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The Effects of Drought on Forest and Forecast of Drought by Climate Change in Gangwon Region

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Abstract

A Gangwon region consisting of over 80% of forest area has industries that have been developed by utilizing its clean region image. However, the recent climate change has increased the forest disease & insect pest as well as the forest fire and the major cause is known to be the increase in the frequency of a drought occurrence. From the aspect of climate change, it can be said that drought and forest are important in every aspect of the adaptation and mitigation of climate change measure as they increase forest disease & insect pest that leads to desolation of usable forest resource. In addition, the increase of forest fire reduces resources that can absorb greenhouse gas, which leads to increase in green house emission. The purpose of this study is to provide a motive for concentrating administrative power for protecting forest in a Gangwon region by selecting a drought management needed local government through a drought forecast according to the climate change scenario of a Gangwon region.

Key Words: forecast of drought, forest, climate change, SPI

Introduction

Water discharge is heavily dependent upon the precipitation and the ecology of forest in upper stream, and it is revealed that a forest is playing an important role in the flood and drought measure in a drainage area through the establishment of green dam concept. Particularly, the role of a forest will inevitably be emphasized furthermore in the use of water resource as flood and drought are expected to occur frequently due to the recent climate change. Disease & insect pest damage from drought and the change in the probability of the forest fire occurrence, in addition to a landslide from flood, call for forecasting flood and drought that result from climate change in order to effectively manage a forest in an era of climate change. Although it is relatively easier to conduct related studies and establish measures against flood that causes short-term damage, related studies and measures against drought are lacking since a drought causes long-term damage and its forecast is difficult. In the case of Gangwon region, a drought is occurring more frequently than the national average and causing damages in a periodic basis in the inland region, thereby calling for the need of drought analysis in Gangwon region in order to adapt to climate change in the region.

Accordingly, the drought forecast was conducted according to regional drought indexes in Gangwon by creating the climate change scenario of fundmental local governments upon utilizing the data regarding the effects of drought on

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forest and the precipitation in Gangwon. Drought management indexes for local governments were calculated to select warning and caution fundamental local government that are vulnerable to drought in the future.

Definition of Drought

A drought is a phenomenon that appears in a region with continuous precipitation that falls below average during a period of water supply shortage. It occurs through the interaction between water supply and demand that is affected by natural phenomenon such as rain or artificial action, and has significant effects on society with economic, environmental and personal levels. A drought is defined as a continuous extended state of precipitation deficiency to the degree of possibly impeding the growth of animals and plants in a certain region, or a state of water retainment level that falls short of the required level for waterpower generation and everyday life purposes (National Disaster Management Institute 2002). For defining a drought quantitatively (procedurally, substantially), it is necessary to analyze various factors such as the level of deviation from the mean value of precipitation or other weather factors to identify the start, end and depth of a drought. Dracup et al. (1980) stated that a drought consists of the period of continuation, scale and depth and presented the Run Theory for analyzing the water shortage attributes, time interval used to dioxide raw data, truncation level for distinguishing drought from other concepts and method for analyzing the locality of a drought.

A drought is defined according to various standards and can be classified into meteorological drought, hydrological drought, agricultural drought and socio-economical drought (Table 1).

Due to the climate change, a drought starts from agricultural drought and hydrological drought to socio-economic drought that affects society and economy. First of all, it affects meteorological drought as a precipitation decreases or the evapotranspiration amount increases with climate change, and the continuation of meteorological drought decreases a soil water content that ends up affecting the growth of animals and plants such as the reduction in crop production, thereby causing an agricultural drought. This leads to the occurrence of the hydrological drought that results in the decrease of the outflow of river or the decrease in the reservoir or a dam inflow. Finally, socio-economic drought occurs that ends up affecting the environment and the local economy. For such reason, there is a tendency that a slight drought is felt in an agricultural region but not in cities.

Effects of Drought on Forest

While forest is significantly affected by climate, it also has so called Allbedo effect and affects a water balance, thereby affecting the climate system of the earth.

Table 1. Classification of drought (Lee, 2012)

Classification	Definition
Meteorological drought	Calculated using precipitation or consecutive days of no precipitation in a given period. Defined as a continuous time of dry level and state compared to normal state or average concept.
Agricultural drought	Indicated through the soil water directly related to the growth of the crops. The area of agriculture is affected first by drought because of its significant dependence on reservoir water.
Hydrological drought	Calculated by comparing the amount of usable water resources such as river, reservoir and underground water with the standard values. The frequency and depth of hydrological drought is defined in drainage basin unit scale through the effects expanded through hydrological system.
Socio-economical drought	As a broad concept of drought definition considering all other aspects of drought, it is defined by relating the demand and supply of economic goods with the elements of meteorological, hydrological and agricultural drought. Occurs when the demand of economic goods exceeds supply due to the shortage of weather related water supply.

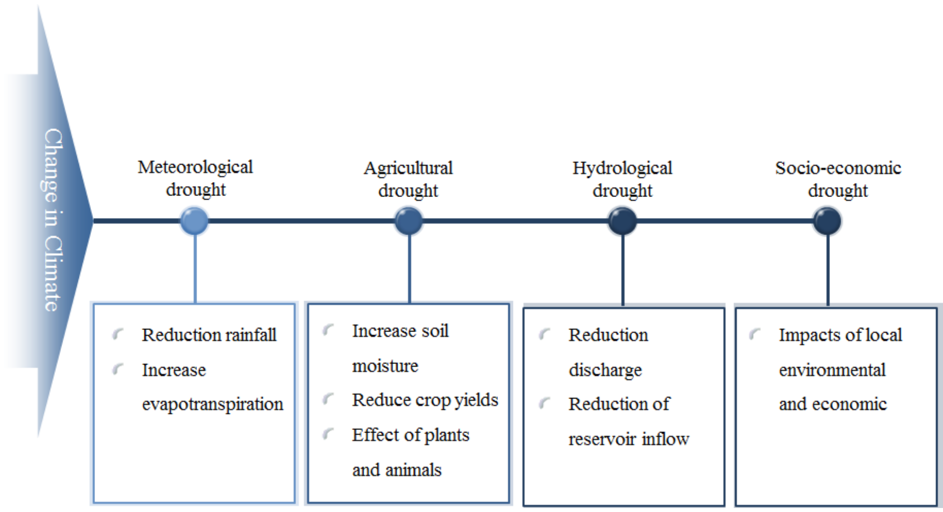
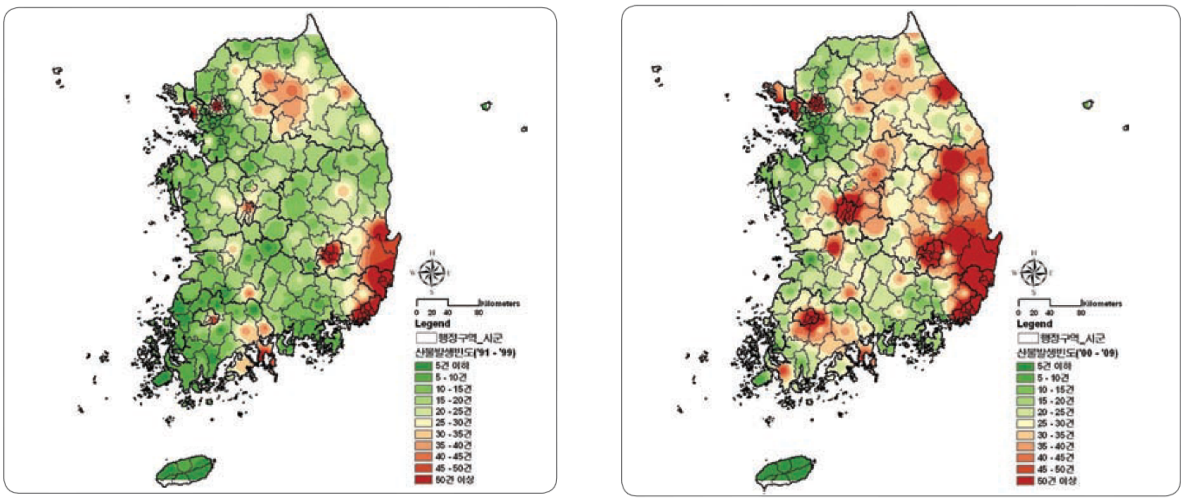


Fig. 1. Impact of drought.



a) 1990s b) 2000s

Fig. 2. Changes in forest fire frequency.

Furthermore, forest can become a source of emitting carbon dioxide in reserve as a massive carbon dioxide repository upon being affected by disaster, disease & insect pest and forest decline. Accordingly, forest is an important key element word of climate change. The forest effect through climate change can be mainly classified into the change in forest ecology, the increase of disease & insect pest, the change in the probability of forest fire occurrence that causes major greenhouse gas emission and forest disaster from torrential downpour. The increase in disease & insect pest and the forest fire effect in particular are most closely related to drought.

According to Won (2012), the frequency of forest fire occurrence in Korea during the 2000s increased by 1,786 incidents compared with that during the 1990s, and it was revealed that highest temperature, relative humidity, effective humidity and mean velocity are climate data related to the occurrence of forest fire.

Insect pests that nibble on leaves stop their activities during rain or the number of insect pests decrease when they nibble on wet leaves as they catch various diseases. However, a drought will improve their habitation environment thereby increasing the area of damage. In addition, global warming that results from climate change increases the number of insect pests by expanding their habitation period, and the adaptability of forest falls behind that of insect pests as the northing of the vegetation zone range is relatively slower, thereby increasing the damage.

Regional Precipitation Analysis

In this study, drought analysis has been conducted based on past precipitation data in administrative district unit instead of drainage area unit. The current circumstance is that water resource related policies including drought need to be implemented in drainage area unit but many policies related to drought are implemented in regional unit with consideration of the national river scale.

In general, the precipitation measured at various observatories within a certain drainage area in floodgate analysis varies. Accordingly, there are many cases that required the representative precipitation within a drainage area in hydrology and for such cases space mean, namely, area mean precipitation is calculated as the representative value (Yoon 1999). As mentioned earlier, area mean precipitation was calculated in this study as the regional representative precipitation in order to calculate the drought index of administrative districts. The methods of calculating area mean precipitation include arithmetic mean, Thiessen method, isohyetal method, hypsometric analysis method, interpolation method, finite element method and Kriging but the Thiessen method was used in this study. Accordingly, Thiessen network was composed in order to utilize the precipitation data of 13 weather stations (Fig. 3).

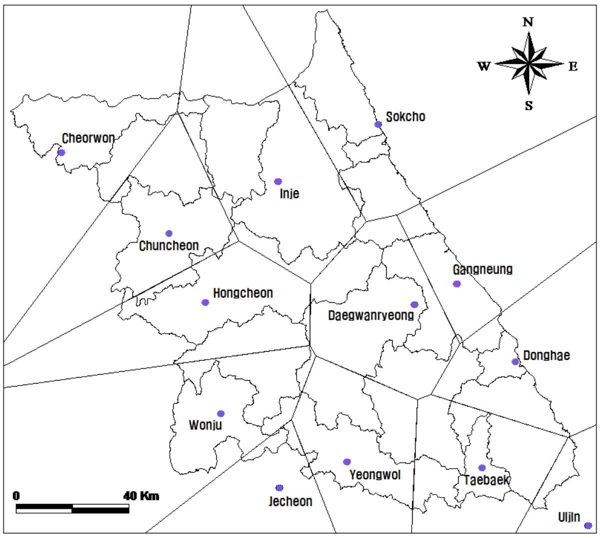


Fig. 3. Thiessen network.

Area weighted average method was used with the developed Thiessen network to create the daily precipitation data of all fundamental local governments. As for Sokcho-Goseong that is in the same floodgate region included in Sokcho Weather Station, total of 17 daily precipitation data were created throughout three decades from 1982 to 2011. The basic statistical data of the regional precipitation for the three decades area are shown in Table 2.

Table 2. General rainfall statistics (1981-2011)

	Cheorwon	Hwachon	Yanggu	Inje	Goseong/Sokcho	Yangyang
Ave. annual (mm/yr)	1,491.2	1,342.8	1,218.0	1,240.1	1,408.5	1,513.7
Max. daily (mm)	394.1	262.5	275.8	279.0	314.2	484.1
Ave. daily (mm/day)	4.0723	3.6664	3.3281	3.3791	3.8464	4.1265
	Chuncheon	Hongcheon	Hoengseong	Pyeongchang	Gangneung	Wonju
Ave. annual (mm/yr)	1,359.3	1,462.1	1,385.8	1,549.2	1,606.6	1,370.3
Max. daily (mm)	308.5	280.8	261.9	534.1	753.3	305.0
Ave. daily (mm/day)	3.7125	3.9905	3.7860	4.2340	4.3872	3.7437
	Yeongwol	Jeongseon	Taebaek	Donghae	Samcheok	
Ave. annual (mm/yr)	1,236.6	1,516.7	1,279.4	1,266.3	1,241.5	
Max. daily (mm)	218.5	369.0	338.5	319.5	329.3	
Ave. daily (mm/day)	3.3771	4.1389	3.4942	3.4604	3.3910	

Forecast of Drought Caused by Climate Change

Drought index

Since a drought occurrence can cause significant damages without any specific measures in place, drought index through which the level of drought can be quantified is often used in drought analysis. Commonly used drought indexes include PDSI (Palmer Drought Severity Index), SPI (Standard Precipitation Index) and SWSI (Surface Water Supply Index) that are selectively used along with their different characteristics.

The first researcher to conduct a quantitative analysis on drought was Koppen who researched the precipitation around the world based on the precipitation required for habitation in order to classify climatic region, and Palmer (1965) developed PDSI that allows time & spatial comparison. In addition, McKee et al. (1993, 1995) explained the definition and characteristics of standardized SPI in their study on the relation between drought frequency and continuation period, and compared the relation between time interval, drought frequency, continuation period and intensity.

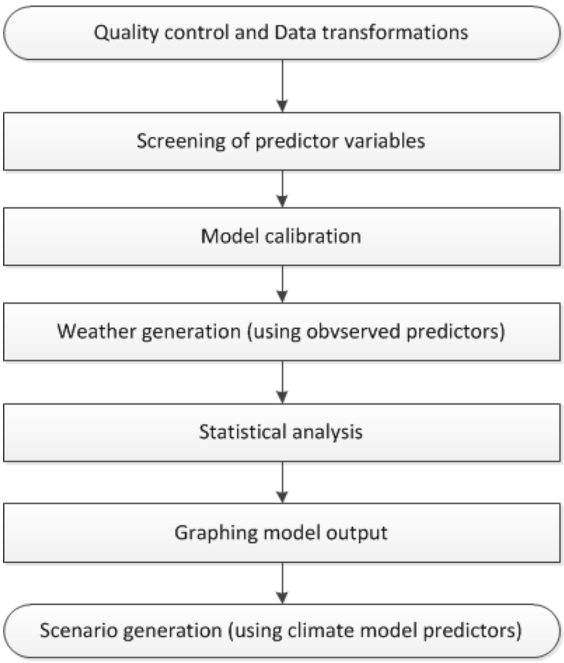


Fig. 4. Downscaling process in SDSM (Wilby et al. 2007).

Drought index is one of the indexes for displaying the state of drought progression or the level of severity through objective numbers. Since there are various standards on drought, drought indexes can be calculated using numerous data with different units and attributes such as water supply index, outflow, precipitation, snowfall, etc.

Development of climate change scenario

Climate change forecast methods are mainly divided into experiential statistical method by analyzing the past observation data and numerical model such as GCM, and climate change forecast based on the greenhouse gas increase using GCM has been conducted in advanced countries since last about two decades. Climate change scenario is an expression of future climate that can be used in researching the potential effect on humans. The Intergovernmental Panel on Climate Change (IPCC) is providing greenhouse gas emission scenario by forecasting the change in greenhouse gas density resulting from demographical and socio-economical development. Currently, the Special Report on Emission Scenarios (SRES) presented in the 4th report by the IPCC (2007) is being used.

The grid in the climate change scenario SRES is over 110 km and it does not include climate scenario for specific fundamental local governments in Gangwon. GCM is a global climate forecast model ideal for forecasting climate in broad scales but it has a weakness of not being able to describe in details of regions because of its wide grid. Accordingly, downscaling is used to forecast regional climate. The types of downscaling include statistical downscaling and dynamical downscaling, and statistical downscaling was used in this study for obtaining high-resolution data in local scale by deducing and using the statistical relation between the observation data of local scale and the GCM data of broad scale.

As for the global climate model (GCM) used in this study, CGCM3.1 T47 model by the Canadian Centre for Climate Modelling and Analysis (CCCMA) was used. For data input and specification of the model, Statistical Downscaling Model (SDSM) of DAI Portal (2012) was used, and SDSM creates statistically specified future climate scenario through the 7 steps shown in Fig. 4.

For the purpose of calculating regional SPI, the regional precipitation data of A1B scenario was created until 2100

Table 3. Precipitation increase comparison of the 2000s

	2000s (mm/yr)	2020s (%)	2030s (%)	2040s (%)	2050s (%)	2060s (%)	2070s (%)	2080s (%)	2090s (%)
Cheorwon	1,491	20.3	22.8	23.5	20.3	24.0	20.9	24.4	20.4
Hwachon	1,343	16.9	17.8	18.3	21.6	21.7	20.2	20.3	19.2
Yanggu	1,218	22.6	18.1	22.5	22.3	24.3	23.2	22.2	30.6
Inje	1,240	16.8	12.5	17.6	25.1	20.1	20.7	20.4	23.2
Goseong/Sokcho	1,408	26.8	24.8	29.5	30.9	30.8	22.0	26.5	30.2
Yangyang	1,514	23.5	17.4	20.3	24.1	25.5	24.6	24.3	24.0
Chuncheon	1,359	16.6	20.8	19.3	19.2	34.0	21.2	30.3	19.2
Hongcheon	1,462	8.8	19.3	17.9	20.9	13.4	16.6	13.6	14.4
Hoengseong	1,386	13.8	14.8	15.6	15.3	11.3	19.8	18.9	21.1
Pyeongchang	1,549	15.1	18.3	16.1	18.9	17.2	17.4	16.3	13.4
Gangneung	1,607	26.2	32.2	32.2	29.7	26.5	29.0	25.8	27.0
Wonju	1,370	17.4	21.2	16.7	23.2	16.7	16.8	25.2	23.6
Yeongwol	1,237	11.4	13.9	10.9	19.6	19.7	17.3	14.9	11.0
Jeongseon	1,517	14.5	14.2	16.8	15.0	24.3	20.0	21.0	24.3
Taebaek	1,279	22.8	16.6	20.0	24.8	22.1	18.0	21.2	22.7
Donghae	1,266	25.5	22.8	32.1	29.6	24.0	24.6	30.5	26.8
Samcheok	1,241	14.9	18.0	20.9	12.5	18.5	18.2	22.9	22.4

A1B climate change scenario.

through the statistical specification of GCM data based on the regional precipitation data of the past three decades. The fluctuation of forecasted precipitation was also shown in the decade unit mean instead of continuous increase and this appeared to have resulted from using statistical specification method based on climate factor and past statistical data.

Drought forecast

The drought index according to A1B climate change scenario was calculated by distinguishing it into that during the 2030s (2021-2050) and during the 2080s (2071-2100). Figure 6 shows the result of interval-specific SPI calculation of Goseong-Sokcho and the SPI calculation result of all fundamental local governments in Gangwon is shown in the study by Lee (2012).

In the comparison of short- & long-term SPI results of the past (1982-2011), the 2030s and the 2080s, the frequency of slight drought occurrence increased in the short-term SPI but the frequency of ordinary drought occurrence is decreasing. In the long-term SPI, however, there was a tendency of increasing frequency of slight & ordinary drought occurrences, which appeared to have resulted from the change in future precipitation pattern and the creation of climate change scenario such as the occurrence of precipitation in certain periods despite about 20% increase of precipitation, as well as the drastic decrease in the number of days with no precipitation according to statistical specification. However, what is clear is the forecast that long-term drought occurrences will increase as time progresses.

Selection of Drought Management Target in Preparation for Climate Change

The long-term drought management index was defined through the period-specific drought index (SPI) based on the regional daily precipitation data forecasted until 2100 through the climate change scenario. As for the drought management index, the relative drought occurrence frequency of 3-, 6-, 9- & 12-SPI was used and based on the ordinary drought occurrence frequency during the three decades of the 2030s (2021-2050) and the 2080s (2071-2100), short-term index and long-term index were calculated respectively based on 3-SPI and 12-SPI. Using the drought management index defined, local governments

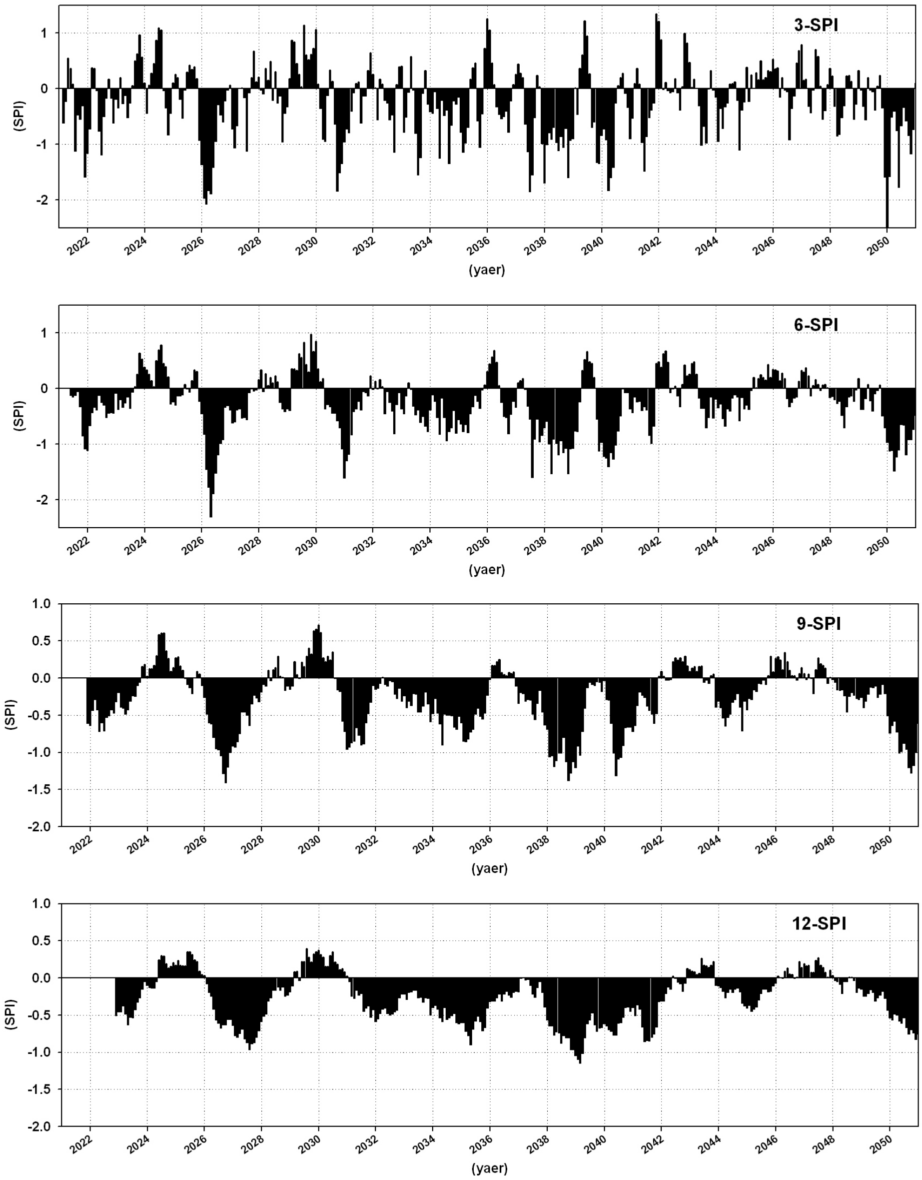


Fig. 5. SPI (2030s) of Goseong-Sokcho.

that require future long-term drought management were selected.

According to the order of drought management index calculated in Table 4, caution local government that needs to be given notice for drought management of Gangwon and warning local government with a concern for drought management was selected. The selection was based on the relative priority order but Chuncheon, Hwachon, Yanggu and Inje that are considered to be relatively stable in water resource because of their major water resources within the local government were excluded in the list of local governments that require drought management. This is a reflection of the fact that geographical condition is established for actively responding to any occurrence of severe drought in local government despite the major water resource being operated according to the national water resource plan.

Goseong, Sokcho, Taebaek and Donghae require long-term drought management all throughout the 2030s and the 2080s according to drought management index, and it was revealed that Jeongseon and Yangyang need to be

Table 4. The result of drought management index

	2030s				2080s			
	Short-term		Long-term		Short-term		Long-term	
	Index	Ranking	Index	Ranking	Index	Ranking	Index	Ranking
Cheorwon	1.0450	10	0.3825	4	0.4238	12	0.2356	11
Hwachon	0.4638	16	0.1988	13	0.2931	13	0.7488	2
Yanggu	0.7781	12	1.1288	1	0.2350	15	0.7325	3
Inje	0.7175	13	0.3744	5	0.2531	14	0.2438	9
Goseong/Sokcho	1.8106	1	0.5556	3	1.5488	3	1.0281	1
Yangyang	1.2625	9	0.1369	15	1.4406	7	0.4163	5
Chuncheon	0.4500	17	0.1369	15	0.1981	16	0.6225	4
Hongcheon	0.6400	14	0.2838	10	0.6463	9	0.2781	8
Hoengseong	0.6363	15	0.1256	17	0.1838	17	0.2075	15
Pyeongchang	1.4075	7	0.1988	13	1.4638	6	0.1425	17
Gangneung	1.7613	3	0.3488	7	1.1438	8	0.2269	13
Wonju	0.8906	11	0.2056	12	0.5975	10	0.2356	10
Yeongwol	1.4775	6	0.3381	9	0.5238	11	0.1813	16
Jeongseon	1.5694	5	0.3588	6	1.5556	2	0.3913	6
Taebaek	1.5713	4	0.3469	8	1.6913	1	0.3325	7
Donghae	1.8100	2	0.6706	2	1.5088	4	0.2331	12
Samcheok	1.3556	8	0.2081	11	1.4825	5	0.2219	14

Table 5. Warning and caution local government for drought management

	2030s		2080s	
	Short-term	Long-term	Short-term	Long-term
Warning	Goseong/Sokcho, Donghae, Taebaek, Jeongseon	Donghae, Goseong/Sokcho, Cheorwon	Taebaek, Jeongseon, Goseong/Sokcho, Donghae	Goseong/Sokcho, Yangyang
Caution	Yeongwol, Pyeongchang, Samcheok, Yangyang, Cheorwon	Jeongseon, Taebaek, Gangneung, Yeongwol, Hongcheon	Pyeongchang, Yangyang, Gangneung, Hongcheon, Wonju	Jeongseon, Taebaek, Hongcheon, Wonju

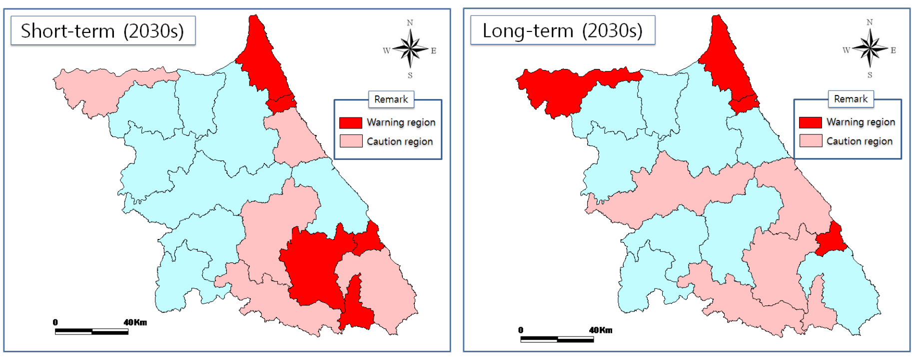


Fig. 6. Fundamental local governments demanding drought management in 2030s.

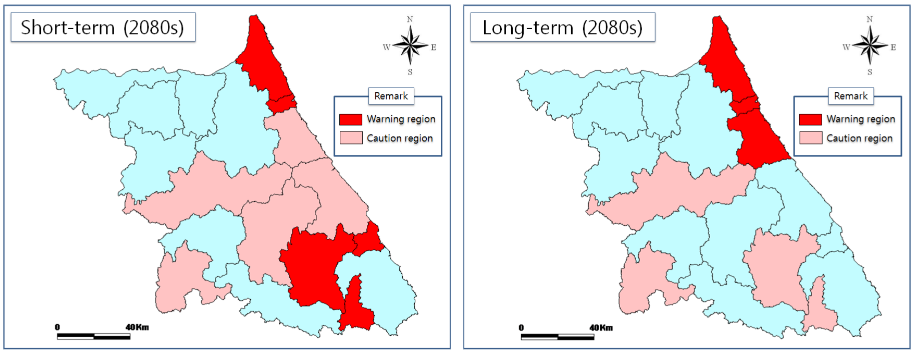


Fig. 7. Fundamental local governments demanding drought management in 2080s.

given notice for short-term drought and Hongcheon for long-term drought.

Conclusions

A Gangwon region consisting of over 80% of forest area is a region of great importance for forest management as it is the representative mountainous region of South Korea. For such reason, it is a period that requires measures against flood and drought that are forecasted through climate change. The current circumstance is that studies and measures against drought are lacking compared to those against flood, and the local governments that were presented in this study as requiring drought management will need to establish comprehensive measures against future drought on their forest areas. From the aspect of climate change, forest policy in the area of climate change adaptation will have important significance in the aspect of protecting the resource of greenhouse gas absorption in the area of climate change alleviation, as well as in the aspect of reducing the risk of greenhouse gas emission through forest fire.

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