

Variations in Root and Tuber Crops Production due to Climate Change

Sung-Eun Hwang¹, Chun-Hwang Chon², and Geon-Young Park^{3†}

Abstract

Climate change which occurring the recent abrupt fluctuations in meteorological and climatological elements is bound, brings about more significant impacts and changes in human life. One of the most important problems due to the impacts of climate change tends to have been decreased the food production, which is expected to make crop resources more and more important. Accordingly, agricultural meteorology should also become more important. In this study, the correlation between meteorological elements and root and tuber crops (potatoes and sweet potatoes), which are emergency crops, and meteorological elements were analyzed, and the impacts of climate changes on the production of such crops were examined. This study concludes that agriculture and food resources are important, and suggests that we should prepare for changes in crops, the weaponization of food, and the lack of water resources in the future. The meteorological element and crops element correlation analysis results. Sweet potatoes, which are negatively influenced by climate change, need breeding improvement and cultivation method development, and potatoes, which are positively influenced by climate change, require preparations for climate changes that exceed the climatic limit. The variations of agricultural production contributed to changes in crop production. Therefore, the importance of agricultural meteorology and the food crop industry should be fully recognized to prepare for climate change.

Key word : Climate Change, Root and Tuber Crops, Meteorological Elements

1. Introduction

Food, clothing, and shelter are the most basic elements of human life, and climate change is bringing about changes in them.

Clothing and housing have shown increasingly uniform patterns according to the development of civilizations and the exchange between them^[1,2]. However, food culture is still considerably local despite the related exchanges between civilizations and the trend toward its simplification. This is the unique characteristic of food culture, as the most important factor of food is fresh ingredients, which are affected by the climate^[3,4].

One of the most important impacts of climate change is the intensifying problem of lack of food^[5]. Accordingly, crop resources are expected to become more

important, along with agricultural meteorology. Thus, the coherence between crops and currently observed meteorological elements, and how climate change will affect crop production, must be determined^[6,7].

Most of the recent studies on crops and climate change were conducted from the purview of engineering and economics. Since 2010, only a few studies have been conducted from the purview of climatology. As eating habits are being westernized and the demand for a healthy diet is increasing, the demand for root and tuber crops (potatoes and sweet potatoes) is also increasing. Root and tuber crops have been known as emergency crops for a long time, and they adapt to diverse climates and are easily stored. In this study, the correlation between root and tuber crops and meteorological elements was analyzed, and the impacts of the continued climate changes on root and tuber crop production were examined.

2. Experimental Section

Data on the climate and crops were used for this study. The observation locations of the climate data

¹National Institute of Meteorological Research, 33, Seohobuk-ro, Seogwipo-si, Jeju-do, 697-100, Korea

²DaeJeon Regional Meteorological Administration, 383 Daehak-ro, Yuseong-gu, Daejeon, 305-338, Korea

³Climate change & Environment Research Institute, 309, Pilmun-daero, Dong-gu, Gwangju, 501-759, Korea

†Corresponding author : inte24@naver.com

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were classified into provincial administrative districts using the ASOS (Automated Synoptic Observing System) distribution of KMA. The meteorological elements included the mean temperature, maximum temperature, minimum temperature, and amount of precipitation. The observation period for the analysis was the past 43 years (1970-2012)^[8]. The observation periods differed by location and element because of the installation and removal of meteorological equipment^[9].

The meteorological data were calculated by averaging and adding up the ASOS monthly data by province. Then the 5years moving average was calculated to analyze the trend in the change for the mitigation of the change due to an abnormal climate. In addition, to analyze the trends in the change across decades, the 1970-1979 period was defined as the 1970s; 1980-1989, the 1980s; 1990-1999, the 1990s; and 2000-2009, the 2000s. Then the trends in the changes for 40 years, from the 1970s to the 2000s, were analyzed.

The crop data were analyzed using the data of Statistics Korea for the amount of production, cultivation area, and production per 10a(acre) of potato and sweet potato for 38 years (1975-2012)^[10,11].

The data for 38 years from 1975 to 2012 were used for the correlation analysis of the climate and the crops. The period to be considered for each crop was determined from its shipping season according to its farming schedule, based on the cropping pattern provided by the Rural Development Administration (RDA), because crops are affected by the climate in different periods.

Is not a full year that growing period of each crops. Therefore, in view of the growing period of the crops were used for correlation analysis after editing the climate elements.

The cultivation period for potatoes is from January to December, and for sweet potatoes, from March to November. The two correlation analysis methods, Pearson and Kendal-τ, were used for the analysis^[12].

The Pearson correlation analysis is a general way of verifying the correlation of two elements. It is defined as a way of determining whether x variables are correlated to y variables, and is expressed as the summation of the difference x minus x_{avg} multiplied by the difference y minus y_{avg} , that whole quantity divided by the square root of the summation of the difference x minus x_{avg} squared multiplied by the difference y minus y_{avg} squared^[13].

$$r = \frac{\sum_{i=1}^n (x_i - \bar{x}) - \sum_{i=1}^n (y_i - \bar{y})}{\sqrt{\sum_{i=1}^n (x_i - \bar{x})^2 - \sum_{i=1}^n (y_i - \bar{y})^2}}$$

In the Kendall-τ correlation analysis, when there are sets of (x1, y1), (x2, y2), ..., and (xn, yn) (wherein xi and yi are unique), and if in (xa, ya) and (xb, yb), xa > xb and ya > yb, or xa < xb and ya < yb, they are said to be concordant, and otherwise, discordant. The Kendall-τ correlation equation is as follows^[13].

$$\tau = \frac{(\text{number of concordant pairs}) - (\text{number of discordant pairs})}{\frac{1}{2}n(n-1)}$$

When you called it r , as follows

$$T = \frac{r}{\sqrt{\frac{1-r^2}{n-2}}} \sim f(n-2; \frac{\alpha}{2})$$

Reported a test statistic

$$|T| > t(n-2; \frac{\alpha}{2})$$

If t is larger than absolute value of the T then it is determined that the correlation^[13].

If the correlation analysis results has correlations, has a value close to 1. Correlation significant level of all the

Table 1. Correlation analysis.

	Pearson	Kendall-τ
Hypothesis	The null hypothesis(H0): No correlation. Hypothesis(H1): Correlation.	
Characteristic	Two variables scale the distance each or if the measured ratio of scale The size of correlation, If it is assumed The variables are normally distributed	It is not assumed The variables are normally distributed or If the measured scale to the sequence used Version of the non-parametric Pearson correlation

correlation coefficients are expressed as star(*) for 0.05 and 0.01. 0.05 is expressed as * weak correlations, 0.01 is expressed as ** strong correlations.

3. Results and Discussion

3.1. Annual Mean Temperature

Fig. 1 is the annual mean temperature slightly decreased in the 1980s in view of the annual variation, 5 years moving average, and 10 years average, but thereafter continuously increased.

The maximum annual mean temperature was 13.87°C in 1998, and the minimum was 11.48°C in 1980. As for the 5 years moving average, the maximum annual mean temperature was 13.22°C in 2008, and the minimum was 12.14°C in 1982, which showed an increase of 0.259°C in 10 years. The 10 year average increased by up to 0.64°C between the 1980s and the 1990s. The 2000s showed the highest value of 13.06°C, and the 1980s had the lowest value of 12.31°C, for a difference of 0.75°C.

3.2. Annual Maximum Temperature

Fig. 2 is the annual maximum temperature slightly decreased in the 1980s in view of the annual variation, 5 years moving average, and 10 years average, but thereafter continuously increased.

The maximum annual maximum temperature was 25.47°C in 2004, and the minimum was 22.18°C in 1972. As for the 5 years moving average, the maximum annual maximum temperature was 24.75 in 1996, and the minimum was 23.35°C in 1974, which showed an increase of 0.253°C in 10 years. As with the mean tem-

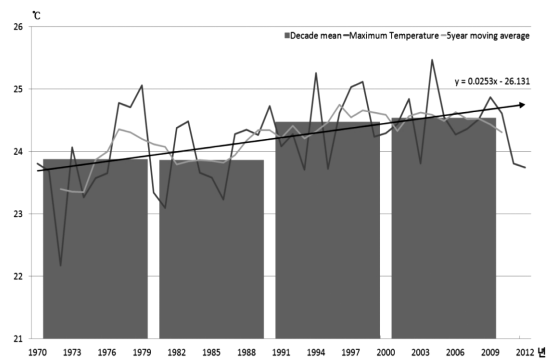


Fig. 2. Same as Fig. 1 except for annual maximum temperature.

perature, the 10 years average increased by up to 0.61°C between the 1980s and the 1990s. The 2000s had the highest value of 24.55°C, and the 1980s had the lowest value of 23.87°C, for a difference of 0.68°C.

3.3. Annual Minimum Temperature

Fig. 3 is the annual minimum temperature temporarily decreased in the late 1970s and the early 1980s in view of the annual variation, 5 years moving average, and 10 years average, but thereafter continuously increased.

The maximum annual minimum temperature was 3.87°C in 2007, and the minimum was 0.75°C in 1981. As for the 5 years moving average, the maximum annual minimum temperature was 3.13°C in 2007, and the minimum was 1.26°C in 1982, which showed an increase of 0.462°C in 10 years. The 10 years average increased by up to 0.80°C between the 1980s and the 1990s. The 2000s had the highest value of 2.89°C, and

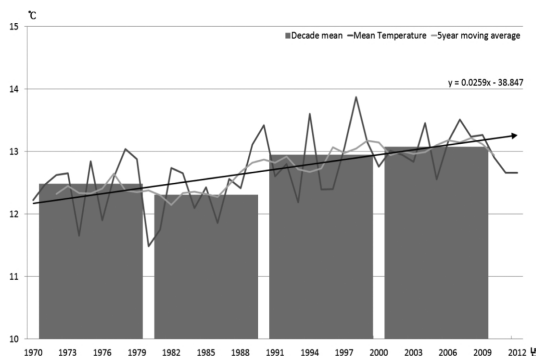


Fig. 1. Interannual variation of annual mean temperature. (10years average, 5years moving average)

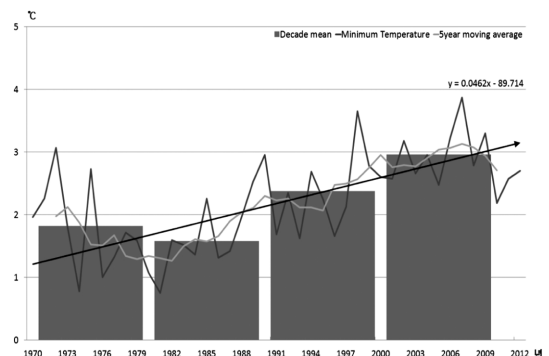


Fig. 3. Same as Fig. 1 except for annual minimum temperature.

the 1980s had the lowest value of 1.58°C, for a difference of 1.31°C.

3.4. Annual Amount of Precipitation

Fig. 4 is the annual amount of precipitation gradually increased with significant fluctuation in view of the annual variation and 5 years moving average. The 10 years average also continuously increased.

The maximum annual amount of precipitation was 1,852.34 mm in 2003, and the minimum was 864.72 mm in 1988. As for the 5 years moving average, the maximum annual amount of precipitation was 1,478.10 mm in 2004, and the minimum was 1,126.41 mm in 1994, which showed an increase of 45.342 mm in 10 years.

The 10 year average was 47.08 mm higher in the 1980s than in the 1970s, for the highest increase. The 2000s had the highest value of 1,359.03 mm, and the 1970s had the lowest value of 1,262.12 mm, for a difference of 1.31°C.

3.5. Potato

Fig. 5 is the potato cultivation area decreased in the early 1980s, and has been relatively constant since. The maximum cultivation area was 51,752 ha in 1975, and the minimum was 20,219 ha in 2003. The maximum 5 years moving average cultivation area was 44,602 ha in 1977, and the minimum was 22,245 ha in 2008. The change in the 5 years moving average cultivation area decreased by 440.22 ha/year.

The potato production per 10 a continuously increased since the beginning of the observation in this study. The maximum production per 10 a was 2,943 kg in 2008, and the minimum was 782 kg in 1978.

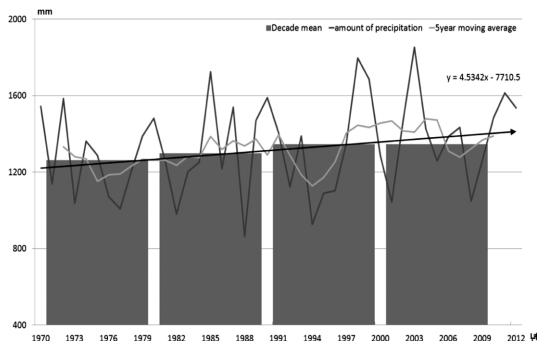


Fig. 4. Same as Fig. 1 except for annual precipitation.

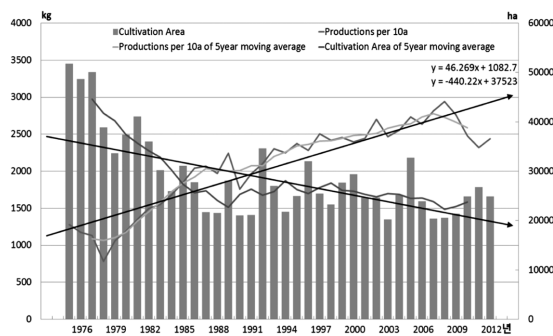


Fig. 5. Secular change and 5years moving average of cultivation area and production per 10a for potato.

The maximum 5 years moving average production per 10 a was 2,777 kg in 2007, and the minimum was 1,068 kg in 1978. The change in the 5 years moving average production per 10 a increased by 46.269 kg/year.

3.6. Sweet Potato

Fig. 6 is the sweet potato cultivation area decreased in the early 1980s, was constant until the 2000s, and slightly increased in the 2000s. The maximum cultivation area was 94,580 ha in 1975, and the minimum was 12,718 ha in 2001. The maximum 5years moving average cultivation area was 44,602 ha in 1977, and the minimum was 22,245 ha in 2008. The change in the 5 years moving average cultivation area decreased by 1,390.7 ha/year.

The sweet potato production per 10 a continuously decreased after the start of the observation. The maximum production per 10 a was 2,463 kg in 1986, and the minimum was 1,415 kg in 2011. The maximum 5years moving average production per 10 a was 2,355

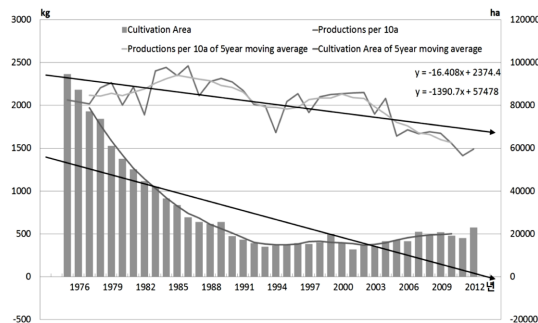


Fig. 6. Same as Fig. 5 except for sweet potato.

Table 2. Correlation analysis of potato, sweet potato and climate element.

		$T_{Annual\ Mean}(^{\circ}C)$	$T_{Annual\ Max}(^{\circ}C)$	$T_{Annual\ Min}(^{\circ}C)$	$R_{Annual}(mm)$
Potato	Pearson	0.458**	0.257	0.701**	0.218
	Kendall's τ	0.349**	0.218	0.525**	0.132
Sweet potato	Pearson	-0.355*	-0.192	-0.454**	-0.058
	Kendall's τ	-0.221	-0.094	-0.237*	-0.055

Significance of correlation coefficient : * :0.05, ** :0.01

kg in 1985, and the minimum was 1,566 kg in 2010. The change in the 5 years moving average production per 10 a decreased by 16.408 kg/year.

4. Correlation Analysis

Table 2 shows the results of the correlation analysis of the meteorological elements and the potato and sweet potato production volumes per 10 a. They showed a positive correlation for all the meteorological elements.

The annual minimum temperature had the highest positive correlation of 0.701, followed by the annual mean temperature (0.458), the annual maximum temperature (0.257), and the annual amount of precipitation (0.218). The annual minimum temperature and the annual mean temperature had a significance value of 0.01. In the Kendall- τ correlation analysis, all the meteorological elements also showed positive correlations. The annual minimum temperature had the highest positive correlation of 0.525, followed by the annual mean temperature (0.349), the annual maximum temperature (0.218), and the annual precipitation amount (0.132). The annual minimum temperature and the annual mean temperature had a significance value of 0.01.

Table 2 shows the results of the correlation analysis of the meteorological elements and the sweet potato production volume per 10a. The analysis showed a negative correlation for all the meteorological elements. The annual minimum temperature had the lowest negative correlation of -0.454, followed by the annual mean temperature (-0.355), the annual maximum temperature (-0.192), and the annual precipitation amount (-0.058). The annual minimum temperature and the annual mean temperature had significance values of 0.01 and 0.05, respectively. In the Kendall- τ correlation analysis, all the meteorological elements also showed negative correlations. The annual minimum temperature had the lowest negative correlation of -0.237, followed by the

annual mean temperature (-0.221), the annual maximum temperature (-0.084), and the annual precipitation amount (-0.055). The annual minimum temperature had a significance value of 0.05.

5. Conclusion

The meteorological element analysis results showed that the mean temperature increased at a rate of 0.259°C in 10 years, and the maximum temperature increased at a rate of 0.253°C in 10 years. The minimum temperature increased at a rate of 0.462°C in 10 years, and the daily amount of precipitation increased at a rate of 45.342 mm in 10 years.

The potatoes showed a positive correlation with all the increasing meteorological elements, which indicated that the climate change positively influenced the growth of the potatoes (Pearson: 0.458, Kendall's τ : 0.349). The sweet potatoes showed a negative correlation with all the increasing meteorological elements, which indicated that the climate change negatively influenced the growth of the sweet potatoes (Pearson: -0.355, Kendall's τ : -0.221). Thus, potatoes, which are grown in the southern region of Korea in summer, are positively influenced by climate change that increases the temperature, whereas sweet potatoes, which are grown in the central region of Korea in winter, are negatively influenced by climate change.

As the westernization of eating habits and the increasing demand for a healthy diet are increasing the consumption of root and tuber crops, the changes in the production of potatoes and sweet potatoes are important factors of food supply. Therefore, sweet potatoes, which are negatively influenced by climate change, need breeding improvement and cultivation method development, and potatoes, which are positively influenced by climate change, require preparations for climate changes that exceed the climatic limit.

Food culture is important for human beings, and food crops are important strategic resources. This study proved that climate change contributed to changes in crop production. Therefore, the importance of agricultural meteorology and the food crop industry should be fully recognized to prepare for climate change.

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