Research article

Assessing Climate Change Vulnerability in Rural Areas: Cases of Apple Farming in 4 Municipals in Gyeonggi Province, Korea

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Abstract Climate change poses a major threat to the environment, economic and social components in agricultural sector in rural communities. If rural agricultural communities are to respond adequately to future climate change, they will require to develop adaptation measure and to do so, it is required to assess vulnerability in their communities. One of the most notable climate change impact in Korean agricultural communities is that fruit cultivation sites are moving northward. In the past, apple cultivation was not preferred in the Gyeonggi province. However, with changing climate, farmers in Icheon and Gapyeong in Gyeonggi province started to cultivate apple. In addition, governmental support through apple cultivation promoting projects increased apple cultivation in the province in recent years. This paper aims to assess climate change vulnerabilities of 4 apple cultivation communities in Gyeonggi province by developing vulnerability indices as function of climate exposure, sensitivity and adaptive capacity. Using z-score normalization, the quantitative analysis was conducted in this study. The main results of vulnerability assessments are founded as follow: Icheon and Gapyeong showed higher vulnerability by higher level of exposure and sensitivity to changing climate than Paju and Yeoncheon. However, adaptive capacity showed that Paju and Yeoncheon as more vulnerable than the Icheon and Gapyeong. Therefore, the study concludes that albeit the same crops cultivated in one province, for effective local-level adaptation measures, identifying components comprising the vulnerability in the community is required. Vulnerability assessment using indices should provide quantitative backgrounds to develop appropriate and effective agricultural community adaptation measures.

Keywords climate change, local-level adaptation, vulnerability assessment, apple farming

INTRODUCTION

Responding to additional challenges from climate change impacts will require significant adaptation measures within agricultural communities (IPCC, 2007). Agricultural communities in Korea have already experienced impact of climate change, including crop and livestock loss from severe drought and flooding, large-scale losses from weather-related disasters, shifts in planning and harvesting times and cultivation lands. According to Ministry of Environment (2015), one of the most notable and critical climate change impact in Korea on agriculture sector is that fruit cultivation sites have been shifting northward and this impact has been appeared mostly in apple cultivation. Total area of apple cultivation in formerly famous southern areas, Daegu and Gyeongsang province, has been decreased about half from 34,770 ha in 1995 to 18,889 ha in 2014 (East-North Regional Statistics Korea, 2015). On the other hand, apple cultivation is increasing in provinces in north, such as Gyeonggi and

Gangwon. Farmers in Gyeonggi province, particularly in Icheon and Gapyeong municipals, adapted apple crop in their cultivation site since early 2000s. Moreover, regional government started to recognize apple as one of important crops in the areas. In recent years, through 'Demilitarized Zone (DMZ) apple cultivation community' project in Paju and Yeoncheon, government supports local farmers who wish to grow apple by providing financial and technical supports. To respond adequately to future changing climate in relatively new and increasing apple farming communities in Gyeonggi province, it is required to assess the risks and vulnerability. The most mutual quantitative vulnerability assessment method is the employment of a composite index comprising a set of indicators. These indicators represent the vulnerability of a studied system and are mathematically combined into a single composite index (Moss et al., 2001). Although there are studies on quantifying vulnerability using indicators, most of the studies are done in macro-level to assess national and regional level of vulnerabilities (Yoo and Kim, 2008; Moss et al., 2001). Effective planning for climate change adaptation programming in agricultural communities requires an assessment of local vulnerabilities so as to bridge the gap between community needs and priorities at the local level (Burton et al., 2002). Not only it is important to assess local level vulnerabilities but it is vital to have crop specified vulnerability assessment considering environment, economic and social conditions of the agricultural communities. This paper will conduct in-depth analysis of the local level vulnerabilities, to compare the differences among apple growing communities by developing vulnerability index and integrating quantitative analysis based on the intensive review of previous studies and policy reports.

OBJECTIVE

The main objective of this paper is to conduct quantitative assessment of climate change vulnerability of four apple farming municipals (Icheon, Gapyeong, Paju and Yeoncheon) within Gyeonggi province in Korea. By developing and using three indices, vulnerability assessments of the areas are done to analyze the variables that determine vulnerability of the communities and compare the differences that exist among the apple farming communities in Gyeonggi province.

METHODOLOGY

As shown in Fig. 1, Gyeonggi province is located in the central western part of Korea and it surrounds the cities of Seoul and is bordered by North Korea. The province has a typical continental climate that the annual temperature is between 10 ℃-13 ℃.

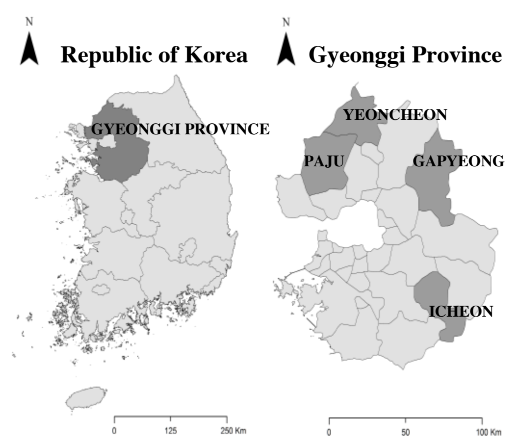

Fig. 1 Study areas

Table 1 Overview of Gyeonggi province and 4 apple farming municipals

Indicators	Gyeonggi	Icheon	Gapyeong	Paju	Yeoncheon
Population (persons)	12,793,556	210,908	62,774	426,733	46,180
Population Density (person/km^2)	1,234	457	74	598	69
Agricultural Land (ha)	176,854	17,349	3,706	11,445	9,012
Apple Cultivation Area (ha)	500	80	88	47	25

Source: Annual Statistics Report of Gyeonggi Province (2014) and statistical year book of each province

Intergovernmental Panel on Climate Change (2007) defines vulnerability to climate change as the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity (IPCC, 2001; Moss et al., 2001; Yoo and Kim., 2008). In this framework, IPCC (2007) defines the terms in climate exposure, sensitivity and adaptive capacity as follow: 1) exposure is the degree of climate stimuli received from either long-term changes in climate conditions, or by changes in climate variability, including the magnitude and frequency of extreme events, 2) sensitivity is the degree to which a system will be affected by, or responsive to climate stimuli (Smit and Wandel., 2006) and it can either be biophysical effect climate change and socio-economic changes, and 3) adaptive capacity is the capability of a system to adapt to impacts of climate change, or, it is the potential or capability of a system to adjust to climate change, including climate variability and extremes, so as to moderate potential damages, to take advantage of opportunities, or to cope with consequences (Smit and Wandel., 2006). As in Eq. (1) this paper takes IPCC (2007) approach of defining climate change vulnerability that a system's total vulnerability is composed of climate change exposure and sensitivity subtracted by adaptation capacity.

$$Vulnerability = (Climate\ Exposure + Sensitivity) - Adaptation \quad (1)$$

Proxy variables are selected as function of exposure, sensitivity and adaptive capacity, as framed by IPCC and in scrutiny based on the intensive review of previous studies, particularly on Vulnerability Resilience Index (VRI), composite index composed of 33 indicators to conduct climate change vulnerability assessment of 16 provincial governments in Korea (Yoo et al., 2008). Moreover, in this paper, since the indicators are selected particularly for the assessment of apple farming, review of various government reports and guidance on apple cultivation are conducted. For exposure proxy variables, apple cultivation guideline developed by Rural Development Administration (2015) is referenced. Unlike previous macro-level studies, this study assesses local level communities that limit authors to select the variables based on availability of the data. Finally, 12 proxy indicators are selected include: number of years with annual average temperature above 8℃ and below 11℃; number of days with maximum temperature over 26℃; maximum rate of precipitation per day; number of days with maximum wind speed over 3m/s; damages from storm and flood per capita; area of apple cultivation per total area; rate of elderly agricultural households; beneficiaries of national basic livelihood; Gross Regional Domestic Production per capita, productivity rate of apple per area; rate of household with Speed Spray holder; and rate of cooperative membership, to assess climate change vulnerability of four apple farming municipals namly, Icheon, Gapyeong, Paju and Yeoncheon, in Gyeonggi province.

Selected proxy variables are analyzed by calculation of the z-score normalization of data. Among other normalization methods, such as scale transformation, rescaling by min-max and distance to a reference, z-score is generally applied in the previous vulnerable assessment studies and this method allows to compare the data that are from different unit. This study uses z-score method that is done by subtracting the mean from the observed value and dividing by the standard deviation for each indicator. This ensures that each of the rescaled variables has a mean of zero and a standard deviation of 1, allowing them to be combined directly. The results of z-score normalization are able to determine positive and negative relations of components.

RESULTS AND DISCUSSION

Exposure is a level of acquaintance to climate risks including temperature, precipitation and wind influencing production and quality of apple for this paper. A system is more vulnerable when it has higher exposure to climate. In analyzing the result of climate exposure, a system is relatively vulnerable if it has a greater z-score. Although production and the quality of apple are influenced by many different elements during a year around, for the purpose of this paper, annual temperature, maximum temperature during April to August, precipitation rate and wind during apple harvest period, April to October, are considered. Apple can be grown satisfactorily with annual average temperature between 8 and 11. Moreover, temperature over 26 during April to August can produce undesirable effect on the shape of apple. Sweetness of apple is affected by precipitation rate during April to October. With higher precipitation, level of sweetness of apple will fall. In addition to quality of apple, abscission of apple also influences the production of apple cultivation. Abscission occurs with wind speed over 3m/s during cultivation season. As shown in Table 2, with regard to climate exposure index, z-scores for the total vulnerability show positive for Icheon (1.64) and Gapyeong (1.28). The positive z-scores indicate that Icheon and Gapyeong are more exposed to climate risks than Paju and Yeoncheon. More specifically, Icheon and Gapyeong are found to have relatively higher vulnerability to be exposed to climate risks such as in adequate temperature and precipitation for shape and sweetness of apple. In other words, this results indicate Paju (-2.81) and Yeoncheon (-0.09) are less vulnerable to be exposed to the climate risks related to temperature and precipitation for developing adequate shape and sweetness of apple. However, Paju and Yeoncheon show relatively higher vulnerability in climate exposure with strong wind. This indicates that apple farms in Paju and Yeoncheon are more vulnerable to abscission from wind. By developing prevention of impact from strong wind, farmers in Paju and Yeoncheon can increase the production of apple.

Table 2 Result of Z-scores on climate exposure index of 4 apple farming municipals

Proxy Variables	Icheon	Gapyeong	Paju	Yeoncheon
Number of yrs. with annual avg. temperature, ＜8 ℃ or ＞11 ℃*	0.79	1.14	-1.31	-0.61
Number of days with maximum temperature over 26 ℃**	0.00	0.97	-1.62	0.65
Maximum rate of precipitation per day***	1.36	0.35	-1.40	-0.30
Number of days with max. wind speed over 3m/s***	-0.51	-1.18	1.52	0.72
Total vulnerability in climate exposure	**1.64**	**1.28**	**-2.81**	**-0.09**

Source: National Climate Data System (http://sts.kma.go.kr/, accessed October 28, 2015)
**data for 2004-2014, **data for April to August of 2014, ***data for April to October of 2014*

Sensitivity proxy variables are selected to reflect a degree to which the apple farming in study areas will be affected by, or responsive to changing climate. If a system is sensitive, it can be affected by small changes in climate. In this paper, proxy variables are selected by taking the system's geographical and socio-economical elements into account. For geographical elements, apple cultivation area and total cost of damage from storm and flood variable are selected. For population elements such as higher rate of single household with over 80 years old residents and socially vulnerable population are selected to analyze how the community is sensitive to climate stimuli. Sensitivity indicators are positively related to climate change vulnerability. This means that if the z-scores show positive and greater numbers, then the variables are relatively more sensitive to changing climate and by the definition, sensitive system is more vulnerable to climate change. In Table 3, Icheon (0.75) and Gapyeong (3.05) municipals show positive z-score in sensitivity whereas Paju (-3.07) and Yeoncheon

(-1.17) show negative. More specifically, except for damages from storm and flood, Gapyeong is found to be the most vulnerable relative to other areas in all other factors. Unlike climate exposure, it is possible to lessen vulnerability related to sensitivity to climate change by developing policies that focus on moderating risks of vulnerable population, elderly people and beneficiaries of national basic livelihood, living in the area.

Table 3 Result of Z-scores on sensitivity index of 4 apple farming municipals

Proxy Variables	Icheon	Gapyeong	Paju	Yeoncheon
Damages from storm and flood per capita (won)	1.61	-0.10	-1.11	-0.39
Area of apple cultivation per total area (%)	1.53	0.16	-0.52	-1.17
Rate of elderly (+80) agricultural households (%)	-1.00	1.66	-0.45	-0.21
Beneficiaries of national basic livelihood (%)	-0.94	1.33	-0.99	0.60
Total vulnerability in sensitivity	**0.75**	**3.05**	**-3.07**	**-1.17**

Source: Annual Statistics Report of Gyeonggi Province (2014) and statistical year book of each province

Adaptive capacity refers to potential or capability of a system to adjust to climate change, so as to moderate potential damages, to take advantage of opportunities, or to cope with the concerns. Economic capacity including Gross Regional Domestic Production (GRDP) and productivity rate of apple can determine how the system can economically, moderate, recover or even prevent itself from impact of climate change. Physical infrastructure, such as Speed Spray, can be used to prevent damages from insects and this can eventually support production to increase. Being member of cooperative can influence adaptive capacity of a system by acquiring information and support easier than nonmembers. Unlike exposure and sensitivity to climate, higher adaptive capacity is negatively related to vulnerability that negative and smaller z-core means higher level of vulnerability. Less adaptive capacity means that a system is less capable of adapting to changing climate that is associated with more vulnerable circumstances. The results in Table 4 show that compared to Paju (-1.14) and Yeoncheon (-2.75), Icheon (2.71) and Gapyeong (1.20) are higher in adaptive capacity. Among the areas, Icheon is the highest in adaptive capacity and this is due to higher development level of apple community in Icheon than other areas. On the other hand, Paju and Yeoncheon show lower level of adaptive capacity, however, in these areas, increasing government support for apple farming by providing Speed Spray and education on apple cultivation have potential to increase adaptive capacity in the future which will make the areas to have favorable condition of apple production.

Table 4 Result of Z-scores on adaptive capacity index of 4 apple farming municipals

Proxy Variables	Icheon	Gapyeong	Paju	Yeoncheon
Gross Regional Domestic Production per capita (won)	1.37	-0.79	0.53	-1.11
Productivity rate of apple per area (kg/10a)	0.42	1.44	-0.79	-1.06
Rate of household with Speed Spray holder (%)	0.57	-0.16	-1.54	1.13
Rate of cooperative membership (%)	0.34	0.71	0.66	-1.71
Total vulnerability in adaptive capacity	**2.71**	**1.20**	**-1.14**	**-2.75**

Source: Annual Statistics Report of Gyeonggi Province (2014) and statistical year book of each province

CONCLUSION

Agricultural communities are highly depending on natural resources that are affected by climate change. Adequate adaptation measures are required for agricultural communities to moderate potential damages and to take advantage of opportunities related to changing climate. Particularly in Korea, changing climate moves the fruit cultivation sites to north-ward to Gyeonggi province. Moreover, increasing damages from extreme events increased needs for adaptation measures for fruit cultivating communities. To develop effective adaptation measures, it requires vulnerability assessments in the communities. In our study, to increase adaptive capacity of apple farming communities, climate change vulnerability assessment for four apple farming communities in Gyeonggi province in Korea are conducted. A climate change vulnerability assessment index was developed to include climate exposure, sensitivity and adaptation to assess climate change vulnerability of Icheon, Gapyeong, Paju and Yeoncheon in Gyeonggi Province, in Korea. The main results of the vulnerability assessments can be grouped into three different parts, climate exposure, sensitivity and adaptive capacity. Vulnerability related to climate exposure assessed the community's climate condition whether it is adequate for the apple cultivations or not. Among four apple farming communities, Icheon is shown to be the most vulnerable followed by Gapyeong, Yeoncheon and Paju. The result shows that inadequate temperature and precipitation in Icheon and Gapyeong could lead the communities more vulnerable. Although Yeoncheon is less vulnerable in total climate exposure, Yeoncheon is highly exposed to wind that the community should develop the adaptive measures, such as windshield, to prevent damages from strong winds. Moreover, the vulnerability assessment found Gapyeong as the most sensitive to climate change followed by Icheon, Yeoncheon and Paju. The reason that Gapyeong was more vulnerable was most likely related to its demographical characteristics: increasing rate of elderly agricultural households and beneficiaries of national basic livelihood. Thus, it is recommended that Gapyeong municipal to support agricultural labor productivity in the region to maintain apple cultivation. Unlike climate exposure and sensitivity, adaptive capacity was found to be higher in Icheon and Gapyeong compared to Paju and Yeoncheon. The higher adaptive capacity was associated with earlier adaptors of apple cultivation, Icheon and Gapyeong, who have already created their own communities to share their know-how and developed technologies to cope with climate damages.

The results of this study can provide vital information on allocation of critical resources in each apple farming municipals to develop effective adaptation measure and policies. This can prevent and reduce the damages from climate change impact in apple communities in Gyeonggi province. By understanding different elements that induce climate change vulnerability, apple farming communities can increase its adaptive capacity and lessen the damage from the impacts. However, a broader application of vulnerability assessment index should have clearer understanding of climate change vulnerability in apple farming communities. Moreover, this study can be more developed to be applied to other regions and other sectors to be referred in integrated climate change vulnerability assessment of rural agricultural communities.

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