AGRICULTURAL DROUGHT FORECASTING AND WARNING SYSTEM

Jong Hoon Park¹, Jong Won Do², Kwang Ya Lee³, Bo Sung Koh⁴, Sang Il Lee⁵, Tae Hyun Ha⁶ and Won-Ho Nam⁷

ABSTRACT

Damage from agricultural droughts spread gradually on wide areas over a long period. In addition, due to climate change, the frequency and intensity of drought have increased. The drought of 2015 in Korea has been the worst due to lowest rainfall. It has been suggested that Korean government revisit the agricultural water management policy and incorporate in it the drought forecasting and warning system for effective drought management. In this study, new information of preparedness and mitigation planning for agricultural drought in Korea, including a long term plan and water saving strategy has been suggested. It analyses the previous drought status using the agricultural drought map, the prediction information related to drought damages, and the drought-related response capability of irrigation facilities. The system can be used to provide current and future drought conditions and the comprehensive data of drought evaluation for supporting decision makers. Also, the agricultural drought forecasting and warning system can give an opportunity to build the proper response for agricultural drought holistically and systematically.

Keywords: Agricultural drought, Drought management, Drought forecasting, Drought policy, Climate change.

1. INTRODUCTION

As global climate change has occurred, the occurrence of drought and its impacts have been increased across Korea. Despite the increase in droughts and its impacts in Korea since 2010, the responses to drought by governments are temporarily.

Moreover, the Korean government has not had any anticipatory defence system, which could announce drought condition and measures from its assessment and analysis. Therefore, the Korean government has realized that anticipatory defence for drought is priority to minimize drought damages.

Droughts, one of typical natural disasters are normal, recurrent, yet relatively infrequent features of climate (Wilhite 1997). Comparing to other natural hazards like

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flood and tsunami, drought’s impact emerge gradually on wide areas over a long period, and often last for years (Hayes et al. 2011; Wilhite et al. 2014). So, the preparedness is quite important and effective to mitigate the impacts from drought.

Effective drought management depends on drought monitoring, the ability to assess the current conditions and predict future drought development (Sheffield et al. 2014; Svoboda et al. 2015). Recent widespread, severe, and long-lasting droughts have heightened awareness of interest in how to better monitor drought and its impacts (Hao et al. 2014). The National Drought Mitigation Centre (NDMC), United States Department of Agriculture (USDA) and NOAA’s Climate Prediction Centre (CPC) and National Climatic Data Centre (NCDC) have partnered to produce the weekly U. S. Drought Monitor (http://drought.unl.edu/monitor), a comprehensive drought assessment product based on a simple 5-category severity classification (Svoboda et al. 2015).

We describe the development of agricultural drought forecasting and warning system that permits integrated handling of meteorological and water-level data. The system offers new information of preparedness and mitigation planning for agricultural drought in Korea including a long term plan and water saving strategy. It analyses the previous drought status using the agricultural drought map, the prediction information related to drought damages, and the drought-related response capability of irrigation facilities.

2. MATERIALS AND METHODS

2.1 Agricultural area in South Korea

In South Korea, the total cultivated paddy rice area is 964000 ha; the total upland agricultural area is 748000 ha accounting for around 44% of the total farmland area (MAFRA, 2014). Agricultural reservoirs are the main water sources in South Korea, and supply water to about 777000 ha (approx. 81%) of the 964000 ha of the total irrigated paddy fields, as shown in Table 1. The design frequency of drought for agricultural water resources in South Korea is the 10-year drought for about 575000 ha (approx. 60%) (Nam and Choi, 2014).

<table>
<thead>
<tr>
<th>Total paddy field</th>
<th>Rain fed paddy field</th>
<th>Irrigated paddy field</th>
<th>Design frequency of drought</th>
</tr>
</thead>
<tbody>
<tr>
<td>964 (100)</td>
<td>187 (19.4)</td>
<td>777 (80.6)</td>
<td>Normal years: 126 (13.1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Three years: 45 (4.7)</td>
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<tr>
<td></td>
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<td>Five years: 22 (2.3)</td>
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<tr>
<td></td>
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<td>Seven years: 9 (0.9)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Over ten years: 575 (59.6)</td>
</tr>
</tbody>
</table>

* units: 10^3 ha (%)

2.2 Irrigation facilities in South Korea

Approximately 19% of the total irrigation facilities are managed by the Korean Rural Community and Agriculture Corporation (KRC) and approximately 81% are managed by local governments (Table 2). The irrigation facilities that are managed by local governments have a small irrigation area and low efficiency (Nam et al. 2015). In addition, most of them do not receive enough care and maintenance, resulting in poor water management (Hong et al. 2016). Additionally, the agricultural reservoirs that are managed by the KRC supply water for approximately 372 thousand ha (48%) of the total irrigated paddy area. The water-level measurement systems at the agricultural...
reservoirs were managed by the KRC using the Rural Infrastructure Management System (RIMS) for approximately 10% of the total reservoirs, as shown in Table 3.

Table 2. Irrigation facilities between Korean Rural Community and Agriculture Corporation (KRC) and local government (KRC, 2014)

<table>
<thead>
<tr>
<th>Total irrigation facilities</th>
<th>Korean Rural Community and Agriculture Corporation (KRC)</th>
<th>Local government</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>Area (ha)</td>
<td>Number</td>
</tr>
<tr>
<td>71,746</td>
<td>752,598</td>
<td>13,763 (19%)</td>
</tr>
</tbody>
</table>

Table 3. Classification of irrigation facilities (KRC, 2014)

<table>
<thead>
<tr>
<th>Classification</th>
<th>Number</th>
<th>Area (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total irrigation facilities</td>
<td>71,746</td>
<td>752,598</td>
</tr>
<tr>
<td>Reservoirs</td>
<td>17,401</td>
<td>440,807</td>
</tr>
<tr>
<td>Water-level measurement</td>
<td>1,654</td>
<td>-</td>
</tr>
<tr>
<td>Non-water-level measurement</td>
<td>15,747</td>
<td>-</td>
</tr>
<tr>
<td>Water pumping and distribution system</td>
<td>7,890</td>
<td>193,087</td>
</tr>
<tr>
<td>Weir</td>
<td>44,848</td>
<td>118,704</td>
</tr>
<tr>
<td>Tide embankment</td>
<td>1,607</td>
<td>-</td>
</tr>
</tbody>
</table>

2.3 Algorithm of drought prediction in agricultural reservoirs

A common reservoir operation model can be run based on the available reservoir storage, which can be measured from the water demand in irrigation districts and water supply analyses using water balance models. The water supply capacity of the reservoir is determined by the available water inflow to the basin using DIROM (Daily Irrigation Reservoir Operation Model) that simulates the inflow from the watershed (Sugawara, 1979). Irrigation water demand, which is defined as crop water demand, is usually estimated based on the method suggested by Doorenbos and Pruitt (1977) and the reference crop evapotranspiration is computed by the FAO Penman–Monteith method (Allen et al. 1998).

A new conceptual water level prediction scheme is presented in this article, which includes protocols based on two approaches (Fig. 1 and Fig. 2). First, this approach includes stochastic methods by using the historical rainfall data to estimate the water-level corresponding to forecast rainfall provided by the Korea Meteorological Administration (KMA). For the water-level non-measurement reservoir, the approach includes a similarity process by selecting near weather stations.

2.4 Agricultural drought forecasting system

In this study, an agricultural drought forecasting system was developed that may delineate a wide range of multi-criteria decision analysis to improve drought management. Effective drought forecasting system depends on several factors: (a) analysis of stochastic drought prediction, and (b) agricultural drought maps obtained from modeling different drought components for paddy and upland, as shown in Fig. 3. A drought forecasting scenarios analysis by examining a set of weather scenarios and water-level aims to help a decision maker prepare based on a better understanding of the available drought countermeasures.
Figure 1. Algorithm of water level prediction for water-level measurement reservoir

Figure 2. Algorithm of water level prediction for water-level non-measurement reservoir
3. RESULTS AND DISCUSSION

3.1 Development of agricultural drought forecasting system

The development of agricultural drought forecasting system proposed in this study was designed to support the preliminary steps of the drought management decision-making process. The web working environment of the web-based GIS, as a captured screen snapshot, can be seen in Fig. 4 (main page). All of the needed information was arranged in terms of maps that the user may overlay in various combinations in order to analyse drought conditions. The user interface was supplied with functions, which were grouped according to four thematic categories, namely: real-time drought conditions and drought forecasting data including meteorological data and water-level in the reservoirs.

3.2 Function of agricultural drought forecasting system

The agricultural drought forecasting system can provide useful information such as (a) the historical water-level and meteorological data, (b) current water demand of irrigation districts as it relates to reservoir water levels, and (c) forecasting water-level in terms of different drought components assessed in the evaluation of a combination of several drought climate scenarios. It should provide additional functionalities in order to help users understand the results in several different formats. First, this system gives the information of the characteristics of reservoir and analyzes them statistically. Second, it makes the agriculture drought maps and analyzes water reserve and average amount of water use. Lastly, it uses the scenario of rainfall prediction by comparing it with the average year, which is the reservoir water-containing rate of change.
3.3 Application of agricultural drought forecasting system

Agricultural drought forecasting system helps developing a better policy and decision making for drought management. Korea experienced a severe drought in 2015. Analysis of this drought using agricultural drought forecasting system indicated an extremely intense drought during 2015, as shown in Fig. 6. Analysis and prediction is obtained from the rate of rainfall, the rate of water reserve and rate of soil moisture.
The status of drought prediction is shown regionally in four steps: Attention (Blue), Warning (Yellow), Alarm (Orange) and Emergency (Red). The spatial distribution of drought severity is illustrated in Fig. 6. Also, drought forecasting maps in 2016 are shown Fig. 7. An analysis of forecasting drought revealed that in general, droughts usually affect specific regions, with the exception of more extreme droughts.

**Figure 6.** 2015 drought maps using agricultural drought forecasting system

**Figure 7.** 2016 drought forecasting maps using agricultural drought forecasting system
4. CONCLUSIONS

Effective drought management can be achieved through the drought monitoring based on the ability of assessing current conditions and predicting future drought development. This study presented an agricultural water management policy with the drought forecasting and warning system. We developed an agricultural drought forecasting system that permits integrated handling of meteorological data and water-level of reservoirs. The system offers new information of preparedness and mitigation planning for agricultural drought in Korea including a long term plan and water saving strategy. It analyzes the previous drought status using the agricultural drought map, the prediction information related to drought damages, and the drought-related response capability of facilities. This system can be used to analyze the agricultural drought maps to prepare for the drought condition on ways of overcoming droughts. It is expected that the Korean government is able to determine drought response, thereby improving the quality of decision-making and increasing the effectiveness of drought management.

REFERENCES


