DEVELOPMENT OF AGRICULTURAL DROUGHT EVALUATION SYSTEM IN KOREA

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ABSTRACT

There are two ways to mitigate drought, structural and nonstructural measures. Structural measures include storage of irrigation water and development of emergency wells, nonstructural measures involve water saving management by early warning system.

To predict and evaluate drought for agriculture, we need to develop drought indices. Presently, drought preparedness are be classified by precipitation, reservoir storage, soil moisture in paddy and upland, and the growing status of crops. However, the indices lack clear quantitative criteria for consistent judgment. Consequently, improvements are needed in selection and utilization of proper drought indices to warn of oncoming drought.

The objectives of this study were to develop an Agricultural Drought Evaluation System, and to evaluate indices for current agricultural status using the system.

We considered several existing drought indices for application to Korea: Reservoir Storage Index (RSI), Standardized Precipitation Index (SPI), Mean Rainfall Index (MRI), Dry Day Index (DDI), Palmer Drought Severity Index (PDSI), Crop Moisture Index (CMI), Percent of Normal, Deciles, and Percent of Median. We determined that four indices are applicable to Korea RSI, SPI, MRI and DDI.

The Agricultural Drought Evaluation System was developed using these four indices to analyze temporal drought status.

INTRODUCTION AND BACKGRUND

Drought is a normal feature of any climate. It is a temporary, recurring natural disaster that, originates from the lack of precipitation and brings significant economic losses. It is impossible to avoid drought, but we can develop drought preparedness and manage drought impacts. The success of both depends on how well we define and quantify drought characteristics.

In any region, drought is multi faceted and always derives from lack of precipitation, but drought may be affected by soil moisture, streams, groundwater, ecosystem functions, and human. This leads us to identify different types of drought. Operational definitions of drought vary, and are crucial for identifying the beginning and, end, degree of drought. The three main types of

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drought are: meteorological, agricultural, and hydrological. Some researchers, particularly economists, also define drought in socioeconomic terms, measuring its impact on social and economic systems.

Many indices exist for analyzing drought status, for example: RSI, SPI, MRI, DDI, PDSI, CMI, and Percent of normal, Deciles, and percent of median. These indices use precipitation, stream flow, and surface water application to quantitatively evaluate drought.

There are two ways to mitigate drought. One is structural, and includes measures such as storage of irrigation water, development of emergency wells, and others. The other is nonstructural, including water saving management by the early warning system. To predict and evaluate agricultural drought, we need to develop improved nonstructural drought indices. Presently, we classify drought preparedness levels by considering precipitation, reservoir storage, soil moisture in paddy and upland, and the growing status of crops, but current qualitative indices lack rigor for consistent judgment. Clearly, we have not selected and utilized proper drought indices to provide early warning of drought outbreaks.

The objectives of this study are to develop an Agricultural Drought Evaluation System, and to evaluate indices for predicting agricultural drought status using the system

CURRENT STATUS OF AGRICULTURAL DROUGHT OCCURRENCE

Historical Drought Analysis

Drought reports published by the Korean government focus on extremely severe drought years, such as 1967-1968, 1994-1995, and 2001, during which the government conducted drought mitigation. But, most agricultural droughts are short temporally short (i.e., monthly, seasonal), and regional. Thus, we performed a newspaper database search for additional drought information for a representative historical period. We compiled climate data from 1966 to 2002 for the agricultural drought analysis. We retrieved 3,386 newspaper articles, of which 546 were agricultural articles. Monthly analysis of all articles yielded a good correlation with known severe drought periods: May 1967 (34 articles), July 1994 (40 articles), and June 2001 (26 articles). Most recorded droughts occurred during the Korean transplanting season, from May to June. The monthly and seasonal drought events we derived from this search are shown in Figures 1., and 2.

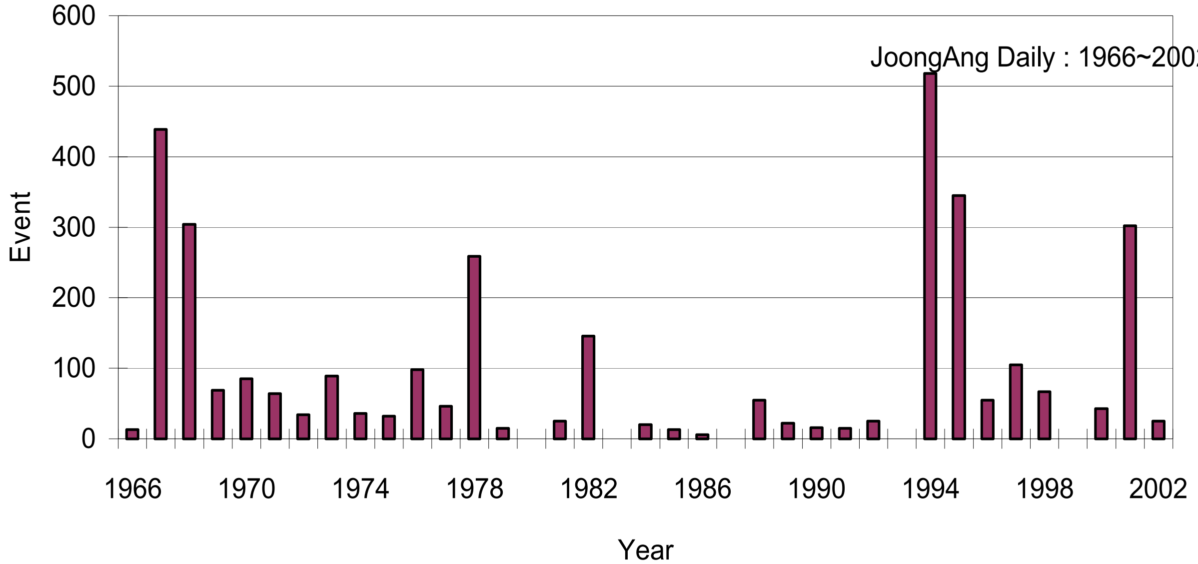
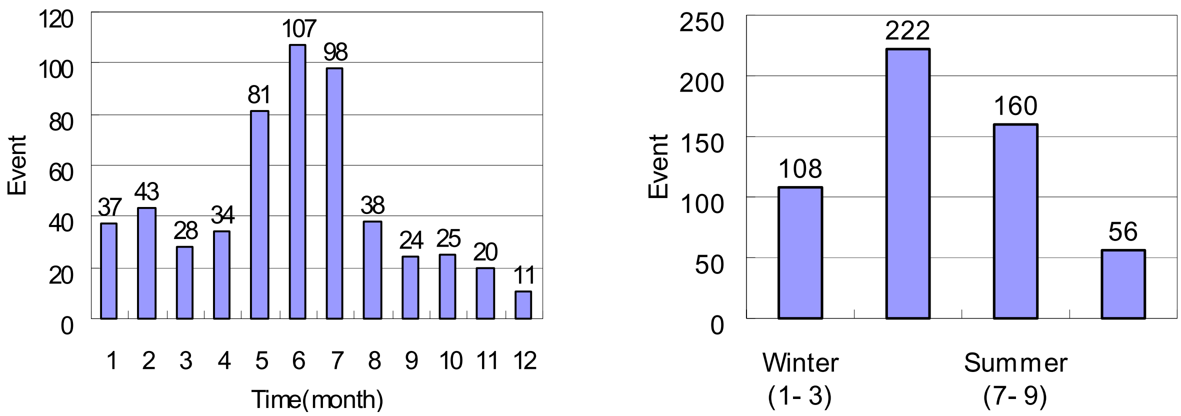


Figure 1. Drought events from the JoongAng Daily (1966-2002)



(a) Monthly

(b) Seasonal

Figure 2. Temporal drought events

Quantifying Agricultural Drought

We used weighing factor analysis to quantify the relative severity of agricultural droughts. Table 1 shows the agricultural drought weighing factors. We recognized that recorded drought events were not limited to the agricultural sector only; therefore, we expanded our analysis to include economic and environmental factors. Soil moisture, stream flow, ground water, and economic conditions complicated the analysis. Figure 3 shows the results of weighing factor analysis and the relative severity of monthly drought events over the historical period.

Table 1. Weighing factors for agricultural drought

Agricultural		Economic		Environmental	
Event	Value	Event	Value	Event	Value
Delay of transplanting	10	Refugee	10	Drinking water shortage	7
Wilting	10	Income decline	10	Power limit	7
Lack of storage	7	Dispute	8	Power generation	6
Water contamination	6	Yield decrease	7	Other industry	4
Crop damage	6	Short of provision	6	Grain price	4
Water supply	5	Alternation crop	5	Disease	4
Auxiliary water source	4	Drought mitigation	4	Forest fire	2
Lack of rainfall	4	Livestock damage	3	Other	1
Lower river flow	4	Relief from drought	2		

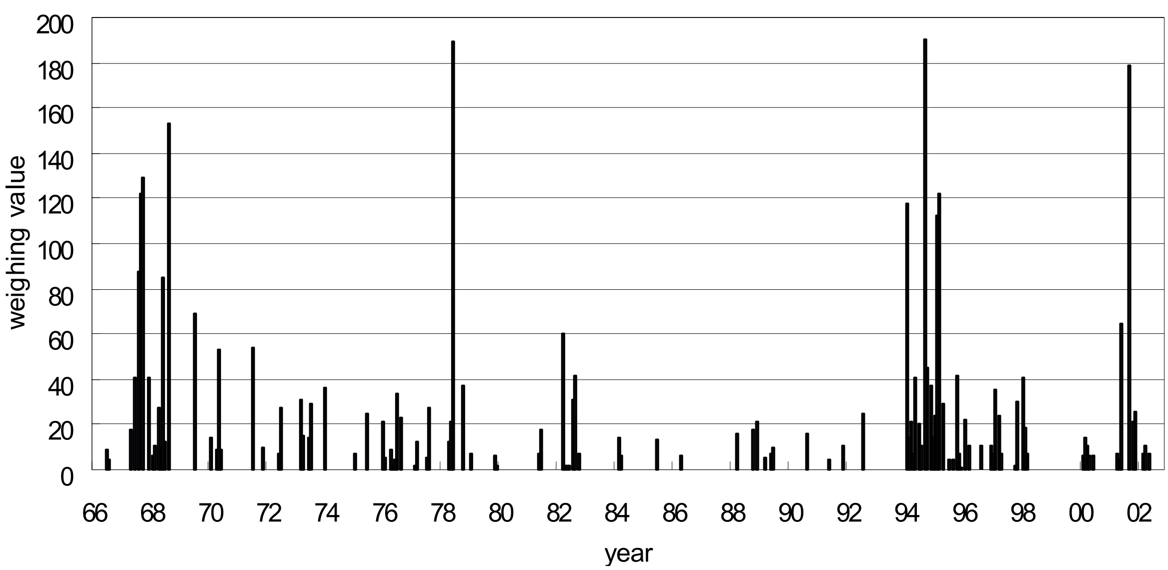


Figure 3. Weighing value of monthly drought events

DEVELOPMENT OF AN AGRICULTURAL DROUGHT INDEX

To develop an improved agricultural drought index, first we accessed the two fundamental available climate data sources—meteorological and daily reservoir storage data. Then, we determined the best existing indices for Korea and defined a useful system of drought stages. During agricultural drought analysis, we mapped drought status over time according to the drought stage classification we developed. As a check, we compared the frequency distributions of reservoir storage data and our derived drought stages.

Meteorological Data

Regional meteorological boundary are defined by local offices of the Korea Rural Community and Agricultural Corporation (KRC). We selected 76 meteorological stations for rainfall data analysis. These stations provide rainfall data for a minimum 30-year period. Each KRC local office compiles meteorological data from one or more stations.

Daily Reservoir Storage Data

Daily irrigation reservoir storage data were obtained from the Rural Water Information System (RWIS). RWIS has daily storage data for 3,277 reservoirs. These data are available for water and irrigation water users to determine effective water applications for paddy irrigation. The daily reservoir storage data are used for agricultural drought analysis.

Applicable Drought Indices for Korea

We considered the following existing drought indices as potentially applicable to Korea: RSI, SPI, MRI, DDI, PDSI, CMI, percent of normal, deciles, and percent of median. We determined that four indices are applicable to Korea: RSI, SPI, MRI, and DDI.

McKee et al.(1993) developed the Standardized Precipitation Index (SPI) for the purpose of defining and monitoring drought. SPI is based just on precipitation and requires less input data and calculation effort than other drought index. A Long-term precipitation record at the desired station is fitted to a probability distribution, which then transformed into a normal distribution. SPI may be computed with different time step (e.g., 1 month, 3 months, …, and 48months). Kim et al. (1999) introduced SPI application in Korea and 3-months delayed SPI is best results for agricultural drought analysis in Korea.

Monthly mean rainfall can directly displayed the water deficit during growing season. Watching the monthly rainfall data provides simple way to analysis the drought status. This value does not major factor for drought analysis. Mean Rainfall Index is helpful to decide the start of drought event.

Since the effects of drought often accumulate slowly over a considerable period of time and may linger for years after the termination of the event, the beginning and end of drought is difficult to determine. Because of this, drought is often referred to as a creeping phenomenon. Drought is caused by insufficient water supply from natural or artificial water resources. As a natural result, rainfall is irregular water source from atmospheric phenomena. Dry day continue for a long time, the water cannot provide sufficiently. The drought will be occurred as any time or any region. Numbers of dry day can help to determine when drought is beginning.

Drought Stage

Droughts are identified as undergoing two or more stages, depending on the drought management agency. (The two main agencies for drought mitigation in Korea are the governmental Ministry of Agriculture and Forestry (MAF) and the Korea Rural Community and Agricultural Corporation (KRC).) MAF assigns two stages: the preparation stage and the mitigation stage. KRC uses four stages to describe the effect of droughts on irrigation reservoir storage: the ordinary/finishing, preparation, warning, and emergency drought stages.
We propose six agricultural drought stages (DS1-DS6). We classify each of our six drought stages by quantitative measures of the four applicable drought indices mentioned earlier: RSI, SPI, MRI, and DDI. Table 2 shows the agricultural drought stages and recommended guidelines for agricultural drought evaluation.

Table 2. Drought stages for agricultural drought

<table>
<tr><th colspan="3">Guideline</th><th rowspan="2">Drought stage</th><th rowspan="2">RSI (%)</th><th rowspan="2">SPI</th><th rowspan="2">MRI (%)</th><th rowspan="2">DDI (days)</th></tr>
<tr><th colspan="2">MAF*</th><th>KRC**</th></tr>
<tr><td rowspan="2">Preparation stage</td><td rowspan="2">Ordinary</td><td rowspan="2">Ordinary/Finishing stage</td><td>DS1</td><td>70</td><td>< -1.0</td><td>85</td><td>10</td></tr>
<tr><td>DS2</td><td>70</td><td>< -1.5</td><td>75</td><td>15</td></tr>
<tr><td rowspan="4">Mitigation stage</td><td rowspan="2">Worrying</td><td>Preparation stage</td><td>DS3</td><td>50</td><td>< -2.0</td><td>60</td><td>21</td></tr>
<tr><td>Warning stage</td><td>DS4</td><td>50</td><td>< -2.0</td><td>50</td><td>21</td></tr>
<tr><td rowspan="2">Spreading</td><td rowspan="2">Emergency stage</td><td>DS5</td><td>30</td><td>≤ -2.5</td><td>40</td><td>30</td></tr>
<tr><td>DS6</td><td>30</td><td>≤ -2.5</td><td>40</td><td>30</td></tr>
<tr><td colspan="8">* MAF; Ministry of Agriculture and Forestry, Korea
** KRC; Korea Rural Community and Agricultural Corporation</td></tr>
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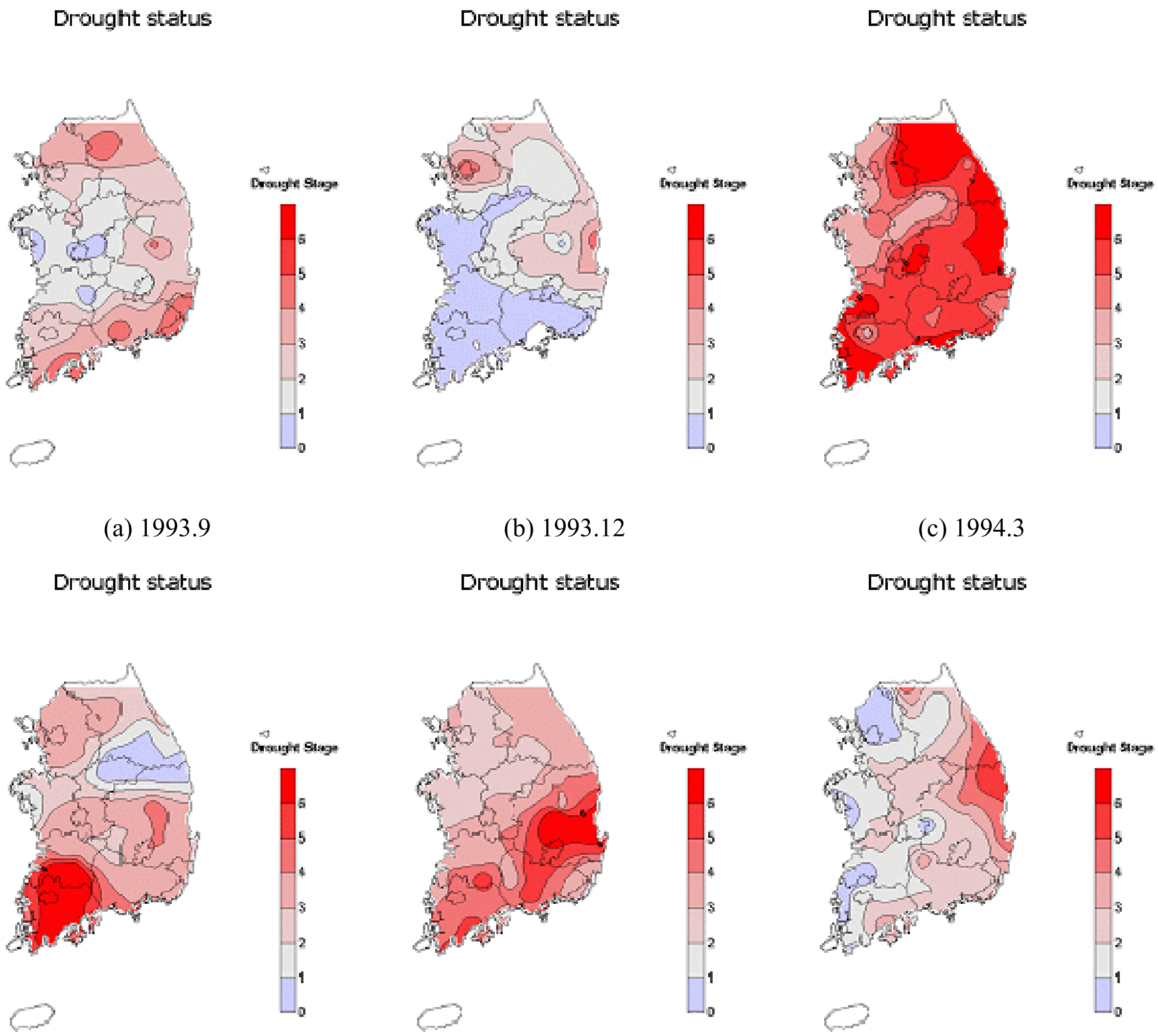

(a) 1993.9 (b) 1993.12 (c) 1994.3

(d) 1994.6 (e) 1994.9 (f) 1994.12

Figure 4. Agricultural drought analysis (1994)

Comparison of Results

We compared the frequency distributions of reservoir storage data and derived drought stages. The results showed in Table 3. Countrywide drought occurs during 2001. Reservoir storage reduced from May, 2001. But, drought phenomenon is showed early spring. In actually, new method showed 2~3 month before than reservoir storage. This implies the new method can express for drought phenomenon and suitable for drought mitigation.

Table 3. Comparison of results between reservoir storage data and derived drought stage for 2001

Classification		Month											
		J	F	M	A	M	J	J	O	S	O	N	D
		Number of local KRC offices											
Reservoir storage	Over 70%	86	86	91	91	75	12	64	68	16	16	22	26
	50-70%	0	5	0	0	16	41	23	22	47	35	39	43
	30-50%	5	0	0	0	0	31	4	1	24	34	25	22
	Below 30%	3	3	3	3	3	10	4	4	7	9	8	3
Drought stage	0-1.0	55	83	0	0	0	46	42	5	4	31	0	41
	1.0-2.0	29	8	8	0	0	17	32	16	1	23	0	19
	2.0-3.0	6	1	8	0	0	17	12	14	4	13	2	12
	3.0-4.0	2	2	56	7	0	6	6	17	13	10	4	7
	4.0-5.0	1	0	17	20	2	1	2	26	11	5	5	7
	5.0-6.0	1	0	5	67	92	7	0	16	61	12	83	8

DEVELOPMENT OF AGRICULTURAL DROUGHT EVELUATION SYSTEM

Agricultural drought evaluation and information system are developed in order to effective drought management in Korea. Drought evaluation system is composed two main modules: the computation module, the operation module. Computation module is calculated the drought index according to weather data and storage data. These results stored in database and used for drought evaluation. These all program operated on prompt mode of DOS environment because this module coded ANSI-C language. The drought evaluation system operated in IBM-PC.

ADIS, Agricultural Drought Information System, is developed in order to provide drought information to water manager. They are used this data to decide irrigation water supply and to make drought mitigation of KRC local office level.

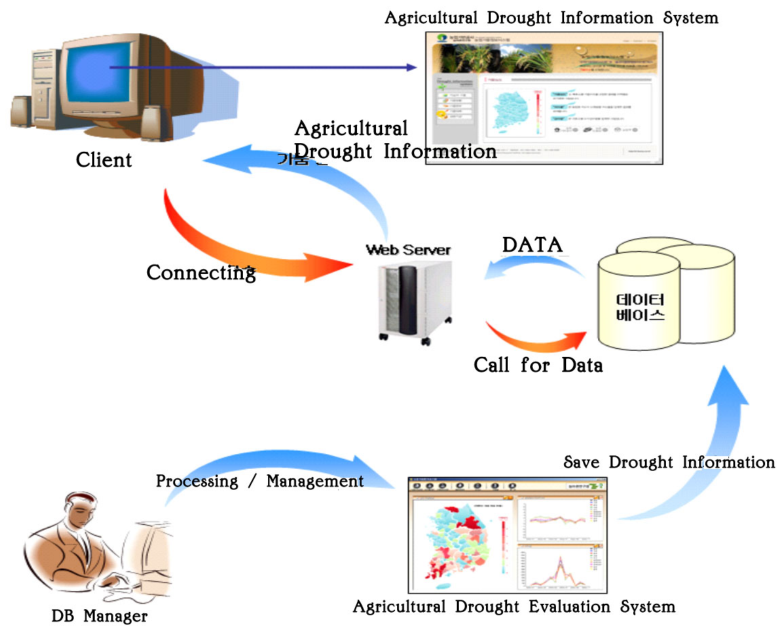

Figure 5. Conceptual diagram for agricultural drought evaluation system

SUMMARY

We are making good progress in developing an Agricultural Drought Evaluation System for Korea. We have classified recent historical agricultural drought by type of event and time, and quantified drought history by weighing value analysis. We initiated the development of an agricultural drought index for Korea, considering available climate data, suitable indices, and drought stage classification. We proposed six agricultural drought stages for drought evaluation and mitigation, and applied the classification spatially to map past agricultural drought. Our drought stage classification showed improvement over using reservoir storage data alone. Currently, we are proceeding with development of the agricultural drought evaluation system, which we will use to evaluate drought indices for assessing current agricultural status.

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