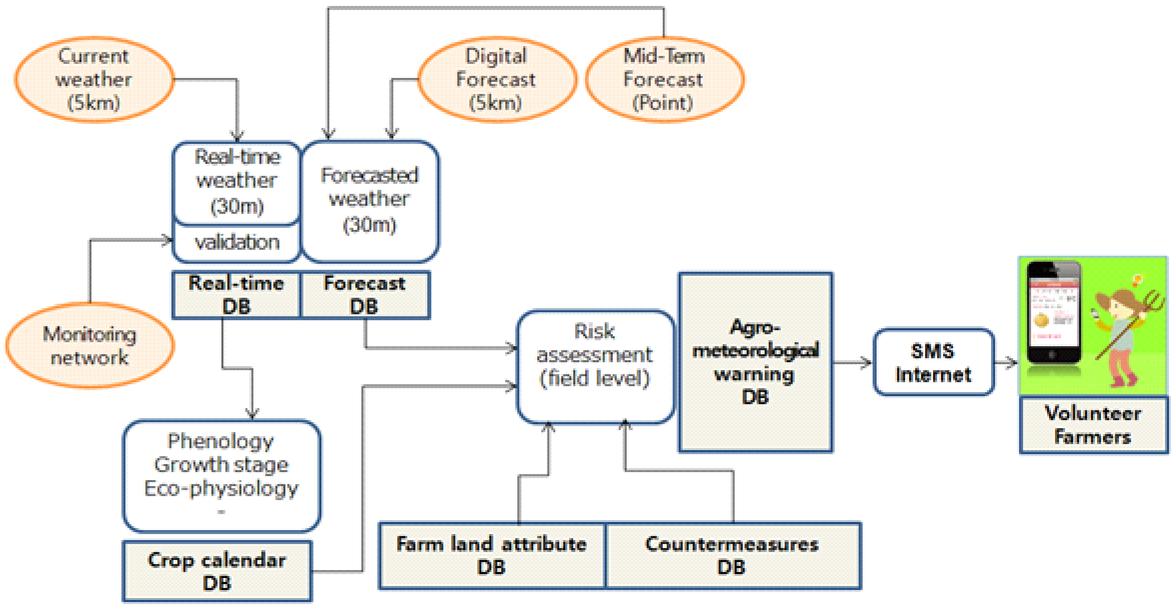

Fig. 1. Information flow of the farmstead-specific agro-meteorological early warning system for weather risk management.

Kim *et al.*, 2015; Kim and Yun, 2016).

In order to produce a detailed precipitation map (270 m grid unit) appropriate for the agricultural sector, the radar reflection intensity was applied to the KLAPS precipitation data (5 km grid unit) to form a 1 km grid resolution. The terrain effect was then reflected by varying the altitude-precipitation regression coefficient according to the slope direction based on 270 m digital elevation model (DEM) (Kim and Yun, 2013).

In the case of solar radiation, the Meterological Imager (MI) of the Communication, Ocean and Meteorological Satellite (COMS) provided by the National Weather Satellite Center of KMA was used for the solar radiation mapping. The surface solar irradiance at 15-minute intervals was continuously collected and converted into a daily solar irradiance in South Korea. The deviation between the actual solar irradiance measured at a nearby weather station and the satellite solar irradiance at the corresponding point was obtained. The distribution of the solar irradiance was estimated with a grid resolution of 30m by applying the solar irradiance rate (Yun, 2009; Kim and Yun, 2015).

Wind distribution has been refined using a micro scale urban climate model (MUKLIMO) to generate detailed wind fields from a medium scale wind vector (5 × 5 km) to a resolution of 270 × 270 m (Sievers and Zdunkowski, 1986).

4.2 Crop Specific Risk Assessments

The types of disaster affecting crops were classified as: freezing, frost, chilling, sunburn, high temperature, drought, wet, wind, and sunshine deficit injury. The mechanism of their occurrences were studied in order to derive the most relevant weather elements and were classified again according to the type of crop-cultivar. Then the growth stages were prioritized. In order to estimate the growth stages (phenology) of the crop, the thermal-time-based models such as the phenology, growth rate and growing degree day (GDD) were introduced. These models were used to develop a crop calendar in this study. Based on the crop calendar at a farmstead, the degree of disaster risk in the current and future weather condition is expressed as a relative risk index to normal climatic condition (Kim *et al.*, 2015; Yun *et al.*, 2015).

4.3 Integrated System and Service

The early warning system for weather risk management is connected to various system components, which consists of estimation of farm-level weather data with 30~270 m grid, calculation of crop specific risk index and delivery of risk warnings to farmers with relevant recommendations to avoid or reduce damage. It also includes distributed web GIS service with visual grasp (http://new.agmet.kr) and mobile text service that notify individual farmers in the service area (Shin *et al.*, 2015). It was employed and implemented in a rural catchment (1,500 km^2) in the Seomjin river basin with diverse agricultural activities. There were 600 volunteer farmers participating in this project in order to get the user-specific weather risk information.

5. Future Plan

The empirical studies have been conducted since 2014 under a 4-year (2014~2017) plan to make the system fully operational by a NAS cooperative research program. Under this plan, the system will be implemented in the Seomjin river basin (6,000 km^2), which accommodates over 60,000 farms and orchards. In addition, the evaluations of volunteer farmers will also be continuously fed back to NAS and reflected in the system. The diverse experience obtained through this study will be highly useful in planning and implementing a nation wide disaster early warning system for the agricultural sector. The system is a great leap forward in protecting agriculture exposed to weather extremes under climate change and its variability. This service system will be promoted nation wide starting 2018.

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