AN ECONOMIC EFFECT OF THE CROP INSURANCE AT THE FARMLAND IN KOREA*

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Keywords
climate change adaptation, crop insurance, extreme weather events, Just-Pope model, evaluation of climate change adaptation options

Abstract
Climate change has a direct and indirect impact on agricultural production through rising temperatures, changes in precipitation and extreme weather events. To cope with climate change efficiently, it is important to carefully estimate the economic effects of adaptation measures and establish innovative methods based on the findings. In this study, we examine statistically the damage and correlation of natural disasters, which are soaring due to climate change, and farm income, and measure the economic effect of crop insurance, which is a representative option for climate change adaptation. To achieve the purpose, we employ the Just-Pope model to perform an econometric analysis and use the data of orchard households. The empirical analysis demonstrates that there exists a negative effect of extreme weather on farm income and the negative effect increases as frequency of weather disasters increases. However, the study also proves that crop insurance is an effective adaptation measure and the economic effect of the crop insurance is greater as more frequent extreme weather events occur. Finally this study shows that insured farmers receive benefits of 1.39 million KRW in comparison with uninsured farmers.

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I. Introduction

Climate change represents a statistically significant change in the average state of the climate; the duration of this can span from years to decades. Climate change can be caused by natural internal processes, external forcing or by artificial changes in atmospheric composition or land use. In its fifth comprehensive report on climate change assessment, the Intergovernmental Panel on Climate Change (IPCC) stated that the impact of human activities on the climate system is a fact, and thus, diagnosed a wide impact. According to the global climate change prospects in the IPCC (2014), if the current trend in climate change continues at the current greenhouse gas emission level, the global average temperature in the late 21st century would be expected to increase by 3.7 ℃; they also indicated that sea level is expected to rise by 63 cm from 1986 to 2005. In the scenarios of global warming, it is expected that weather patterns such as droughts, floods and typhoons, as well as weather conditions will change greatly per region on a yearly basis.

Climate change has a direct and indirect impact on agricultural production through rising temperatures, changes in precipitation and extreme weather events. In many parts of the world, it has been clearly observed that climate change has a significant impact on crop and food production; furthermore, negative repercussions are more common than the benefits. In particular, under climate change scenarios where the average regional temperature increases by 3 to 4 °C or higher, agricultural productivity will be adversely affected, thus, jeopardizing world food production and food security (IPCC, 2014).

In Korea, the temperature has risen by 1.8 ℃ over the past 100 years (1912 ~ 2010) and the precipitation has increased by more than 200mm (Kwon, 2012). In other words, the climate in Korea has been changing faster than the global average. Compared to the mean temperature in the past 40 years (1970 to 2010), future climate change forecasts are projected to rise by 1.8 ℃ in 2020 and 3.7 ℃ in 2050 (KMA: Korea Meteorological Administration, 2012). Specifically, the average annual temperature of the Korean peninsula has risen by 1.2 ℃ (0.41 ℃ / decade) for the past 30 years from 1981 to 2010, and the average annual precipitation tends to increase slightly by 78mm (KMA, 2012).

As climate change worsens, extreme weather events such as heavy rainfall, typhoons, drought, cold waves and heavy snowfall frequently occur and agricultural damage increases accordingly. As the sub-tropicalization of the Korean peninsula has progressed rapidly, the quantity of farmlands and the pattern of the cultivation area have changed; the winter pest damage has also increased (Kim et al., 2009).

The agricultural sector is more vulnerable to climate change than it is to other industries. Therefore, the impact of climate change on agriculture should be scientifically analyzed, wherein systematic and phased adaptation measures should be prepared. Since climate change adaptation measures require a considerable amount of time and budget, it is important to carefully estimate the economic effects of adaptation measures and establish innovative methods based on the findings.

In order to establish a comprehensive and effective adaptation measure to climate change, an economic analysis of options for responding to climate change should be preceded, but the analysis of various climate change adaptation options is still lacking. Hence, in this study, we analyze the economic effects of crop insurance under climate change, particularly extreme weather events in the farm level. Through the analysis, we evaluate the crop insurance as an adaptation option for climate change.

II. Background and Literature Review

1. Extreme Weather Events in Korea

According to the IPCC (2014), climate changes include sudden changes in precipitation pattern or increasing frequency and intensity of extreme weather such as typhoon, localized heavy rains, cold waves and heavy snowfalls, as well as increasing average temperature and precipitation. Recently, Korea has also experienced greater frequency and higher intensity of these extreme weather events. The increasing special reports being issued on extreme weather by the Korea Meteorological Administration is proof of this trend. The special reports on extreme weather refer to announced forecasts when disasters are likely to occur due to extreme weather. Currently, these reports are issued in the case of strong winds, heavy seas, heavy rainfall, heavy snowfall, droughts and tsunamis, as well as winds carrying yellow dusts, cold waves, typhoons and heat waves.

As Table 1 shows, over the last 20 years, the total number of issued special reports on extreme weather increased by 241%, from 596 in 1995 to 1,439 in 2015. Especially, special reports on cold wave have been issued 79 times annually on average in the last five years, compared to only once on average between 1990 and 1994. On other weather disasters such as heavy rainfalls, heavy snowfalls and draughts, the frequency of special reports issued has been significantly increased; that is, the average temperatures and precipitation in Korea are increasing, but the fluctuation of weather is getting bigger with the increase of freezing and drying phenomenon.

Table 1. Number of special reports issued each year

Year	Total number of special reports on extreme weather	Heavy rainfalls	Cold waves	Heavy snowfalls	Draught
1990	655	169	0	46	0
1991	529	114	0	68	10
1992	448	82	3	37	11
1993	534	127	0	39	8
1994	640	58	1	41	25
1995	596	101	4	27	16
1996	376	58	1	50	6
1997	465	116	1	45	21
1998	1,097	320	10	47	30
1999	1,051	294	7	50	25
2000	374	205	4	51	30
2001	866	161	5	91	59
2002	1,021	167	0	52	34
2003	1,138	294	14	81	39
2004	1,006	241	8	59	55
2005	1,016	323	8	210	43
2006	957	305	3	125	49
2007	1,152	428	0	82	41
2008	1,467	354	12	167	89
2009	1,760	526	51	159	187
2010	1,760	601	53	280	85

(continued)

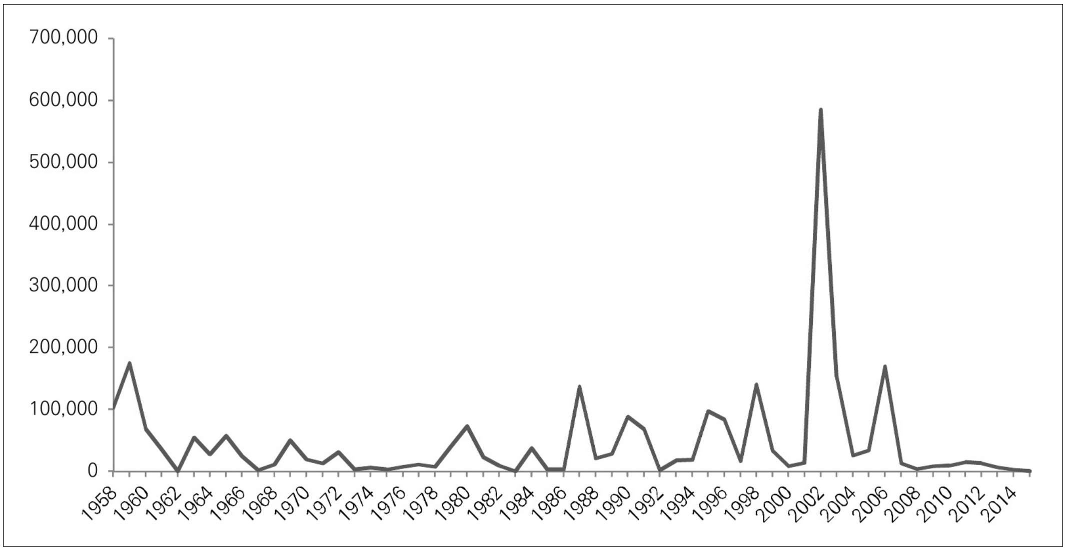
Year	Total number of special reports on extreme weather	Heavy rainfalls	Cold waves	Heavy snowfalls	Draught
2011	1,652	661	86	208	117
2012	1,614	458	111	242	101
2013	1,465	447	87	222	122
2014	1,460	365	82	288	155
2015	1,439	264	29	143	189
1990-1994(average)	561	110	1	46	11
2011-2015(average)	1,526	439	79	221	137

Source: MPSS (Ministry of Public Safety and Security), Each year.

According to the Natural Disaster Yearbook published by the MPSS, since 1990, the scale of damage to the agricultural sector by natural disasters has significantly increased, including but not limited to farmland loss and destruction. The amount of damage by natural disasters increased from 28.4 billion KRW average in the 1960s to 101.5 billion KRW in the 2000s. The analysis of damage by natural disasters after 1916 reveals that in 6 of 10 years, most damage occurred due to natural disasters after 2000. In particular, in 2002 typhoon ‘Rusa’ and localized heavy rainfall caused the bulk of the damage. It was the year of the worst damage by natural disasters in Korea’s recorded history. The agricultural sector also suffered from loss and destruction of farmland, estimated at 585.3 billion won. It is estimated that the total damage in the agricultural sector may be more than the amount announced by the MPSS, given that crop damage is greater than farmland damage (loss or destruction of land) due to natural disasters in the agricultural sector.

Figure 1. Amount of damage from farmland loss and destruction due to natural disasters (1958 to 2015)

Unit: million won



Source: MPSS, Each year.

The frequency of extreme weather events in Korea is rapidly increasing and the damage in the agricultural sector due to extreme weather is also increasing. However, most previous studies that analyze the impacts of climate change on agriculture, considered changes in mean temperature and precipitation as major regressors. In other words, they are trying to estimate the effects of changes in mean temperature or precipitation on agriculture (Adams et al., 1990; Kim et al., 2009; Gammans, Mérel and Ortiz-Bobea, 2017).

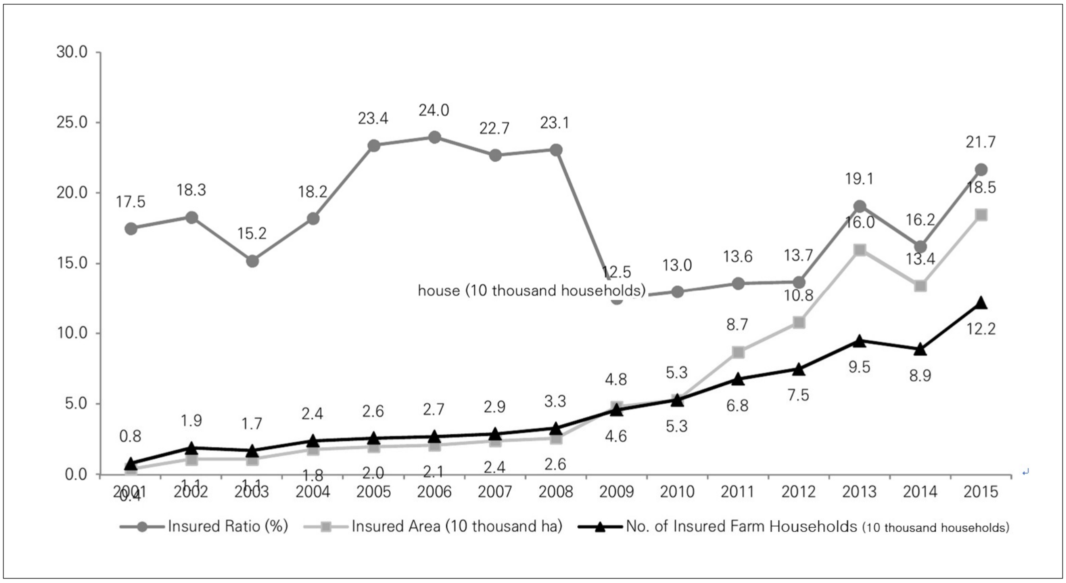
However, damage to agriculture due to climate change is more likely to be caused by extreme weather events that occur intensively in a short time than slowly changing temperature and precipitation. Changes in average temperature and precipitation can be accommodated by changes in cultivation areas or cultivation periods, but extreme weather events such as typhoons, cold waves or heat waves are difficult for farmers to respond in the short term. Previous studies verified that extreme weather events have negative effects on crops. Lee et al. (1991) review the effects of meteorological disasters on the productivity of oilseed crops and suggest the variety improvement and the advanced cultural practice for stable production. Kim et al. (2010) analyze the damage situation of seedlings caused by meteorological disasters and proposed measures for them. Kim et al. (2012) demonstrate the negative effects of heat waves and heavy rainfalls on the rice yield through the panel data analysis. Lobell, Sibley and Ortiz-Monasterio (2012) show that under extreme heat (greater than 34°C), there is statistically significant acceleration of withering with the satellite data of wheat in India. Through the empirical analysis of U.S. crop yields, Schlenker and Roberts (2009) provide evidence that crop yields are optimally increasing with temperature, but if temperature rises more than the thresholds, yields decline sharply. Welch et al. (2010) estimate the impacts of daily minimum and maximum temperature and solar radiation on rice yields in tropical and subtropical Asia; they find that as minimum temperature increases, rice yields decrease, but with higher maximum temperature, rice yields increase. However, these are only a measure of the physical damage of crops, and the impact on the farm income and farmer's risk management has not yet been analyzed.

2. Crop Insurance in Korea

The crop insurance in Korea was introduced in 2001 to help farmers to adapt to the effects of natural disasters, to stabilize income and support farmers. It is one of the most widely adopted adaptation strategies to climate change in Korea.

The crop insurance started in 2001 and insured against damage to apple and pear trees due to typhoons, hail and frost. In 2001, 8,055 farm households bought the crop insurance and 17.5% of total production area was enrolled, which is 4,096 ha. Compared with 2 items in 2001, the range of insurance coverage was further extended to 46 items and various other natural disasters in 2015. In 2015, 122,054 farm households bought the crop insurance, covering 185,239 ha of farmland (respectively, a 15-fold and 45-fold increase since 2001). Since the crop insurance was extended to rice from 2009, the number of insured farm households and the area of insured farmland increased. However, rice growers were not greatly interested in buying the insurance initially and the insured ratio of rice was low, so the total insured ratio also dropped sharply as Figure 2 presents. On the other hand, for orchard for special risk introduced in 2001, the number of insured farm households has steadily increased from 17.5% in 2001 to 45.4% in 2015, implying a successful landing of the crop insurance to market.

Figure 2. Insured Ratio by Year



Source: MAFRA (2016).

In 2015, 18,049 apple growers bought the crop insurance for special risk, the greatest number except for rice (54,415 growers), followed by 9,775 insured pear growers for special risk. The highest ratio of area insured consists of pears (81.6% of pear production area) followed by apples (76.8%) and sweet persimmons (32.0%). The areas insured for field crops or greenhouse crops make up just 5%, and the insured area for rice, only 26.6%.

Table 2. Insured by Major Crops (2015)

Unit: ha, households, %

Category		Production area	No. of insured farm households	Insured area	Insured ratio of area
Orchard (special risk)	Apples	20,674	18,049	15,887	76.8
	Asian Pears	12,045	9,775	9,830	81.6
	Tangerines	16,414	57	45	0.3
	Sweet persimmons	10,478	3,109	3,348	32.0
	Astringent persimmons	9,175	3,109	2,179	23.8
Orchard (multiple risk)	Peaches	9,318	1,798	1,167	12.5
	Grapes	10,974	197	78	0.7
	Plums	3,976	613	272	6.8
	Japanese apricots	7,017	300	211	3.0
Field crops	Soy Beans	26,597	594	855	3.2
	Fall Onions	13,019	311	205	1.6
	Garlic	12,903	56	41	0.3
	Tea	749	80	63	8.3
	Red Peppers	20,828	871	236	1.1
Rice	Rice	515,276	54,415	137,171	26.6
Greenhouse crops	Greenhouse watermelons	13,960	373	183	1.3
	Greenhouse strawberries	6,769	1,020	385	5.7
	Greenhouse melons (Chamwei)	5,345	2,213	1,191	22.3
	Greenhouse tomatoes	6,928	821	310	4.5

Source: MAFRA (2016).

The share of the national area covered by the crop insurance was 21.7 % in 2015, with 122,054 farmers buying the crop insurance. The highest insured ratio is in Jeonbuk, followed by Jeonnam and Chungnam. The insured area in Jeonnam is 55,496 ha and the insured area ratio is 39.9%. From Table 3 and Figure 4, it can be seen that Jeolla has the high frequency of extreme weather events and large agricultural lands, as well as the high insured ratio of area.

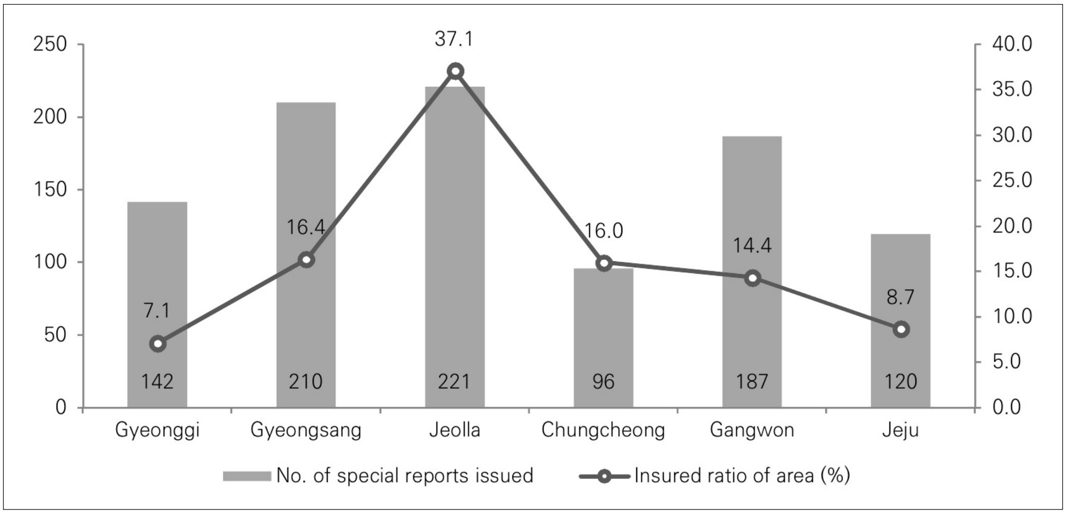
Table 3. Insured by Provinces (2015)

Unit: ha, household, %

Category	Production area	No. of insured farm households	Insured area	Insured ratio of area
Total	854,301	122,054	185,239	21.7
Gyeonggi	83,286	4,044	5,934	7.1
Gangwon	38,216	2,684	5,487	14.4
Chungbuk	50,550	3,867	4,528	9.0
Chungnam	138,005	11,519	25,659	18.6
Jeonbuk	103,254	19,255	41,185	39.9
Jeonnam	157,297	30,699	55,496	35.3
Gyeongbuk	135,402	26,829	23,811	17.6
Gyeongnam	93,113	14,945	13,584	14.6
Jeju	23,680	3,087	2,060	8.7

Source: MAFRA (2016).

Figure 3. Special Reports on Extreme Weather and Insured Ratios by Provinces (2015)



Source: MAFRA (2016) and MPSS (2016).

The agricultural insurance budget of MAFRA, which includes the crop insurance, increased from 16.6 billion won in 2001 to 285.3 billion won in 2015. The agricultural insurance budget has increased 17 times and the share of the agricultural insurance in the total budget of MAFRA has increased from 0.2% in 2001 to 2.0% in 2015. This shows the growing importance of the agricultural insurance in agricultural policy.

Table 4. MAFRA budget for Agricultural Insurance (2001 to 2015)

Unit: 100 million won, %

Years	Budgets of MAFRA (A)	Agricultural insurance budget (B)	Ratio (B/A)
2001	93,634	166	0.2
2002	102,450	247	0.2
2003	101,496	363	0.4
2004	106,907	388	0.4
2005	110,630	499	0.5
2006	118,560	998	0.8
2007	121,208	1,031	0.9
2008	124,242	1,161	0.9
2009	129,887	1,218	0.9
2010	129,888	1,319	1.0
2011	131,929	1,663	1.3
2012	136,778	1,856	1.4
2013	135,267	2,348	1.8
2014	135,344	2,701	2.0
2015	140,431	2,853	2.0

Source: Nonghyup Property & Casualty Insurance (2015), MAFRA (2016).

Thus, crop insurance is one of the most important policy-driven farmer's risk management options and is also one of the major options of adaptation to climate change; crop insurance has also been rapidly distributed. However, so far, previous studies on crop insurance have only estimated policy effects such as an increase of total production or cultivation area (Young and Westcot, 2000; Han, 2014); recently, several studies have tried to analyze the effect of crop insurance on production or cultivation area in farm level. Kim (2001) conducted an empirical analysis of apple farm households and measured the welfare effect of crop insurance and income insurance. Comparing the welfare effects of crop insurance and income insurance, Kim insisted that income insurance is a more desirable policy tool. Gray et al. (2004) showed that if the policies including crop insurance were implemented, the expected profit of the farm household increased and the profit distribution changed. On the basis of this, Gray et al. analyzed empirically how the profit distribution of producers is changed by implementing multiple policies at the same time. They found that individual policies increase expected returns and lower risk, but the effect of using crop insurance with other policies such as marketing loan payment and direct payment is rather reduced. Choi, Chae, and Yun (2010) evaluated the overall performance of crop insurance in Korea. After evaluating the performance of crop insurance for ten years using econometric methods, they analyzed the problems of crop insurance and suggested the political reform measures. They found that the risk management measures such as disaster prevention facilities have an alternative relation to insurance, and the crop insurance is effective in reducing instability in farm household income. Han (2014) analyzed empirically the effect of crop insurance on farmers' production patterns and the effect on crop market caused by changed production. Using DID (difference-in-differences), Han estimated the effect of crop insurance on the production by crop type and business type. From the results, Han found that the participation rate of crop insurance affects the quantity produced positively and therefore may affect the market price of the item insured.

Di Falco et al. (2014) states that the demand for crop insurance increases according to weather condition, and crop insurance is an effective measure for risk management. However, research on whether or not crop insurance is beneficial to the farm economy when natural disasters occur, which is the intrinsic goal of crop insurance, has not yet been conducted.

III. Model and Economic Theory

1. Just-Pope Model

With the increasing threat of extreme weather events, the benefits of the crop insurance are growing as a strategy for farmers' effective risk management. Nevertheless, the impact of the crop insurance in reducing damage by extreme weather has not been studied so far. Earlier studies on the crop insurance have focused largely on the political effects, for example, changes of areas cultivated and quantity produced.

This study focuses on the effect of the crop insurance in mitigating farmers' income damage and fluctuations due to extreme weather, which is the primary goal of crop insurance. For this analysis, the Just-Pope model (Just and Pope, 1978) is employed.

An evaluation of extreme weather events and crop insurance was accomplished by a Just-Pope mean function model, which characterized the expected income and variance of income per farm by different functions (denoted mean function, f and variance function or risk function, g, respectively):

$$y = f(X; \alpha) + g(X; \beta) \varepsilon$$

where y represents farm income, X is the vector of independent variables, α and β are parameter vectors, and $\varepsilon \sim N(0, 1)$. After assigning functional forms to f and g, econometric estimation of the Just-Pope mean function yielded the systematic effects of regressor on both expected income and the variance of income.

The Just-Pope model is a 3-step approach in which step 1 estimates income from crop cultivation by OLS (Ordinary Least Squared):

$$y = f(X; \alpha) + u$$

where u is the residual term. Furthermore, step 2 estimates the variability of income from crop cultivation with the square of error terms derived at step 1 as a dependent variable.

$$var(y) = E[(y-E(y))^2] = E(u^2) = [g(X; \beta)]^2$$

Step 3 applies the estimate of the error terms derived at step 2 to remove heteroscedasticity and then re-estimates income from crop cultivation.

$$y/g(X; \beta) = f(X; \alpha)/g(X; \beta) + \varepsilon$$

Since income risk may be modeled as heteroskedasticity, the parameters in the mean function cannot be efficiently estimated if the income risk is not accounted for. In the empirical literature, this is done by estimating the mean function and the variance function together, primarily by a feasible generalized least squares (FGLS) three-stage estimator (Asche and Tveteras, 1999).

Using the minimizing Akaike's information criterion, we choose regressors, and the equation of an empirical panel estimation for farm income from crop cultivation at step 1 is:

$$CropInc_{it} = \alpha_0 + \alpha_1 D^{fulltime}_{it} + \alpha_3 D^{expert}_{it} + \alpha_4 Age_{it} + \alpha_5 Age_{it}^2 + \alpha_6 Acre_{it} + \alpha_7 D^{ins}_{it} \times Warning_{it} + \alpha_8 D^{crop}_{it} + c_i + u_{it}$$

where i is farmer's id; t is time; CropInc is income from crop cultivation; $D_{fulltime}$ is full-time farmers; Age is farmer's age; Acre is farmer's cultivation area; D_{ins} is farmer's buying the crop insurance policy; Warning is the number of issued weather alerts; and D_{crop} is a dummy variable; c is an individual effect; u is an idiosyncratic error.

The equation for estimating variability of income from crop cultivation at step 2 is:

$$ln(CropInc_{it}-E(CropInc_{it}))^2 = \beta_0 + \beta_1 D^{fulltime}_{it} + \beta_2 D^{expert}_{it} + \beta_3 Age_{it} + \beta_4 Age_{it}^2 + \beta_5 Acre_{it} + \beta_8 D^{ins}_{it} \times Warning_{it} + \beta_9 D^{crop}_{it} + c_i + \nu_{it}$$

They are consistent estimates of the variances, which are calculated as the antilogarithm of the predictions from step 2. At step 3, using the squared root of the variance predictions as weights the original model by weighted least squares (WLS) is estimated (McCarl, Villavicencio and Wu, 2008).

2. Probit Model

After exploring how crop insurance mitigates damage to farms caused by abnormal weather, we examine whether the farmer's choice of adopting crop insurance would be affected by the extreme weathers. We model a representative risk-averse farm household as choosing to adopt a crop insurance to maximize the expected utility from final revenue, given the production function, land and other constraints (Yesuf et al.). We assume that farmers are price-takers and they operate in perfect competition market structure (Yesuf et al.). Also, assuming that the utility function is state-independent, solving this problem would give an optimal adaptation strategy undertaken by the representative farm household, given by equation:

$$A_{it} = A(X_{it}; \alpha) + \varepsilon_{it}$$

where A is equal to 1 if household i adopted an insurance scheme at time t, and X_{it} is the vector of independent variables including the farmer's characteristics and climatic variables. The inclusion of the extreme weather event variable in the equation allows us to test whether the frequency of extreme weather events is a potential complement or substitute for the decision to adopt crop insurance. α is a vector of parameters, and ε_{it} is the error term. A risk averse household chooses to adopt the strategy of adopting crop insurance, A = 1, over the strategy of not adopting crop insurance, A = 0, if, and only if, the expected utility from adaptation strategy is greater than the expected utility of strategy.

3. Data

In order to estimate the damage caused by climate change and examine the effect of crop insurance on damage reduction, we use data on farm income, insurance expenditure and general characteristics of farm households from "Farm Economic Survey", and data on special reports on extreme weather events from "Natural Disaster Yearbook". The Farm Economic Survey is a statistical survey carried out annually by Statistics Korea on 2,800 sample farms in 560 sample locations nationwide. The sample farm households are replaced every five years. When the panel is replaced, the identification number of each farm is also changed. It makes it difficult to utilize it as panel data. Hence, in this study, only the data from 2008 to 2012 that used the same sample is used for examination.[1]

In this study, we use only orchard farm data from the Farm Economic

[1] Most recently, the survey panel has been replaced since 2013, and data are currently available until 2016, so a data for four years is available for the latest panels. In this study, we used the panel data for 5 years from 2008 to 2012 to get as much data as possible.

Survey, for the crop insurance was first introduced for orchard farms and the insured ratio of orchard farms is relatively high. If we use the whole data set of orchard farm for examination, it is difficult to obtain meaningful findings in the quantitative analysis because of the huge income gap. The minimum value of income from orchard farm data set is negative 120 million KRW and the maximum value is 426 million KRW. Therefore, we use only 549 observations from the second and third quintiles of farm income except the extremes.

Full-time farmers in the analysis account for approximately 59%, full-time farmers account for approximately 63% of insured fruit growers and full-time farmers account for approximately 58% of uninsured fruit growers. Specialized fruit growers account for approximately 61% of all fruit growers, and among the insured fruit growers, specialized fruit growers account for approximately 74%. However, in the uninsured fruit growers, only 58% are specialized fruit growers; as such, more full-time farmers or specialized fruit growers purchased the crop insurance in comparison to part-time or non-specialized fruit growers.

126 orchard farms, which make up 23% of total orchard farms, purchased the crop insurance and 423 farms did not. Average farm income from crop cultivation and off-farm income were 30 million KRW and 5.11 million KRW, respectively. For the insured farms, farm income from crop cultivation was 36 million KRW and off-farm income was 5.2 million KRW. On the other hand, for the uninsured farms, farm income from crop cultivation was 28 million KRW and off-farm income was 5.1 million KRW. Insured farms had relatively high agricultural income, while there was no big difference in off-farm income levels of insured and uninsured farms. The average orchard area is 77a. The average orchard area of insured farms is 87a, which is larger than that of 74a of uninsured farms.

The Natural Disaster Yearbook provides quarterly statistics on special report on extreme weather events for each of the six regions in Korea (Seoul and Gyeonggi-do; Busan and Gyeongsang-do; Gwangju and Jeolla-do; Daejeon and Chungcheong-do; Gangwon-do; Jeju-do). Considering the fruit growing period, we use data from the second and third quarter; in addition, the total number of special reports issued for strong winds, heavy rainfall, heavy snowfall, drought, cold waves, typhoons and heat waves is used. The frequency of special reports on heavy seas, tsunamis and winds carrying yellow dusts is excluded, for these extreme weather events hardly affect fruit tree growth.

The average number of special reports issued in the second and third quarter was 116, and insured farms experienced 127 special reports. Therefore, we can assume that there is correlation between the frequency of extreme weather events and farmers' decision-making on buying the crop insurance.

Table 5. Basic statistics of key variables

Variable	Average	Standard deviation	Min. value	Max. value
All fruit growers (obs.=549)				
D (full-time grower=1, class 1 and 2 two-job grower=0)[2]	0.59	0.49225	0	1
D (specialized grower=1, general · sideline· self-sufficient grower=0)[3]	0.61	0.48731	0	1
D (insured=1, uninsured=0)	0.23	0.42090	0	1
Age	66.05	9.95046	32	91
Cultivated area (a)	76.84	60.9259	0	447
Farm income from crop cultivation (1,000 KRW)	29937	18614.7	4970.5	221756.1
Number of special reports issued in 2nd & 3rd quarters	116.3	42.0317	49	212
Insured growers (obs.=126)				
D (full-time grower=1)	0.63	0.48554	0	1
D (specialized grower=1)	0.74	0.44143	0	1
Age	65.40	9.09952	37	91
Cultivated area (a)	87.10	66.0790	4.1	446.6
Farm income from crop cultivation (1,000 KRW)	36037	23952.6	8129.6	221756.1
Number of special reports issued in 2nd & 3rd quarters	127.0	35.2997	49	212
Uninsured growers (obs.=423)				
D (full-time grower=1)	0.58	0.49427	0	1
D (specialized grower=1)	0.58	0.49465	0	1
Age	66.25	10.1922	32	85
Cultivated area (a)	73.78	59.0434	0	294.5
Farm income from crop cultivation (1,000 KRW)	28120	16297.4	4970.5	117913.2
Number of special reports issued in 2nd & 3rd quarters	113.2	43.3704	49	212

Source: Kim et al. (2015).

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[2] In this case, full-time fruit growers refer to those who do not have family members engaged in other work than farming for more than 30 days each year. In addition, Class 1 two-job fruit growers refer to those whose agricultural income is more than their off-farm income, and the Class 2 two-job fruit growers refer to those whose agricultural income is smaller than their

IV. Results

Table 6 presents the results of estimating the effects of extreme weather events and crop insurance on farm income. According to the result of the estimation, the correlation between the farm owners' age and farm income is not statistically significant. Moreover, the difference in farm income between the full-time growers and the part-time growers is not statistically significant either. However, specialized growers are expected to earn 9.07 million KRW more in farm income than others. It shows that the scale of cultivation affects the farm income rather than how much farmers concentrate on farming. The larger the farmland is, the more the farm income is. As the cultivation area is increased by 10a, the farm income is increased by about 130 thousand KRW. This implies that there exists an economy of scale in fruit farming.

About the extreme weather events, the result presents that the farm income is lower, as the frequency of special reports on extreme weather events issued during the second and third quarter of the major crop growth period is increasing. That is, orchards are actually experiencing economic damage due to extreme climates such as heat waves, cold waves, typhoons, heavy rainfalls, and droughts. It is estimated that an average of 27,680 KRW of economic damage occurs to uninsured farmers every time a special report is issued. By applying the average annual 116 special reports between 2009 and 2012, it is estimated that extreme weather caused approximately 3.21 million won of damage to fruit growers.

off-farm income (Statistics Korea, 2015).

[3] In this case, categories of specialized fruit growers, general fruit growers and sideline fruit growers comply with the farmer classification standard of Statistics Korea. The specialized fruit growers refer to those who have at least 3ha of farmland or at least 20 million won of agricultural income. The general fruit growers refer to those who have farmland smaller than 3ha and at most 20 million won of agricultural income. The sideline fruit growers refer to those whose off-farm income is more than agricultural income among fruit grower who have at least 30a of farmland or at least 2 million won of agricultural income. The self-sufficient fruit growers refer to those whose agricultural income is smaller than 2 million won among those who have farmland smaller than 30a (Statistics Korea, 2015).

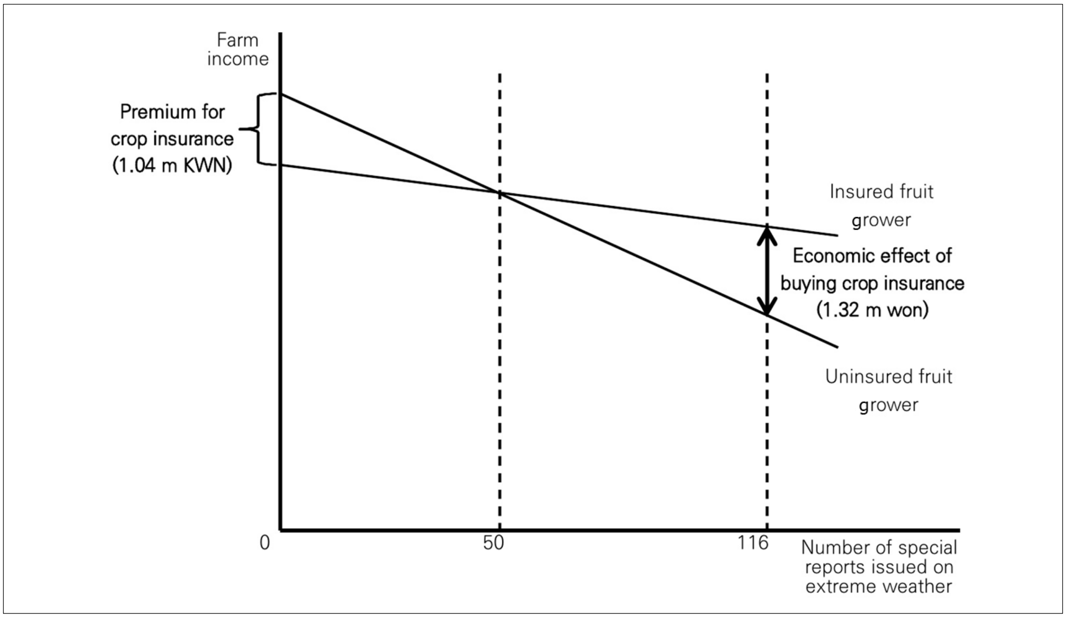
Table 6. Result of estimated effect of the crop insurance for reducing damage by extreme weather events

Variable	Coef.	Std. Err.	P>|z|
D (full-time fruit grower=1, part-time fruit grower=0)	1430.33	905.70	0.114
D (specialized fruit grower=1, general · sideline · self-sufficient fruit grower=0)	9069.64	966.10	0.000
Age	-544.68	571.04	0.340
Age2	1.50	4.61	0.745
Cultivated area (a)	134.34	12.34	0.000
Number of special reports issued in 2nd & 3rd quarters	-27.68	14.95	0.064
Number of special reports issued in 2nd & 3rd quarters *D (insured=1)	20.36	6.70	0.002
D (general apple=1)	-2706.86	1924.01	0.159
D (dwarf apple=1)	479.80	2406.97	0.842
D (Asian pear=1)	4479.17	1653.94	0.007
D (grape=1)	2310.13	1810.55	0.202
D (peach=1)	-53.00	1491.01	0.972
D (persimmon=1)	-481.36	1497.97	0.748
D (tangerine=1)	-2746.62	2903.42	0.344
Constant term	45303.90	17504.55	0.010
# of obs.			549
Wald chi^2 (14)			368.12
Prob>chi^2			0.000

Source: Kim et al. (2015).

Meanwhile, through the examination, we find that the crop insurance can mitigate the economic damage caused by extreme weather events. As Table 6 shows, the crop insurance reduces farm income loss by 20,360 KRW per special report. Hence, compared with 27,680 KRW for an uninsured grower, an insured fruit grower is expecting that an economic loss of only 7,320 KRW occurs every time a special report is issued. By applying 116 times of average special reports issued between 2009 and 2012, it is estimated that an insured grower is damaged by 850 thousand KRW. This is approximately 2.36 million KRW smaller than 3.21 million won for the uninsured fruit growers. Considering that the average crop insurance premium of the insured farmers in this sample is 1,040 thousand KRW; the comprehensive effect of crop insurance on farm income is 1,322 KRW.

Figure 4. The economic effect of crop insurance on farm income



Source: Kim et al. (2015).

Table 7 presents the estimated result of the effect of the crop insurance and extreme weather events on farm income volatility. According to the result of analyzing the effects of crop insurance and extreme weather on the variability of farm income, the variability of farm income of full-time or specialized growers is higher than others. Furthermore, the estimation result shows that as a fruit grower cultivates in a larger scale, the variability of farm income is also increased. This means that the higher the farm income is, the higher the variability is.

The number of special reports on extreme weather events has a positive correlation with the volatility of farm income. As the extreme weather events occur frequently in the fruit growing season, the volatility of farm income also increases. That is, natural disasters such as heat wave, cold wave, heavy rain and snowfall, typhoons and droughts not only aggravate the farm income, but also increase the uncertainty of farm income. The estimation result shows that the crop insurance reduces the volatility of farm income slightly, but the effect is not statistically significant. This analysis suggests that the volatility of farm income depends on the frequency of natural disaster and the scale of cultivation area rather than the crop insurance and farm owner's age.

Since this study is based on farm-level information, it is hard to make an accurate estimation of the variability of farm income. To better an analysis of the effect of crop insurance on the variability of farm income, it is necessary to carry out estimation to the exclusion of the scale of production. Therefore, more accurate results can be obtained if farm income per unit area rather than fruit grower's total agricultural income is analyzed in future studies.

Table 7. Result of the estimated effect of crop insurance for reducing variability of farm income

Variable	Coef.	Std. Err.	P>|z|
D (full-time fruit grower=1, part-time fruit grower =0)	0.7555	0.2040	0.000
D (specialized fruit grower =1, general · sideline · self-sufficient fruit grower =0)	0.3719	0.2193	0.090
Age	-0.0297	0.0948	0.754
Age^2	0.0000	0.0008	0.966
Cultivated area (a)	0.0116	0.0019	0.000
Number of special reports issued in 2nd & 3rd quarters	0.0065	0.0032	0.039
Number of special reports issued in 2nd & 3rd quarters*D (insured=1)	-0.0001	0.0018	0.974
D (general apple=1)	-0.2018	0.3341	0.546
D (dwarf apple=1)	0.4127	0.3245	0.203
D (Asian pear=1)	0.7183	0.2700	0.008
D (grape=1)	0.4563	0.2535	0.072
D (peach=1)	-0.1941	0.2671	0.467
D (persimmon=1)	-0.0402	0.2391	0.867
D (tangerine=1)	0.8925	0.4494	0.047
Constant term	16.3680	2.9443	0.000
# of obs.			549
Wald chi^2 (14)			121.04
Prob>chi^2			0.000

Source: Kim et al. (2015).

Finally, Table 8 presents the results of the probit estimation. According to the Probit analysis, as the time passes, the incentive for crop insurance increases, which is considered to be a positive publicity effect. In addition, it was found that the incentive of insurance for the specialized fruit grower is higher than that of the others, and the larger the cultivation area, the greater the insurance incentive. Thus, the farmers who are engaged in large - scale farming are more interested in risk management. As for the cultivated items, the insurance incidence of dwarf apples and Asian pears is relatively high and grapes are low, which is consistent with Table 2.

Table 8. Estimation result of crop insurance probit

Variable	Coef.	Std. Err.	P>|z|
Trend	0.3428	0.0595	0.000
Number of special reports issued in 2nd & 3rd quarters $_{t-1}$	0.0044	0.0020	0.024
D (full-time fruit grower=1, part-time fruit grower=0)	0.1741	0.1495	0.244
D (specialized fruit grower=1, general · sideline · self-sufficient fruit grower=0)	0.3590	0.1576	0.023
Age	0.1068	0.0721	0.138
Age^2	-0.0009	0.0006	0.124
D (general apple=1)	0.0516	0.2234	0.817
D (dwarf apple=1)	0.7278	0.2100	0.001
D (Asian pear=1)	0.3766	0.1839	0.041
D (grape=1)	-0.4323	0.1829	0.018
D (peach=1)	-0.2781	0.1941	0.152
D (persimmon=1)	-0.0369	0.1757	0.834
D (tangerine=1)	-0.4556	0.3351	0.174
Cultivated area (ha)	0.2206	0.1339	0.099
Constant term	-5.7429	2.2538	0.011
# of obs.			549
Wald $chi^2(14)$			74.67
Prob>chi^2			0

The number of special reports on extreme weather events of the previous year has a positive correlation with the farmers' choice on crop insurance and is statistically significant. This result is quite intuitive, indicating that farmers who have experienced natural disasters adopt more crop insurance to hedge against bad environmental conditions. This implies that more frequent extreme weather events make the farmer more willing to undertake crop insurance.

V. Conclusion

In this study, we try to statistically prove the damage and correlation of natural disasters, which are soaring due to climate change, on farm income, and to measure the economic effect of crop insurance, which is a representative option for climate change adaptation. To achieve the purpose, we employ the Just-Pope model to perform an econometric analysis and use the data from "Farm Economic Survey" and statistics of special reports on extreme weather.

In this study, we find that the farm income is influenced not only by the characteristics of the farm owner such as age, or full-time/part-time farming, but also the size of the farm, the cultivated items and the frequency of extreme weather. As the farmland size increases, both farm income and income volatility also increase. On the other hand, as the frequency of natural disasters increases, farm income decreases, but income volatility continues to climb due to increased uncertainty. In addition, it is verified that as a countermeasure against the decrease of farm income due to meteorological disasters, crop insurance has statistically significant effects and its impacts increase as the frequency of weather disaster increases.

By applying 116 times the annual average special report on extreme weather during 2009 ~ 2012, the crop insurance has economic effects of 1,230 thousand KRW per farm household. If the number of annual special reports issued is 51 times or fewer, the expected benefits from crop insurance are lower than the premium of crop insurance. In other words, in areas where weather conditions are favorable and natural disasters occur less frequently, crop insurance premiums are higher than expected economic effects of crop insurance, so it is a reasonable choice not to join the crop insurance. For example, the insured rate of Jeju, which has a smaller number of special reports on extreme weather than other regions, appears to be very low.

From the result of analyzing the effect of extreme weather events on farmers' decision-making about crop insurance, we find that the more frequent natural disasters farmers suffer, the greater the intention to purchase crop insurance.

These findings from the study can provide several implications to researchers and policy-makers. Our finding shows that extreme weather events have an adverse impact on farm income and the damage is expected to increase with the increasing frequency of extreme weather events due to climate change. However, most studies on the impact of climate change on agriculture were about how average temperature or precipitation would affect agricultural production and land use. There are still very limited statistical data and research on extreme weather events and agriculture. Hence, it is required to produce statistics on natural disasters that can be used in the agricultural sector and to conduct further studies on the impact of abnormal temperatures on the sector.

As it is proven that crop insurance is an effective means of adapting to climate change, it is necessary to conduct campaigns and promotions regarding crop insurance. As climate change is expected to become more severe in the future, the effect of the insurance is expected to increase. In a region with a low frequency of extreme weather, farmers do not prefer crop insurance because the premium is higher than the crop insurance effect; it will be more effective to focus public relations of the crop insurance and encourage farmers to be insured in the regions where weather disasters occur frequently.

As a result of the study, crop insurance is considered to be a very effective tool for farmers' risk management due to climate change, but as Goodwin and Smith (2013) insist, because of the high subsidy rate, there is a tendency to distort the production market, which transfers the financial burden to the taxpayers. Hence, there is a need for a systematic supplement that allows insurance to work reasonably in the long term.

From the estimation results, we found crop insurance does not have a statistically significant effect on farm income volatility, but considering the limitation of farm-level data, which is significantly affected by size of business, it is necessary to carry out estimation to the exclusion of the scale of production to better an analysis of the effect of crop insurance on the variability of farm income. Therefore, more accurate results can be obtained if farm income per unit area rather than fruit grower’s total agricultural income is analyzed in future studies.

Lastly, this study also has limitations. In this study, we use sample data, which includes only 2^{nd} and 3^{rd} quantiles of farms. Because of the limitation of data, the representation of analysis results is also limited. In order to obtain a higher level of representation and analyze responses of farmers in various farm income levels, in further studies, it is necessary to update the data set and carry out a further analysis using various models such as quantile regression or mixed level regression.

Appendix. Criteria for issuing special reports on extreme weather

Category	Warning	Alert
Strong winds	Wind speed is forecasted 14m/s or faster, or instantaneous wind speed 20m/s or faster on land, but wind speed is forecasted 17m/s or faster, or instantaneous wind speed 25m/s or faster in mountainous areas.	Wind speed is forecasted 21m/s or faster, or instantaneous wind speed 26m/s or faster on land, but wind speed is forecasted 24m/s or faster, or instantaneous wind speed 30m/s or faster in mountainous areas.
Heavy seas	Wind speed faster than 14m/s is forecasted to continue for at least 3 hours or the significant wave height higher than 3m is forecasted in the sea.	Wind speed faster than 21m/s is forecasted to continue for at least 3 hours or the significant wave height higher than 5m is forecasted in the sea.
Heavy rainfalls	Rainfall more than 70mm for 6 hours or rainfall more than 110mm for 12 hours is forecasted.	Rainfall more than 110mm for 6 hours or rainfall more than 180mm for 12 hours is forecasted.
Heavy snowfalls	Fresh snow cover deeper than 5 cm for 24 hours is forecasted.	Fresh snow cover deeper than 20 cm for 24 hours is forecasted. However, fresh snow cover deeper than 30 cm for 24 hours is forecasted in mountainous areas.
Dryness	Effective humidity not higher than 35% is forecasted to continue for two or more days.	Effective humidity not higher than 25% is forecasted to continue for two or more days.
Windstorm tsunamis	Values greater than the effective standard value for tsunamis are forecasted by rising sea level due to complex effects including astronomical tides, windstorms, or low pressure. However, the effective standard value is specified for each region.	Values greater than the effective standard value for tsunamis are forecasted by rising sea level due to complex effects including astronomical tides, windstorms, or low pressure. However, the effective standard value is specified for each region.
Earthquake Tsunamis	Tsunamis by earthquakes with wave height of 0.5 to 1.0m are forecasted around coastal areas of Korea due to submarine earthquakes higher than scale 7.0 in the waters around the Korean Peninsula (21N~45N, 110E~145E).	Tsunamis by earthquakes with wave height greater than 1.0m are forecasted around coastal areas of Korea due to submarine earthquakes higher than scale 7.0 in the waters around the Korean Peninsula (21N~45N, 110E~145E).
Extreme colds	From October to April, one of the following occurs. ① The lowest temperature in the morning is forecasted to be at least 10℃ lower than the previous morning, and lower than 3℃, and 3℃ lower than the temperature in the previous year. ② The lowest temperature in the morning lower than －12℃ is forecasted to continue for two or more days.	From October to April, one of the following occurs. ① The lowest temperature in the morning is forecasted to be at least 15℃ lower than the previous morning, and lower than 3℃, and 3℃ lower than the temperature in the previous year. ② The lowest temperature in the morning lower than －15℃ is forecasted to continue for two or more days.

Category	Warning	Alert
	③ Severe damage is forecasted due to extremely low temperature.	③ Severe damage is forecasted in extensive areas due to extremely low temperature.
Typhoon	The forecast is that typhoons cause strong winds, heavy seas, heavy rainfalls and windstorms tsunamis to reach their warning standards.	The forecast is typhoons cause any one of the following. ① Reach the strong winds (or heavy seas) alert level. ② Total rainfall more than 200mm. ③ Reach the windstorms tsunamis alert level.
Winds carrying yellow dusts	The forecast is the average ultrafine dust (PM10) concentration/hour greater than 400㎍/m3 continues for at least two hours due to winds carrying yellow dusts.	The forecast is the average ultrafine dust (PM10) concentration/hour greater than 800㎍/m3 continues for at least two hours due to winds carrying yellow dusts.
Heat waves	The forecast is that the daily highest temperature higher than 33°C continues for two or more days.	The forecast is that the daily highest temperature higher than 35℃ continues for two or more days.

Source: Korea Meteorological Administration. <http://www.kma.go.kr/>. May 11, 2015.

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