ISSN 2234-3075(Print)
ISSN 2288-7806(Online)
Http://dx.doi.org/10.14771/AIM.11.1.2

An Exploratory Study on a Relationship between Changes in Cultivated Area of Major Crops and Farm Income by regions[1]
- From Comparative Analysis to Optimal Portfolio Analysis -

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Abstract

This study is exploratory research on a relationship between changes in cultivated area of major crops and farm income by regions. We investigated level of income, volatility of income, and migration of suitable region by climate changes as factors influencing changes in cultivated area. Research processes are as follows. First, we classify the regions where cultivated areas are expanded or reduced through the trends of cultivated area by region and crop during recent 10 years. Second, we compare the changes in income related factors between groups during the same periods. Finally, the results from portfolio analysis show changes in stable income-based optimal crops. From these procedures, we found that the changes in cultivated area are not simply explained by income-related factors. In cases of vegetables, however, we also found that high volatility of income could contribute to reduce cultivated area of the crops. The results from portfolio analysis are not always consistent in all of cases. This means that crop selection can be decided by other factors than stable income.

[1] This study has been conducted with the resource of the Ministry of Agriculture, Food and Rural Affairs and support from the Technology Commercialization Support Project of the Agriculture, Food, and Technology Planning Committee.

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1. Introduction

The agricultural product market of Korea is moving towards an uncertain direction due to various environmental factors. After the Free Trade Agreement (FTA) with numerous countries such as the United States, EU, and Chile, etc. the pressure from price competition for domestic agricultural products grew stronger due to the increase of the amount of agricultural product imports. There are also regions where the profitability of the existing crops cultivated decreased due to changes in the optimal cultivation area. Recently, due to severe weather phenomena such as heat waves and cold waves, there are an increasing amount of cases where the productivity of crops worsened. As such, gaining a stable agricultural profit is becoming uncertain.

Rapid change in the agricultural population is also one of the causes that increases the uncertainty of agricultural profit. Due to aging society, it is becoming difficult for farming households who are reducing cultivation size to achieve economic effect due to the decrease of gross profit together with size, thus leading the decrease of profitability. For those who become farmers through family business succession or those who newly became farmers, there is a high possibility for them to bring change upon the existing crop system, since they have high motivation to introduce new crops. On the other hand, there is high uncertainty for productivity since they do not have high production technology abilities. As such, crop change or crop selecting decision becomes important in order to procure a stable agricultural profit, in the midst of increasing uncertainty.

In terms of policy, one must determine whether it is effective to provide policy support at a certain farming household when there is a need to introduce new crop types or changing the crop type in order to improve the income of farming households. Accordingly, studies were conducted regarding the influence exerted by population statistical factors, socio-economic traits, and environmental conditions of the land possessed by the farmland to crop change and selection (Kim & Lee, 2002; Kurukulasuriya & Mendelsohn, 2008; Seo & Mendelsohn, 2008; Moniruzzaman, 2015; Khanal & Mishra, 2017). In the perspective of farming households, it is important to predict how to distribute and expand a certain crop in which proportion at a limited farmland to increase high levels of income. Major studies related to optimal crop selection include studies (Stonehouse et al, 1988; Mainuddin et al., 1997; Raju & Kumar, 1999; Singh, 2001; Sarker & Quaddus, 2002; Zeng et al., 2010; Filippi et al., 2017) utilizing linear programming (LP) based methodology as the optimized algorithm and studies (Carvallo et al., 1998; Kumar et al., 1998; Benli & Kodal, 2003; Garg & Dadhich, 2014; Li & Guo, 2015) utilizing non-learning programming (NLP) based methodology. Some studies are using the machine-learning-based methodology to deduct the optimized issue in crop selection (Fowler et al., 2015; Kumar et al., 2015; Abdi-Dehkordi et al., 2018). For recent research trends related to crop selection, empirical studies are being conducted in situations facing crop type change and new crop introduction due to climate changes. Kurukulasuriya & Mendelsohn (2008), Seo & Mendelsohn(2008), Moniruzzaman(2015) studied the factors which exert influence on crop selection in the situation of adjusting to climate change, while Khanal & Mishra (2017) studied the influence exerted on the farmer's food and crop portfolio constitution by climate threats. Dong et. al.(2016) proposed a selecting method for selecting crops in a climate change situation. Meanwhile, in Abdi-Dehkordi et. al.(2018)'s study related to the optimal crop selection, the optimal portfolio is proposed by devising measures for water scarcity due to climate change and analyzing cultivation patterns in diverse irrigation conditions.

While diverse studies are being conducted related to crop selection, related studies are not being conducted in Korea. The present research condition in Korea is that there is inadequate verification regarding theoretical foundation stated by preceding studies. There is especially inadequate amount of related studies compared to the fact that crop change is occurring regularly due to high geographical diversity and numerous small and mid-sized farming households. Rural Development Administration is providing profitability analysis information for each crop type by publishing resources on the profit of agricultural product by each region annually. Furthermore, it is conducting management condition surveys and economic analysis research regarding regional specialized crop type and small area crop types. Also, Return Farm Center is providing returning farmer consultations and training, as well as information related to returning farming policies. It is also providing information regarding primary crop and promising crop type for each city and province. However, since the crop types are limited and are not specific – with the provided information being only 5 categories, namely, management scale, average investment costs, annual management fees, average income, farmland price – they are inadequate to be utilized in crop selection decision-making. Although information related to crop selection are being provided through various routes, they are insufficient as research results and sources which can support the decision-making in a comprehensive perspective by connecting all this information. Of course, studies for theoretical contributions in the existing studies related to crop selection are also important. However, it is more pressing to conduct exploratory research which can become the foundation of related studies and can enhance the understanding of crop selection in the agricultural environment of Korea. As such, the objective of this study is to explore what is the optimal crop portfolio which can achieve high levels of income while being stable regionally in the agricultural environment of Korea which has great differences by each region. In order to do this, one must first understand the changes in agricultural environment and assist in grasping the primary crop types of each region. To do this, this research will first use the agricultural area research information from Statistics Korea from 2001 to 2015 to examine the changes and trends of cultivation surface area in the primary crop types of each region for the past 10 years, and go on to determine whether the cultivation surface area of the representative crop type of each region increased or decreased. Following this, this research will examine whether there are differences by each type by comparing the profitability and fluctuation changes of each crop type income calculated based on the earning survey data of Rural Development Administration during the same period. Finally, by using the optimal portfolio method based on linear programming, we will compare the optimal crop type changes of the current time and the 10 years ago. Through this, this research will detect which factors induce the crop selection changes for each region and deduct the implication of the results. The terms, profitability of income and fluctuation, used in this research are ideas introduced in the portfolio analysis. The profitability of income refers to net income ratio, which is the proportion of a farming household's gross income (sales) compared to income (profit). As such, it can be said that crop types with high profitability have higher net income ratio compared to other crop types. In the case of cultivation surface area, it refers to the cultivation surface area combining the total unit by each crop type nationwide in megalopolis units.

2. Precedent Study

2.1 Factors influencing crop selection

Factors influencing crop selection can be broadly categorized into natural factors and unnatural factors. Natural factors, such as soil, precipitation, and temperature, etc., are closely related to crop growth. As such season precipitation and temperature are used as primary variables in studies related to agricultural changes due to climate change (Seo & Mendelsohn, 2008; Kurukulasuriya & Mendelsohn, 2008; Moniruzzaman, 2015; Khanal & Mishra, 2017). Unnatural factors are ones such as production cost, agricultural product costs, and socio-statistical variables of the farming household. These are diverse factors which influence the crop selection decision excluding natural factors. Most studies regarding crop selection are conducted by considering both natural and unnatural factors. There are diverse variables used in studies. Seo & Mendelsohn (2008) set precipitation amount, temperature, soil type, farmer’s age, education level, number of family members, and crop costs to study how crop selection in South America changes. Kurukulasuriya & Mendelsohn (2008) added altitude and surface water use probability as natural factors, on top of those mentioned above, and considered cultivation surface are as the unnatural factor. Moniruzzaman(2015) additionally studied the farmland surface area, cellphone usage, and electricity usage as variables. Khanal & Mishra (2017)’s study used the farmer’s gender, education level, marital status, whether the farmer is a full-time farmer or not, the number of stationary animals, fertility level of soil, and irrigation surface area ratio as variables. Dong et. al. (2016) defined the vulnerability due to climate changes and the degree which nature and technology contributes to crop growth and proposed the crop selection method based on this. Domestic studies related to factors influencing crop selection include those by Kim & Lee(2002) and Kwon, et al.(2016). Through sources on decision-making situations of cultivators, Kim & Lee(2002) defined physiological environment factors, labor, cultivation surface area, agricultural product cost and measure strategy, cultivation of crop, consumption trends, weather prediction, conservatism in crop selection, and the role of elite farming households and National Agricultural Cooperative Federation as factors influencing cultivating crop selection. Kwon, et al.(2016) considered cultivation surface area, sales from primary products, rent, management fees including consignment farming fees and hired labor cost, and farmer’s family labor input amount to predict Jeju Island’s crop selection changes in cases of climate change.

2.2 Methodological study for optimal crop selection

There are diverse studies related to optimal crop selection in the agriculture field. Stonehouse et al.(1998) used Multi-Period Linear Programing to discover the crop type and cultivation order which can maximize profits for the next 20 years. Singh(2001) decided upon the optimal crop type pattern which can maximize the net profitability according to the availability of water resources through the linear programming (LP) method. The constraint regarding the object function used here include water resources according to season, possible amount of soil that can be used, minimal amount of wheat and rice necessary, socioeconomic conditions of the farmers, and

Table 1. Outline of preceding studies related to factors influencing crop selection

Author (Year)	Use variable	Study content
Seo & Mendelsohn (2008)	Precipitation, temperature, soil type, farmer’s age, education level, number of family members, agricultural product cost	Study on how crop selection in South America changes due to climate change
Kurukulasuriya & Mendelsohn (2008)	Precipitation, temperature, soil type, altitude, surface water use probability, electricity usage, cultivation surface area, number of family members, agricultural product cost	Study on influence of climate change on primary crops in Africa
Moniruzzaman (2015)	Precipitation, temperature, cultivation surface area, number of family members, number of wage workers, surface area of house, usage of cellphones, usage of electricity	Study on crop selection change according to climate change in Bangladesh
Ohsang Kwon, et al. (2016)	Planted area by each crop type, sales of primary products, rent, management fees including consignment farming fees and hired labor cost, farmer’s family labor input amount	Study on crop selection change according to climate change in Jeju Island
Dong et al. (2016)	Vulnerability regarding climate change, contribution level of nature and technology	Study on adequate crop selection constitution evaluation method for climate change
Khanal & Mishra (2017)	number of family members, gender, education level, marital status, whether the farmer is full-time farmer, number of stationary animals, soil fertility level, irrigation surface area ratio, plowing land surface area, climate threat variables based on precipitation	Study on what influence is exerted by climate threats upon the farmer’s food crop portfolio constitution

preferred crop in specific regions as variables. Sarker & Quaddus(2002) used the value attained through LP to apply it to goal program (GP) model to conduct research on crop optimization in units of countries. Filippi et al.(2017) used Mixed Integer Linear Programming, which can consider irrigation scaling's complexity, to solve the problem of optimal crop selection.

Table 2. Summary of precedent studies on optimal crop selection method
Multi-purpose in order to deal with the complexity of agricultural environments

Classification	Methodology	Study
Linear programming series	Linear Programming	Stonehouse et al.(1988) Singh(2001) Sarker & Quaddus(2002)
	Mixed Integer Linear Programming	Filippi et al(2017)
	Multi-Mbjective Linear Programming	Mainuddin et al.(1997) Raju & Kumar(1999)
	Fuzzy Multi-Objective Linear Programming	Zeng et al.(2010)
Non-linear programming series	Non-Linear Programming	Kumar et al.(1998) Carvallo et al.(1998) Benli & Kodal(2003) Garg & Dadhich(2014)
	Random-Fuzzy-Variable-based Inexact Two-stage Stochastic Chance-Constrained Programming	Li & Guo(2015)
Machine learning series	Crop Selection Method	Kumer et al.(2015)
	Multi-Objective Genetic Agorithm	Fowler et al.(2015)
	Genetic Algorithm	Abdi-Dehkordi et al(2018)

There are also studies (Mainuddin et al, 1997; Raju & Kumar, 1999) conducted on optimization of crop type cultivation by using Multi-Objective Linear Programming (MOLP). Since Multi-Objective Linear Programming is inadequate to apply in situations where there are ambiguous subjective selection or uncertain objectives, Zeng et al.(2010) used Fuzzy Multi-Objective Linear Programming (FMOLP), which supplements this limitation, to optimize crop cultivation land.
In order to apply Linear Programming (LP), the objective function and the constraint must be linear. Since it is difficult to meet this condition, there are studies which applied the Non-Linear Programming (NLP) method to optimize crop types (Kumar et al., 1998; Carvallo et al, 1998; Benli & Kodal, 2003; Garg & Dadhich, 2014). Of these, Benli & Kodal(2003)'s study discovered that in a situation where there is inadequate irrigation, Non-Linear Programming (NLP) is able to find higher agricultural income than Linear Programming (LP).
Recently, there are an increasing number of studies using more complex situations or ones that use machine-learning method. Li & Guo (2015) used the Random-Fuzzy-Variable-based Inexact Two-stage Stochastic Chance-Constrained Programming (RFV-ITSCCP), which considers uncertainty and ambiguity of probability, in order to effectively deal with changes such as river conditions, economic profit, and production amount, etc. Compared to the existing Linear Programming (LP)model, this has a higher efficiency. Kumar et al.(2015)'s study used a method called Crop Selection Method(CSM) which combines various machine-learning methods. Fowler et al.(2015) used the Multi-Objective Genetic Algorithm (MOGA) to conduct optimization. Abdi-Dehkordi et al.(2018) used Genetic Algorithm (GA) to optimize crop selection according to climate change.

2.3. Study on the changes in crop cultivation land in Korea

For studies regarding changes in the cultivation area of domestic crops due to climate change, there is an insufficient of research done on diverse crop types, despite active studies done in certain fruit crops. Since the general research results show that rice is being cultivated nationwide as the main crop and that the cultivation land is being further expanded due to global warming, it has been excluded from preceding studies.
Ahn et al. (2008), who studied vegetable cultivation land, estimated that the safe cultivation zones for alpine cabbages is 20,626ha in 24 eup and myeon nationwide, and the cultivation-available zones is 112,277ha in 29 eup and myeon. It was also predicted that if the temperature rises by 2℃ due to global warming, the safe cultivation zones will be 6,314ha in 3 eup and myeon, while the cultivation-available zones will be reduced to 9,950ha in 15 eup and myeon. Currently, the surface area of the safe cultivation land of alpine agriculture in North Korea is around 156,000ha, being 5.0~7.6 times wider than South Korea. If the temperature rises 2℃, it is predicted that it will increase to 263,309. Concerning garlic cultivation land, Heo et al. (2006) stated that compared to the 1980's the majority of the garlic cultivation land moved north by almost 100km, excluding the eastern coast of Korea. It was predicted that within the next 30 years, cold-season garlic cultivation will become difficult in the coastal area of Chungcheongnam-do, while in the eastern coast and the inland, both cold season and warm season cultivation will become possible. Moon et al. (2013)'s study predicted

that warm season garlic cultivation land was dispersed in the coastal and southern areas of Jeju-do but will the cultivation land will gradually increase. As such, in 2011-2020, in climate change scenario A1B, it will increase by 129% than the current surface area, 168% in RCP4.5, and 213% in RCP8.5.

Moon et al. (2017) conducted a study on fruit crops and predicted that the cultivation area of Unshiu oranges will increase in the 2030’s, and that the cultivation-possible area will also primarily increase in the coastal area of Jeollanam-do area. Although land tangerines such as Hanrabong only include partial areas of the Jeju-do coastal area currently, it was predicted that the cultivation area will be expanded to the cultivation land of Unshiu oranges by the 2030’s while the cultivation possible land will expand to the north, up to part of the southern coastal area. Son et al. (2015) stated that although sweet persimmon cultivation-possible land was limited to a specific area in the southern coastal area for the past 30 years, in 2090, it will expand not only in the southern coastal area, but also eastern and western coastal area and also the inland, thus enabling cultivation in almost 50% of the nation. Choi et al. (2011) stated that although the cultivation surface area for pears steadily increased in the 90’s and steadily decreased since the 2000’s, change occurred in flatlands rather than mountainous lands. Furthermore, while the cultivation surface area of pears increased in Gyeonggi-do areas such as Chungju, Eumseong, and Icheon, it decreased in Gyeongsangnam-do and Jeollabuk-do areas such as Wanju, Milyang, and Hamam. The cultivation area for apples noticeably moved to the surrounding mountainous areas of the Baekdudaegan Mountain Range. It was also predicted that the cultivation area will continue to move north and towards mountains areas with low temperatures Seo et al. (2007) conducted studies on apples and predicted that the cultivation area for apples will decrease 32% than the current state if the annual temperature increases by 2 degrees. Kim et al. (2009) predicted that in 2011-2011, the cultivation area for Fuji types, which is around 6.5% of the whole country based on the average year, will decrease to 1.8% of the whole nation, to 0.3% in 2041-2070, and to 0.1% in 2071-2011 to the Taebaek Mountain Range region. Han et al. (2015) analyzed that the cultivation area will rapidly decrease from 40.9% in the past 30 years to 0.8% in the 2070’s. Gwak et al. (2008) conducted a study on kiwi fruits. While kiwi fruits are currently only being grown in certain areas in Gyeongsangnam-do and Jeju-do, it was predicted that the cultivation area will be dispersed to Chungcheongnam-do area if the temperature rises 3 degrees and to Gangwon-do area if it rises 4.5 degrees. Kwon (2012) predicted that the Jeju-do coastal areas (average altitude of 114m) will gradually move to areas with higher altitude surrounding Hallasan (average altitude of 372m). Son et al. (2015) stated that although grapes were able to be cultivated in most areas in Gangwon-do, North Chungcheong-do, and Gyeonggi-do for the last 30 years, in the 2060’s it will be able to be cultivated nationwide but will later rapidly decrease and will only be able to be cultivated in Gangwon-do, Gyeongsang-do, Jeolla-do Muju, and Jangsu regions in the 2090’s.

Table 3. Summary of preceding studies related to changes in domestic crop cultivation land

Crop type	Author (Year)	Summary of main results
Alpine cabbage	Jaehoon Ahn et. al. (2008)	Predicted that the safe cultivation zone surface area in South Korea will reduce 69.3% and North Korea will increase 68.8% if the temperature rises 2℃
Garlic	Inhye Heo et. al. (2006)	Predicted that the cultivation area will move north. Predicted that in 30 years, cultivation will be possible only in the warm-season areas in coastal areas of Chungnam, while possible for both cold-season and warm-season areas in inland
	Kyeonghwan Moon et. al. (2013)	Predicted that although warm-season garlic cultivation land is dispersing in the coastal areas and southern areas of Jeju-do, it will gradually increase to 129%~213% in 2011-2020
Tangerine	Yeongil Moon et. al. (2017)	Predicted that cultivation possible area of Unshiu oranges will increase in the 2030’s, primarily in the coastal area of Jeollanam-do area. Predicted that land tangerines will expand to the whole southern coastal area Jeju-do and partially to the north
Sweet persimmon	Inchang Son et. al. (2015)	Predicted that although it was limited to certain regions in the southern coastal areas in the past 30 years, in 2090, it will expand to 50% of the whole nation, up to east coastal area, west coastal area, and inland
Pear	최인명 외 (2011) Inmyeong Choi et. al. (2011)	The cultivation surface area gradually increased in the 1990’s and gradually increased since 2000’s. Changes in the cultivation land generally occur in the flatlands rather than mountainous lands.
Peach	Inmyeong Choi et. al. (2011)	The cultivation land surface area increases for peaches in the Gyeonggi-do area, including Chungju, Eumseong, and Icheon, etc., and decrease in the Gyeongsangnam-do and Jeollabuk-do area, including Wanju, Milyang, Haman, etc.
Apple	Hyeongho Seo et. al. (2007)	The cultivation land will move northwards or towards mountainous ranges with high altitudes. Predicted that the cultivation area will reduce 32% if the temperature rises 2℃.
	Suok Kim et. al. (2009)	Approximately 6.5% of the cultivation area nationwide will reduce to 1.8% in 2011-2040,

Crop type	Author (Year)	Summary of main results
		0.3% in 2041-2070, and 0.1% in 2071-2100 to the Taebaek Mountain Ranges.
	Inmyeong Choi et. al. (2011)	There is a noticeable movement of the current cultivation area to the surrounding mountainous range in the Baekdudaegan Mountain Range.
	Hyeonhee Han et. al. (2015)	The cultivation area will rapidly decrease to 0.8% in 2070 from the 40.9% in the past 30 years.
Kiwi Fruit	Taesik Kwak et. al. (2008)	Predicted that although it is cultivated in certain areas in Jeju-do and Gyeongsangnam-do, the cultivation area will disperse to Chungnam area if the temperature rises 3℃ and to Gangwon-do area if it rises 4.5℃.
	Yeongsoon Kwon et. al. (2012)	Predicted that the Jeju-do coastal areas (average altitude of 114m) will gradually move to areas with higher altitude surrounding Hallasan (average altitude of 372m)
Grape	Inchang Son et. al. (2015)	Predicted that although grapes were able to be cultivated in most areas in Gangwon-do, North Chungcheong-do, and Gyeonggi-do for the last 30 years, in the 2060's it will be able to be cultivated nationwide but will later rapidly decrease and will only be able to be cultivated in Gangwon-do, Gyeongsang-do, Jeolla-do Muju, and Jangsu regions in the 2090's.
Winter barley	Daejun Kim et. al. (2012)	Predicted that unlulled barley, rye, and beer barley's cultivation land will gradually move north and expand gradually to the whole nation

Kim et. al. (2012)'s study, conducted on food crops, analyzed the changes in cultivation land by each climate change scenario and by each variety of unlulled barley, rye, and beer barley. It was predicted that while 53% of the Korean peninsula is impossible to cultivate barley, by the 2090's, it will decrease to under 10%. Beer barley, which has the weakest cold-resistance, has a cultivation surface area ratio of only 6% currently, but is estimated to increase up to 72% by 2090.

3. Research Method

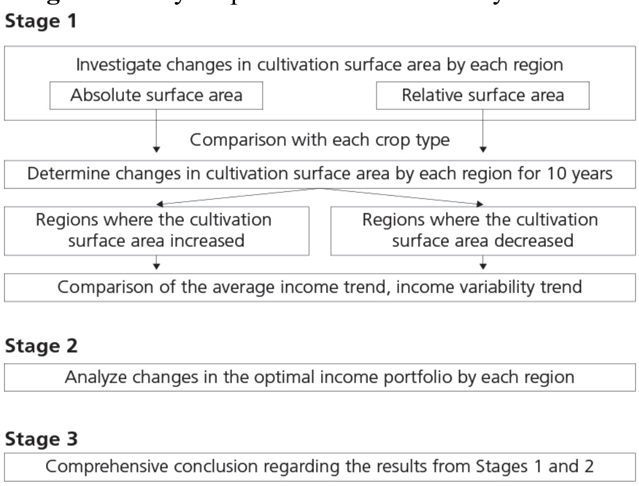
3.1 Data collection and Analysis Object

In order to grasp the primary crop types for each region and analyze the changes of crops selected in each region, the data on cultivation surface area used is from the agricultural surface area survey resource from Statistics Korea from 2001-2015. Out of these, data was collected for 80 non-food crop items, 34 facility crop items, and 7 outdoor special crops from each area in megalopolis units. Data collected for optimal portfolio analysis was collected for 59 items in each area in megalopolis units in the same period from the Rural Development Administration agricultural product profit resource. Nine areas were selected as megalopolis, namely, Gangwon, Gyeonggi, Gyeongnam, Gyeongbuk, Jeonnam, Jeonbuk, Jeju, Chungnam, and Chungbuk. For the analyses object time, in order to reduce the influence of the changes for 10 years and influence exerted by a certain year, the data collected for 5 years during 2011-2015 were defined as first term and second term, and thus used in the analysis. The crop type dealt with in the agricultural product profit resource from Rural Development Administration was 59, mainly focusing on the primary crops in each region. After excluding crop types that were investigated for only a certain time during the whole 15 year period, the crop types used in the analysis are as follows: 13 types in Gangwon, 23 types in Gyeonggi, 28 types in Gyeongnam, 31 types in Gyeongbuk, 35 types in Jeonnam, 22 types in Jeonbuk, 9 types in Jeju, 25 types in Chungnam, and 13 types in Chungbuk.

3.2 Analysis procedure

This study deals with numerous types of crops and data on cultivation surface area and income of several regions. Furthermore, rather than following the existing theoretical basis, it is the exploratory research regarding the relationship between climate change, profitability changes in each region, and cultivation surface area. As such, an adequate analysis procedure is necessary for the objective of this research, which is different than the existing regular research frameworks.

Image 1. Analysis procedure of this study



The analysis procedure is constituted in 3 stages. In stage 1, for changes in the cultivation surface area by each region, we compared changes in the relative surface area, which divided the surface area of the whole nation by each region's surface area according to each item and by the absolute surface area, which indicates the actual surface area, with the annual surface area of the first term – 5 year period from 2001 to 2005 – with the annual surface area of the second term – 5 year period from 2011 to 2015. Through this, we determined whether the cultivation surface area of the primary crops increased or decreased by each region and analyzed the enhancement ratio of the first and second term of income volatility with income average by each item for the regions where the surface area decreased and increased. Although the analysis of the cultivation surface area change is followed by the income change, for the comparison and analysis of the two variables, it is logical to assume that the factors related to income affects changes in the cultivated surface area. In stage 2, we used the income resource by each item in each region measured in units of farming households to compare and examine which changes are shown in the first and second semester by the optimal portfolio based on minimum risk in units of megalopolis regions. In this analysis, it was also assumed that the optimal portfolio change is an influencing factor in changes in cultivated surface area, in the perspective of income, to interpret the results. In stage 3, we deducted the implications by region and item by aggregating the results in stages 1 and 2.

3.3 Optimal portfolio analysis method

The method based on the Mean-Variance (MV) model proposed by Markowitz (1952) was used to deduct the optimal portfolio used in stage 2 of the research procedure. Markowitz's Mean-Variance (MV) model applied the Quadratic Programming (QP) method, a Non-Linear Programming (NLP) method, to measure the danger through the variance of income of each type. In this model, it is presumed that all investors are rational and have the tendency to avoid risks (Baganzi & Lau, 2017). According to the Luenberger 1998)'s optimal problem equation explained in the research of Baganzi & Lau(2017), if the earnings rate is $\overline{r_1}, \overline{r_2}, \cdots, \overline{r_n}$ for an asset of $i,j=1,2,\cdots,n$, the weighted value is defined as $w_{(i,)} i=1,2,\cdots,n$, which is applied in every n number of asset followed by the portfolio. In this case, the average of the earnings rate of the Mean-Variance portfolio is set as a specific value $\bar{r}$, and the portfolio with the lowest deviation in the corresponding average value can be expressed in the following equation of optimized problem.

$$\text{Minimize } \sum_{i,j=1}^{n} w_i w_j \sigma_{ij} \qquad (1)$$

$$\text{Subject to } \sum_{i=1}^{n} w_i \overline{r_i} = \bar{r} \qquad (2)$$

$$\sum_{i=1}^{n} w_i = 1 \qquad (3)$$

An optimized problem as this includes the trade-off relation between the predicted earnings rate and the deviation of earnings rate of the portfolio (Luenberger, 1998). The optimized condition of the Markowitz problem resulted can be found by using the Lagrange multiplier and . Lagrangian(L) is in the following form.

$$L = \sum_{i,j=1}^{n} w_i w_j \sigma_{ij} - \alpha\left(\sum_{i=1}^{n} w_i \overline{r_i} - \bar{r}\right) - \beta\left(\sum_{i=1}^{n} w_i - 1\right)$$

The year where the stage 1 derived function of L is 0 for each variable . If the differentiation is applied for two variable cases, it can be understood by connecting the generalization of n number of cases. The two variable cases can be expressed as the following.

$$L = \left(\omega_1^2\sigma_1^2 + \omega_1\omega_2\sigma_{12} + \omega_2\omega_1\sigma_{21} + \omega_2^2\sigma_2^2\right) - \alpha\left(\overline{r_1}\omega_1 + \overline{r_2}\omega_2 - \bar{r}\right) - \beta(w_1 + w_1 - 1)$$

Accordingly,

$$\frac{\partial L}{\partial w_1} = \left(2\sigma_1^2 w_1 + \sigma_{12} w_2 + \sigma_{21} w_2\right) - \alpha\overline{r_1} - \beta \qquad (4)$$

$$\frac{\partial L}{\partial w_2} = \left(\sigma_{12} w_1 + \sigma_{21} w_1 + 2\sigma_2^2 w_2\right) - \alpha\overline{r_2} - \beta \qquad (5)$$

is as such, the unknown values of w_i, w_i, α, β can be found by using the equation (2)-(5).

By using this method, one may decide the constituent ratio of each crop type by solving the simultaneous equation of the linear-programming method for each n number of crop types. In this research, the statistics tool R based on programming was used, as well as the Minimum Variance Portfoilo analysis function based on the fPortfolio package's MV model provided by R to deduct the optimal portfolio result.

Table 4. Changes in Cultivation Surface Area for Primary Crop Types by Each Region (Original source: Statistics Korea)

Nationwide				Jeollanam-do			
'01~05 Top Crop Types	Surface Area (ha)	'11~15 Top Crop Types	Surface Area (ha)	'01~05 Top Crop Types	Surface Area (ha)	'11~15 Top Crop Types	Surface Area (ha)
Paddy rice	1,009,249	Paddy rice	828,263	Paddy rice	196,725	Paddy rice	170,482
Bean	86,071	Bean	74,008	Barley	19,646	Bean	12,320
Pepper	64,707	Pepper	40,805	Bean	19,578	Onion	10,851
Sesame	37,713	Sesame	34,416	Beer barley	19,478	Sesame	8,302

Nationwide				Jeollanam-do			
'01~05 Top Crop Types	Surface Area (ha)	'11~15 Top Crop Types	Surface Area (ha)	'01~05 Top Crop Types	Surface Area (ha)	'11~15 Top Crop Types	Surface Area (ha)
Garlic	33,083	Apple	30,934	Garlic	13,750	Garlic	7,671
Barley	32,618	Persimmon	29,156	Field rice	12,627	Pepper	7,444
Persimmon	28,298	Sesame	25,484	Sesame	11,161	Persimmon	6,541
Beer barley	26,893	Garlic	25,473	Pepper	9,854	Barley	6,160
Perilla seed	26,513	Tangerine	21,345	Onion	8,222	Spring onion	5,393
Apple	26,494	Onion	21,181	Persimmon	7,223	Sweet potato	4,340
Gangwon-do				Jeollabuk-do			
Paddy rice	45,088	Paddy rice	34,008	Paddy rice	148,104	Paddy rice	126,674
Bean	7,910	Bean	6,925	Barley	10,125	Barley	7,978
Corn	6,225	Corn	6,092	Pepper	8,012	Bean	5,854
Alpine cabbage	4,600	Perilla seed	5,700	Bean	5,215	Pepper	5,155
Pepper	4,212	Alpine cabbage	4,599	Watermelon	3,120	Sweet potato	3,351
Perilla seed	4,169	Alpine potato	3,486	Sesame	3,111	Perilla seed	3,237
Spring potato	3,419	Pepper	2,905	Perilla seed	3,022	Unlulled barley	2,744
Alpine potato	3,306	Alpine radish	2,306	Unlulled barley	2,583	Wheat	2,418
Medicinal crop	1,963	Spring potato	2,030	Autumn radish	2,551	Watermelon	2,310
Spring cabbage	1,852	Medicinal crop	1,598	고구마 Sweet potato	2,037	참깨 Sesame	2,125
Gyeonggi-do				Jeju-do			
Paddy rice	114,414	Paddy rice	87,976	Tangerine	24,184	Tangerine	21,310
Bean	7,302	Bean	6,592	Bean	5,247	Winter radish	5,837
Pepper	4,826	Perilla seed	5,919	Garlic	3,951	Bean	5,598
Perilla seed	4,647	Sweet potato	3,268	Beer barley	3,034	Other grains	2,915
Pear	4,168	Pepper	3,087	Autumn potato	2,818	Garlic	2,864
Sweet potato	3,457	Pear	2,722	Cabbage	2,156	Cabbage	2,273
Grape	3,293	Green onion	2,409	Regular radish	1,993	Carrot	1,432
Spring onion	2,788	Grape	2,391	Carrot	1,920	Autumn potato	1,213
Lettuce	2,519	Spring onion	1,983	Spring potato	1,785	Buckwheat	964
Sesame	2,281	Spring potato	1,797	Sesame	1,568	Beer barley	882
Gyeongsangnam-do				Cbungcheongnam-do			
Paddy rice	97,061	Paddy rice	77,441	Paddy rice	170,215	Paddy rice	150,530
Persimmon	10,755	Persimmon	9,736	Bean	6,985	Bean	6,573
Bean	7,534	Sweet Persimmon	7,443	Pepper	6,920	Perilla seed	6,097
Watermelon	7,502	Garlic	5,557	Perilla seed	5,596	Watermelon	4,296
Garlic	5,570	Bean	5,208	Watermelon	4,587	Pepper	4,232
Beer barley	4,367	Onion	4,601	Pear	4,375	Sweet potato	2,991
Unlulled barley	3,797	Watermelon	3,414	Sesame	3,167	Spring potato	2,635
Sweet persimmon	3,625	Apple	3,229	Spring onion	2,954	Garlic	2,547
Sesame	3,399	Pepper	2,588	Garlic	2,810	Pear	2,463
Onion	2,870	Sesame	2,586	Grape	2,727	Strawberry	2,164
Gyeongsangbuk-do				Chungcheongbuk-do			
Paddy rice	134,592	Paddy rice	108,379	Paddy rice	56,769	Paddy rice	42,211
Pepper	16,778	Apple	19,089	Pepper	9,671	Bean	10,217
Apple	16,769	Bean	13,531	Bean	9,338	Perilla seed	4,741
Bean	14,954	Pepper	10,131	Perilla seed	4,073	Pepper	3,991
Grape	10,696	Grape	8,128	Grape	3,679	Apple	3,980
Sesame	8,043	Persimmon	7,920	Apple	3,456	Peach	3,802
Peach	7,110	Peach	7,312	Sesame	3,076	Corn	3,707
Persimmon	6,440	Sesame	5,043	Peach	2,973	Grape	2,686
Korean melon	5,947	Korea melon	4,898	Corn	2,708	Sesame	2,154
Medicinal herb	4,982	Plum	4,794	Watermelon	1,858	Autumn cabbage	1,742

4. Research Results

As stage 1 of the analysis procedure, the changes of the cultivation surface areas of the main crop types of each region were organized as shown by <Table 4>. The object crop types were set so that we could determine the increase or decrease according to the top 10 crop types according to surface area for each region. Crop types whose cultivation surface areas occurred over 30% in <Table 4> are shaded so that it would be easier for comparison. The following are crop types listed in order of greatest to least increase rate nationwide. Although onion(34%), perilla seed(30%), apple(17%), persimmon(4%) had increase in the cultivation surface area, beer barley(78%), rice barley(52%), pepper(37%), sesame(32%), garlic(23%), paddy rice(18%), bean(14%), and tangerine(12%) decreased. In the case of paddy rice is not dealt with in the analysis since it is cultivated nationwide and is in the trend of decreasing in arable land. In terms of regional characteristics, Gangwon-do has great increase in alpine radish (55) and perilla seeds (37%) and decrease in spring cabbage (88%), spring potato (41%), and pepper (31%) in Gangwon-do. In Gyeonggi-do, there was an increase in the cultivation surface area for potato (84%) and perilla seed (27%) while a decrease in lettuce (44%), sesame (43%), pepper (36%), and pear (35%). While there was a clear increase for sweet persimmon (105%), onion (60%), and apple (35%) in Gyeongnam, there were significant decreases in beer barley (85%), watermelon (54%), unlulled barley (33%), and bean (31%). Other than decreases in pepper (40%) and sesame (37%), there were no significant changes in Gyeongbuk. In Jeonnam, only the cultivation surface area increased for sweet potato (47%) and onion (32%), while the cultivation surface area for grain-type crops greatly decreased for field rice (90%), beer barley (78%), rice barley (69%), and bean (37%). There were significant increases in wheat (450%) and sweet potato (65%) in Jeonbuk, while great decreases for autumn radish (41%), pepper (32%), and sesame (32%). There were great increases for radish (148%), buckwheat (693%) and great decreases for beer barley (71%), spring potato (60%), autumn potato (57%), sesame (55%) in Jeju. In Chungnam, there were great increases in the cultivation surface area for sweet potato (84%) and spring potato (75%) while great decreases in grape (60%), green onion (55%), pear (44%), pepper (39%), and sesame (36%). In Chungbuk, while there were great increases in corn (37%) and peach (29%), there were decreases in pepper (59%), cabbage (31%), sesame (30%), and grape (27%).

Since the change in cultivation surface area (ha) for each region in <Table 4> is affected by the nationwide cultivation increase and decrease trend for certain crop types, one must examine the changes in relative ratio for each region in order to determine the difference between cultivation surface areas of each region. In order to do this, the relative ratio of the cultivation surface area of top 10 crop types of each region was organized as shown in <Table 5>. The crop types with changes in cultivation area in <Table 4> are shaded for easier comparison. As shown in the surface area comparison, the cultivation surface area for alpine radish in Gangwon increased, thus covering 95.7% of the surface area of the whole country. It was also found that although perilla seed was not included in the ranking, it rose to top 7, and that spring cabbage in top 5 and spring potato in top 7 were pushed out of the ranking. As shown in the surface area comparison, lettuce decreased 3.6%p, while pear and perilla seed showed the opposite trend than the change trend for Gyeonggi-do. For sweet potato, there were no changes in the surface area, but the relative ratio decreased 7.1%p. As such, the cultivation surface area for sweet potato in other regions increased. Compared to the fact that the surface area for sweet persimmon increased by 2 times in Gyeongnam, the relative ratio increased only 6.6%p. Watermelon and persimmon also decreased, including the relative ratio. Unlike the decrease of surface area for Korean melon and grape in Gyeongbuk, the relative ratio decreased because the surface area decreased became greater in other regions. In contrast to the surface area increase for apple, the relative ratio decreased. Compared to the fact that surface area for autumn potato decreased in Jeju, there were no significant changes in the relative ratio, and for carrots, the surface area and relative ration reduced 3.2%. While the surface area for beer barley rapidly decreased, the relative ratio increased from 11.3% to 15.2% with the nationwide decreasing trend. As with the surface area decreasing trend, the surface area and relative ratio decreased for rice barley in Jeonnam, while for onions, the surface area increased but the relative ratio did not show any significant changes. For Jeonbuk, rice barley and unlulled barley surface area increased along with the relative ratio, and for autumn radish, the cultivation surface area significantly decreased but did not show any great changes in the relative ratio. The reason why the relative ratio for wheat stopped at 7.7%p despite the 4.5 times increase for the cultivation surface area is because the cultivation surface area for wheat rapidly increased nationwide. The cultivation surface area for sweet potato increased, along with the relative ratio

Table 5. elative Ratio Changes in the Cultivation Surface Area of Primary Crops in Each Region (Original Source: Statistics Korea)

Gangwon-do				Jeollanam-do			
'01~05 Top Crop Types	Relative Proportion (%)	'11~15 Top Crop Types	Relative Proportion (%)	'01~05 Top Crop Types	Relative Proportion (%)	'11~15 Top Crop Types	Relative Proportion (%)
Alpine potato	98.3	Alpine potato	98.4	Field rice	72.6	Winter cabbage	97.3
Alpine radish	74.4	Alpine radish	95.7	Beer barley	72.4	Beer barley	73.1
Alpine cabbage	73.6	Alpine cabbage	90	Rice barley	60.2	Field rice	68.4
Corn	38	Corn	38.1	Mung beans	56.8	Mung beans	64.9
Spring cabbage	30.6	Green chili	17.4	Citron	52.6	Citron	61.6
Spring radish	24.1	Cabbage	16.7	Onion	52.1	Onion	51.2
Spring potato	20.8	Perilla seeds	16.6	Regular cabbage	44.6	Wheat	41.8
Cabbage	18.8	Cucumber	15.9	Garlic	41.6	Rice barley	39.2
Rye	16.7	Squash	14.4	Millet	39	Spring onion	37.4
Red bean	16.3	Buckwheat	13.9	Chives	33.4	Chives	37.1
Gyeonggi-do				Jeollabuk-do			
Lettuce	38.1	Flowering plant	35.5	Potato	44.5	Rice barley	50.8
Flowering plant	34.4	Lettuce	34.5	Rice barley	31	Unlulled barley	41.4
Spinach	30.5	Spinach	24.9	Other grain	25.6	Other special crop	36.1
Sweet potato	22.9	Other cabbage	22.2	Unlulled barley	25.2	Potato	36
Young radish	21.1	Green onion	21.9	Autumn radish	25	Spring radish	32.5
Other cabbage	21	Cucumber	21.8	Ginger	23.8	Wheat	25.7
Green onion	20.3	Other radish	19.8	Peanut	18.9	Autumn radish	24.1
Cucumber	18.3	Pear	19.7	Wheat	18	Radish	21.1
Perilla seeds	17.5	Perilla seeds	17.2	Paddy rice	14.7	Ginger	17.7
Pear	17.4	Sweet potato	15.8	Autumn potato	14.2	Sweet potato	16.2
Gyeongsangnam-do				Chungcheongnam-do			
Sweet persimmon	50.7	Sweet persimmon	57.3	Ginger	58.4	Strawberry	33.4
Citron	44.8	Unlulled barley	38.4	Rye	27.8	Ginger	28.4
Persimmon	38	Spinach	35.2	Chive	27.7	Watermelon	27.6
Unlulled barley	37	Strawberry	34.2	Strawberry	26.9	Chive	25
Green chili	34.8	Persimmon	33.4	Perilla seed	21.1	Tomato	21.9
Strawberry	32.8	Green chili	33.1	Watermelon	18.7	Cucumber	19.1
Watermelon	30.6	Potato	25.3	Autumn cabbage	18.3	Autumn radish	18.3
Japanese apricot	30.3	Citron	24.5	Pear	18.3	Field rice	18.2
Rye	27.8	Watermelon	21.9	Peanut	17.6	Pear	17.9
Wheat	27.4	Garlic	21.8	Tomato	17.1	Perilla seed	17.7
Gyeongsangbuk-do				Chungcheongbuk-do			
Oriental melon	76.7	Oriental melon	87.1	Peach	19.4	Peach	25.3
Plum	76.6	Plum	83.6	Corn	16.5	Corn	23.2
Apple	63.3	Apple	61.7	Perilla seed	15.4	Grape	16.1
Peach	46.5	Grape	48.8	Grape	15	Regular cabbage	15.7
Grape	43.6	Peach	48.7	Pepper	14.9	Perilla seed	13.8
Other fruits	38.7	Ginger	42.4	Other grains	14.9	Bean	13.8
Medicinal crops	37.4	Medicinal crops	34.3	Red bean	14.7	Apple	12.9
메밀 Japanese apricot	31.9	Spring cabbage	28.7	사과Apple	13	Other grains	12.5
Peanut	26.2	Other fruit	28.1	Medicinal crop	11.3	Regular radish	11.9
Pepper	25.9	Peanut	27.6	Bean	10.8	Autumn cabbage	11.8
Jeju-do							
Tangerine	99.8	Winter radish	100				
Canola	99.5	Tangerine	99.8				
Autumn potato	70.1	Autumn potato	69.2				
Carrot	57.8	Carrot	54.6				
Cabbage	40.4	Buckwheat	37.9				
Millet	24.3	Cabbage	35.1				
Regular radish	21.4	Other grain	28.2				
Other grain	15.1	Regular radish	17.2				
Other special crop	12	Field rice	16.7				
Garlic	11.9	Beer barley	15.2				

from 13.5% to 16.2T. In Chungnam, the cultivation surface area for strawberry increased along with the relative ratio by 6.5%. On the other hand, the surface area decreased for autumn cabbage, as well as the relative ratio from 18.3% to 12.5%. The cultivation surface area of pears decreased significantly but barely showed any change in the relative ratio. While there was narrow decrease for watermelon, the relative ration increased 8.9%p. For Chungbuk, the cultivation surface area for pear, corn, and bean increased, along with relative ratio. The surface area for pepper rapidly decreased and the relative ration decreased from 14.9% to 9.8%. Although the surface area decreased for grapes, it did not show much change for relative ratio with 1.1%p increase. Although the surface area for perilla seed increased narrowly, the relative ratio decreased 1.6%p.

By comparing <Table 4> and <Table 5>, the results of classifying the region and crop types with an increase and decrease in the cultivation area for 10 years is shown in <Table 6>. The criterion of determining the increase of a crop type's cultivation was defined as when the surface area increased or was the same, while the relative ratio was increased. The criterion for determining the decrease of the cultivation is when the surface area decreased or was the same, while the relative ratio decreased. <Table 6> allows comparison between the average income for 5 years (from '01- to '05) and the average income for 5 years (from '11 to '15) concerning the crop types of the selected regions and calculates the income volatility rate of change for 10 years. Comparison for the 10-year period during the first/second term of 5 years is also possible. The income volatility rate of change has also been calculated.

<Table 7> shows the t—test results for the difference in the increase rate of income and the increase rate of income volatility between the groups with increased cultivation surface area and groups with decreased cultivation surface area, as a summarized statistical table regarding <Table 6>. Comparison analysis was conducted for crop type classification for the crop type group for all crop types, fruits, foodstuffs and grain types, and vegetables.

Table 6. Income and income volatility Rate of Change for Cultivation Surface Area Increase/Decrease for 10 Years (Unit: 1,000 KRW/ha)

Region	Crop type	Classification	Surface area	Relative ratio	`01-`05 Income	`11-`15 Income	Income rate of change	`01-`05 Income volatility	`11-`15 Income volatility	Income volatility rate of change
Gyeongnam	Sweet persimmon	Fruit	Increase	Increase	1,093	1,940	0.78	505	959	0.90
Gyeongnam	Strawberry (Semi-forced)	Fruit	Same	Increase	5,633	11,002	0.95	2,286	3,459	0.51
Gyeongnam	Strawberry (Forced)	Fruit	Same	Increase	6,586	11,124	0.69	2,420	5,065	1.09
Gyeongnam	Apple	Fruit	Increase	Increase	2,490	3,830	0.54	929	1,645	0.77
Chungnam	Strawberry (Semi-forced)	Fruit	Increase	Increase	4,904	9,190	0.87	1,346	4,062	2.02
Chungnam	Strawberry (Forced)	Fruit	Increase	Increase	6,325	12,595	0.99	1,699	5,959	2.51
Chungnam	Cherry tomato	Fruit	Increase	Increase	7,883	8,386	0.06	3,043	4,385	0.44
Chungnam	Facility grape	Fruit	Increase	Increase	5,072	7,390	0.46	1,599	2,181	0.36
Chungnam	Tomato (Semi-forced)	Fruit	Increase	Increase	7,570	7,047	-0.07	3,206	3,559	0.11
Chungnam	Peach	Fruit	Increase	Increase	2,278	3,011	0.32	961	1,191	0.24
Gangwon	Alpine radish	Vegetable	Increase	Increase	1,072	1,303	0.22	482	832	0.73
Gangwon	Alpine Cabbage	Vegetable	Same	Increase	1,077	1,283	0.19	447	571	0.28
Gyeongbuk	Spring cabbage	Vegetable	Increase	Increase	782	768	-0.02	532	415	-0.22
Jeonnam	Spring onion	Vegetable	Same	Increase	1,379	1,495	0.08	1,004	1,145	0.14
Chungbuk	Autumn cabbage	Vegetable	Increase	Increase	1,078	1,492	0.39	759	790	0.04
Gyeonggi	Spring potato	Foodstuff	Increase	Increase	649	1,115	0.72	334	719	1.15
Jeonbuk	Sweet potato	Foodstuff	Increase	Increase	807	1,622	1.01	474	947	1.00
Chungnam	Sweet potato	Foodstuff	Increase	Increase	1,027	1,587	0.55	370	1,073	1.90
Chungnam	Spring potato	Foodstuff	Increase	Increase	712	1,046	0.47	447	841	0.88
Chungbuk	Outdoor green corn	Foodstuff	Increase	Increase	648	858	0.32	232	351	0.51

Region	Crop type	Classification	Surface area	Relative ratio	`01-`05 Income	`11-`15 Income	Income rate of change	`01-`05 Income volatility	`11-`15 Income volatility	Income volatility rate of change
Gyeongnam	Watermelon (Semi-forced)	Fruit	Decrease	Decrease	1,960	3,343	0.71	634	1,460	1.31
Gyeongnam	Citron	Fruit	Decrease	Decrease	1,179	1,811	0.54	735	1,407	0.91
Jeonnam	Sweet persimmon	Fruit	Decrease	Decrease	1,479	1,729	0.17	872	980	0.12
Chungnam	Outdoor grape	Fruit	Decrease	Decrease	2,378	2,951	0.24	792	1,938	1.45
Gangwon	Spring cabbage	Vegetable	Decrease	Decrease	1,109	1,104	0.00	372	667	0.79
Gyeonggi	Facility grape	Vegetable	Decrease	Decrease	1,192	1,570	0.32	465	1,205	1.59
Gyeongnam	Facility pepper	Vegetable	Decrease	Decrease	8,688	14,282	0.64	3,617	7,166	0.98
Gyeongbuk	Facility pepper	Vegetable	Decrease	Decrease	6,360	6,378	0.00	5,433	4,461	-0.18
Jeonnam	Spring cabbage	Vegetable	Decrease	Decrease	653	1,394	1.13	369	1,037	1.81
Jeonnam	Facility pepper	Vegetable	Decrease	Decrease	6,367	7,623	0.20	2,981	4,472	0.50
Jeju	Carrot	Vegetable	Decrease	Decrease	737	1,812	1.46	489	2,077	3.25
Jeju	Cabbage	Vegetable	Same	Decrease	1,636	1,015	-0.38	717	893	0.25
Chungnam	Autumn cabbage	Vegetable	Decrease	Decrease	818	1,273	0.56	553	1,121	1.03
Chungnam	Spring onion	Vegetable	Decrease	Decrease	1,515	2,340	0.54	987	1,900	0.93
Gangwon	Spring potato	Foodstuff	Decrease	Decrease	773	1,146	0.48	334	787	1.35
Gyeonggi	Sweet potato	Foodstuff	Decrease	Decrease	511	1,009	0.97	221	790	2.58
Gyeongnam	Barley beer	Foodstuff	Decrease	Decrease	209	148	-0.29	65	59	-0.09
Jeonbuk	Autumn potato	Foodstuff	Decrease	Decrease	772	1,149	0.49	652	700	0.07
Jeonbuk	Spring potato	Foodstuff	Decrease	Decrease	654	785	0.20	495	481	-0.03
Jeonbuk	Ginger	Special-use	Decrease	Decrease	2,004	3,239	0.62	1,642	2,370	0.44
Chungnam	Ginger	Special-use	Decrease	Decrease	1,823	2,581	0.42	1,550	2,088	0.35

Table 7. The T-test result for the increase rate of income and the increase rate of income volatility of the groups with increase/decrease cultivation surface area by each crop type

Crop type classification	Comparison object	Surface area decrease Group(n)	Surface area increase Group(n)	Average difference	t-test	
					Test statistic	p-value
All crop types	Income increase rate (%)	42.9 (21)	47.6 (20)	-4.7	-0.384	0.703
	Income variation increase rate (%)	92.4 (21)	76.8 (20)	15.6	0.624	0.536
Fruit type group	Income increase rate (%)	41.3 (4)	55.9 (10)	-14.6	-0.727	0.481
	Income variation increase rate (%)	94.7 (4)	89.5 (10)	5.2	0.117	0.909
Foodstuffs and grain type group	Income increase rate (%)	37.1 (5	61.3 (5)	-24.2	-1.018	0.339
	Income variation increase rate (%)	77.9 (5)	108.7 (5)	-30.8	-0.541	0.603
Vegetable type group	Income increase rate (%)	44.7 (10)	17.2 (5)	27.5	1.081	0.299
	Income variation increase rate (%)	109.4 (10)	19.3 (5)	90.1	2.010	0.066

The results of analysis show that the increase rate of income was slightly high, and the increase rate of income volatility was low when comparing the surface area increase group with the surface area decrease group in the total crop type section, but this is not a significant degree statistically. In terms of each crop type group, the increase rate of income for fruits was high for surface increase groups and the increase rate of income volatility was relatively low. However, this was not significant. For foodstuffs and grain crops, the increase rate of income as well as the increase rate of income volatility of increase were high but was not significant. On the other hand, for vegetables, the increase rate of income for surface area increase group was comparatively lower than the surface area decrease group. However, the increase rate of income volatility had a significant difference of 0.1, and the rate of increase of surface area increase group was significantly low. Although the observed value used in the t-test was low and was not at the level of being able to determine the statistical significance, there is meaning in that we can explore and check which differences there are for each crop type group when the regional crop types are classified into surface area increase group and surface area decrease group.

Table 8. Changes in the Primary Crop Type Portfolio Component Ratio by Each Region (Original source: Rural Development Administration)

Nationwide				Jeollanam-do			
'01~05 Top Crop Types	Component Ratio (%)	'11~15 Top Crop Types	Component Ratio (%)	'01~05 Top Crop Types	Component Ratio (%)	'11~15 Top Crop Types	Component Ratio (%)
Apple	10.82	Strawberry (forced)	11.75	Apple	19.5	Cherry tomato	17.49
Strawberry(semi-forced)	9.16	Strawberry(semi-forced)	10.33	Outdoor spinach	17.36	Watermelon(semi-forced)	15.47
Cucumber (forced)	7.99	Beer barley	7.21	Strawberry (forced)	9.8	Apple	11.18
Facility pepper	7.66	Apple	5.14	Colored sweet pepper	9.59	Facility chrysanthemum	10.51
Facility zucchini	6.98	Outdoor watermelon	4.82	Facility eggplant	9.52	Cucumber (forced)	9.19
Cucumber(semi-forced)	6.92	Outdoor spinach	4.35	Outdoor grape	6.58	Autumn cabbage	7.71
Watermelon(semi-forced)	5.68	Tomato (forced)	4.22	Beer barley	3.52	Cabbage	4.48
Strawberry(forced)	5.32	Colored sweet pepper	4.11	Cherry tomato	3.21	Strawberry (forced)	4.22
Tomato(forced)	5.3	Outdoor chive	4.05	Cucumber(semi-forced)	2.88	Facility spinach	3.77
Outdoor green corn	4.56	Cherry tomato	3.74	Peach	2.44	Green onion	3.71
Gangwon-do				Jeollabuk-do			
Peach	19.59	Cabbage	29.82	Strawberry(semi-forced)	27.33	Peach	22.65
Cucumber(semi-forced)	14.15	Autumn radish	24.58	Watermelon(semi-forced)	19.6	Sweet potato	15.07
Spring cabbage	13.1	Spring potato	13.07	Sweet potato	13.3	Alpine cabbage	14.95
Alpine radish	12.09	Autumn cabbage	9.54	Alpine radish	6.44	Facility eggplant	13.2
Spring potato	11.06	Colored sweet pepper	8.45	Spring cabbage	5.18	Outdoor watermelon	8.73
Spring radish	8.63	Tomato(semi-forced)	4.19	Facility lettuce(skirt))	4.8	Autumn radish	7.02
Outdoor green corn	8.13	Alpine cabbage	3.25	Pear	3.84	Apple	6.37
Tomato(semi-forced)	6.11	Alpine radish	2.81	Strawberry (forced)	3.64	Outdoor grape	4.08
Cabbage	4.24	Spring cabbage	2.44	Autumn potato	3.4	Ginger	1.9
Colored sweet pepper	1.76	Peach	1.85	Alpine cabbage	3.35	Autumn potato	1.42
Gyeonggi-do				Jeju-do			
Pear	17.59	Sweet potato	20.51	Chive	38.08	Outdoor watermelon	77.91
Peach	17.3	Tomato (semi-forced)	16.37	Kiwi fruit	25.7	Chive	9.02
Spring radish	14.22	Cucumber(suppressed)	14.42	Cabbage	20.78	Autumn potato	6.53
Outdoor green corn	7.51	Facility zucchini	8.02	Beer barley	10.78	Facility tangerine	3.96
Facility Korean melon	7.1	Autumn radish	6.46	Carrot	3.04	Outdoor tangerine	2.1
Facility spinach	6	Facility lettuce	5.13	Autumn potato	1.33	Kiwi fruit	0.48
Green onion	5.65	Facility Korean melon	4.9	Outdoor watermelon	0.3	Carrot	0
Outdoor grape	5.57	Spring cabbage	4.56	Outdoor tangerine	0	Beer barley	0
Cucumber (suppressed)	4.89	Facility lettuce	4.31	Facility tangerine	0	Cabbage	0
Spring potato	4.84	Outdoor grape	3.31				
Gyeongsangnam-do				Chungcheongnam-do			
Facility pepper	13.75	Facility eggplant	33.31	Strawberry(semi-forced)	14.99	Strawberry (forced)	27.15
Outdoor spinach	12.57	Peach	11.06	Facility zucchini	11.11	Outdoor grape	15.72
Peach	7.73	Outdoor grape	10.1	Facility pepper	8.62	Facility lettuce (skirt)	9.28
Carrot	7.51	Tomato (forced)	9.32	Outdoor green corn	8.4	Pear	7.83
Kiwi fruit	7.03	Spring potato	8.41	Outdoor grape	7.49	Facility pepper	7.47
Outdoor grape	6.77	Facility pepper	5.21	Sweet potato	7.04	Outdoor green corn	7
Facility zucchini	6.1	Sweet potato	4.1	Peach	6.71	Cucumber (suppressed)	6.14
Outdoor green corn	5.43	Strawberry (forced)	3.6	Pear	6.69	Facility grape	6.07
Beer barley	4.92	Watermelon(semi-forced)	3.19	Cucumber(semi-forced)	6.41	Ginger	4.16
Colored sweet pepper	4.65	Apple	2.77	Strawberry (forced)	5.45	Sweet potato	3.99
Gyeongsangnam-do				Chungcheongbuk-do			
Facility Korean melon	17.43	Facility Korean melon	32.21	Facility zucchini	34.3	Watermelon(semi-forced)	29.82
Cucumber(semi-forced)	13.09	Outdoor watermelon	29.53	Outdoor grape	13.93	Outdoor watermelon	19.8
Cucumber(forced)	9.77	Facility pepper	7.4	Apple	10.87	Facility zucchini	18.12
Green onion	9.58	Facility chive	4.53	Pear	10.75	Apple	16.39
Tomato(semi-forced)	7.51	Cucumber (forced)	4.09	Watermelon(semi-forced)	9.93	Spring potato	5.2
Pear	7.29	Cucumber(semi-forced)	3.48	Outdoor watermelon	6.03	Facility grape	3.81
Facility pepper	5.13	Strawberry (forced)	2.48	Autumn radish	4.6	Outdoor green corn	3.22
Tomato (forced)	4.29	Spring potato	2.29	Spring cabbage	4.53	Peach	1.8
Sweet potato	3.84	Spring radish	2.18	Spring potato	2.03	Autumn cabbage	1.59
Strawberry(forced)	3.52	Strawberry(semi-forced)	2.09	Outdoor green corn	1.92	Spring cabbage	0.13

<Table 8> shows the results of the primary crop type constitution of each region which can maximize the income stability by using the optimal portfolio method due to the Mean-Variance (MV) model as stage 2 of the analysis procedure. This is the top 10 crop type of the portfolio component ratio by distinguishing the results of data for 5 years in ’11-’15 and results of data five years in ’01-’05 from the income data of primary crop types in each region. It can be seen that the crop type selected and distributed of each region and the component ratio are different in terms of income stability. To explain meaning of <Table 8> in ratio terms, if it is assumed that the farmers of each region are gathered in one organic body to make a decision and intend to achieve stable income, it compares how the optimal crop type combination between that of 10 years ago and now.

If we interpret the analysis results, in terms of income stability, the optimal portfolio changed from peach, cucumber, spring cabbage, alpine radish to cabbage, autumn radish, and spring potato in Gangwon-do. In Gyeonggi-do, the portfolio ratio decreased for pear, peach, and spring radish, while the portfolio increased for sweet potato, tomato (semi-forced), cucumber (forced). In Gyeongnam, the portfolio moved from facility pepper and outdoor spinach to facility eggplant, peach, and outdoor grape. In Gyeongbuk, the ratio for facility Korean melon increased and the ratio for outdoor watermelon increased more than cucumber. In Jeonnam, the portfolio moved from apple and outdoor spinach to cherry tomato, watermelon (semi-forced), and facility chrysanthemum. In Jeonbuk, the ratio increased more for peach and alpine cabbage than strawberry and watermelon. In Jeju, the ratio for chive, kiwi fruit, and cabbage decreased and the portfolio for outdoor watermelon increased. In Chungnam, the ratio for strawberry and outdoor grape increased while in Chungbuk, the ratio for facility zucchini and outdoor grape decreased while the ratio for watermelon increased. However, these results are as such only if it is presumed that the risk for income variability changes.

<Table 9> is a summary for synthesizing the analyses results of stages 1 and 2, as stage 3 of the analysis procedure. It outlines the optimal portfolio component ratio changes in terms of stable income for crop types of groups where the cultivation surface area increased or decreased by each

Table 9. Summary of the changes of portfolio component ratio of the surface area increase/decrease group (Including cultivation land change)

Region	Surface area increase group			Surface area decrease group			Direction correspondence number
	Crop type	01-'05 Composition ratio (%)	11-'15 Composition ratio (%)	Crop type	01-'05 Composition ratio (%)	11-'15 Composition ratio (%)	
Gangwon	Alpine radish	12.09	3.25	Spring cabbage	13.1	2.44	2/4
	Alpine cabbage*	0	2.81	Spring potato	11.06	13.07	
Gyeonggi	Spring potato	4.84	0.57	Facility spinach	6	0	1/3
				Sweet potato	0	20.51	
Gyeongnam	Apple*	4.21	2.77	Facility pepper	13.75	5.21	5/8
	Sweet persimmon*	0.94	2.76	Beer barley	4.92	0	
	Strawberry(semi-forced)	0.93	0	Watermelon(semi-forced)	2.74	3.19	
	Strawberry(forced)	0	3.6	Citron	0.7	0	
Gyeongbuk	Spring cabbage	1.16	1.76	Facility pepper	5.13	7.4	1/2
Jeonnam	Chive	0	0.09	Sweet persimmon*	2.28	0	3/4
				Spring cabbage	0.93	0.77	
				Facility pepper	0	0	
Jeonbuk	Sweet potato	13.3	15.07	Autumn potato	3.4	1.42	2/4
				Ginger	0.94	1.9	
				Spring potato	0.01	0.64	
Jeju				Cabbage	20.78	0	2/2
				Carrot	3.04	0	
Chungnam	Strawberry(semi-forced)	14.99	27.15	Outdoor grape	7.49	15.72	2/10
	Sweet potato	7.04	3.99	Ginger	0.23	4.16	
	Strawberry(forced)	5.45	0.02	Autumn cabbage	0	0	
	Facility grape	4.77	6.07	Chive	0	0	
	Cherry tomato	2.65	1.24				
	Tomato(semi-forced)	2.16	0.48				
Chungbuk	Outdoor green corn	1.92	3.22				3/3
	Autumn cabbage	1.11	1.59				
	Peach*	0	1.8				

region. The case where the portfolio component ratio increased in cultivation surface area increase group and the case where the portfolio component ratio decreased in the cultivation area decrease group have been shaded for emphasis. It also indicates the number of cases where the direction of increase and decrease was same for each region. It can be interpreted that the fact that there are many coinciding directions means that the portfolio method well predicted the cultivation surface area changes in terms of stable income securement. Although the number of coinciding directions is around half, being 21 out of a total of 40, in cases where the top crop types with high regional portfolio component ratio, there are relatively many cases where the direction coincides. Alpine cabbage, apple, sweet persimmon, and peach, which were found by preceding studies to have cultivation surface area changes, are indicated with an Asterix and bold letters. The increase in the cultivation surface area of alpine cabbage in Gangwon-do, sweet persimmon in Gyeongnam, and peach in Chungbuk can be explained in terms of the influence of climate change. For these crop types, the direction also coincides for portfolio component ratio change. As such, it implies that the income stability may also increase for regions that relate to positive direction for cultivation surface area changes. While it is presumed that the reason for the increase in the cultivation surface area for apple in Gyeongnam is due to the increase of the cultivation surface area in mountainous territories, it shows the trend of decreasing portfolio component ratio. The decrease in the cultivation surface area for sweet persimmon in Jeonnam does not coincide with the direction of the cultivation land changing trend. However, the cause for this can be the fact that there are more superior crop types than sweet persimmon in terms of the income contribution ratio in Jeonnam, or because of the competitive difference with Gyeongnam, which is a chief producing district.

Part of the cases in <Table 9> shows that the surface area increase of alpine radish and alpine cabbage in Gangwon-do has a close relation to the cultivation land change, and since the cultivation surface area relative ratio rose from 70% 10 years ago to 90% recently, thus becoming almost a monopoly market. Since the income for each unit surface area is higher compared to other regions, these can be seen as Gangwon-do's primary crops. However, since cabbage and radish are crop types with great price fluctuation, the contribution may be greatly influenced by the climate and market conditions in terms of income stability. As for facility spinach in Gyeonggi-do, it is a chief producing district covering 60% of the facility spinach cultivation surface area nationwide of 2,243ha in 2017. This is a similar scale to Gyeongnam, the chief producing district, covering 55%, with the outdoor spinach surface area being 2,355ha nationwide in the same year. The survey data regarding cultivation surface area from Statistics Korea show that the surface area of outdoor spinach decreased approximately 5% compared to 10 years ago, while the surface area of facility spinach decreased 20%. From this, we can interpret the surface area decrease of the facility spinach which is influenced less by the climate is due to the decrease in the added value. While the causes can be the price competitiveness decrease due to the decrease in spinach consumption, or the increase in facility maintenance costs, it is difficult to give a precise analysis. The chief producing district of strawberry in terms of cultivation surface area was Gyeongnam 10 years ago, recently, Chungnam rose to a similar level. The reason why the surface area of strawberry increased for both Gyeongnam and Chungnam is because the income contribution rate of strawberry is high. The income change of strawberry in Gyeongnam and Chungnam in <Table 6> shows that it increased by almost 2 times for the period of 10 years. Interestingly in the portfolio component ratio, it was recommended that the component ratio of forced strawberry should be increased in Gyeongnam, where winter is the primary shipping period. In Chungnam, where spring is the primary shipping period, it was recommended that the component ratio of semi-forced strawberry should be increased. Considering the facility maintenance cost, one may consider the influence where the risk during the winter is lower in Gyeongnam, located in the southern region. Jeju-do, the chief producing district of tangerine, carrot, and cabbage, is showing the trend where the cultivation surface area is decreasing and being excluded from the portfolio. While the cultivation surface area's relative ratio for carrots narrowly decreased from 57.8%에서 54.6% compared to 10 years ago, in the same period, Gyeongnam increased from 11.5% to 18.5%, while Gyeongbuk increased from 4.6% to 10.4%. In <Table 6>, the income change for each ha increased from 740,000 KRW to 1,810,000 KRW, but the income deviation significantly increased from 490,000 KRW to 2,080,000 KRW, and this is perceived to be related to the exclusion from the portfolio. For cabbage, Jeju's importance decreased from 40.4% to 35.1%; Jeonnam increased from 15.1% to 21.1%, Gyeongbuk increased from 5.7% to 11%, while Gangwon narrowly increased from 18.8% to 16.7%. Compared to 10 years ago, the income average for each ha for Jeju changed from 1,630,000→1,010,000; Jeonnam changed from 590,000→950,000 KRW; Chungnam changed from 760,000→890,000 KRW; and Gangwon changed from 1,200,000→1,640,000 KRW. The rapid decrease of Jeju's income may have caused the change in the cultivation surface area. One may consider further research for the possibility of the cultivation land of cabbage having moved to the inland due to climate change.

5. Conclusion

As an exploratory research on the relationship between changes in cultivated area of major crops and farm income by regions, we investigated the income and income volatility of crop types as factors that can influence changes in the cultivated surface area for each region. Furthermore, in some of the crop types, we also considered the cultivated area's changes due to climate change. The results from the analysis showed that it is difficult to merely explain the cause for changes in cultivated surface area of major crop types as income and income volatility. In terms of item groups, while it was difficult to find the significant relation between cultivated surface area and income/income volatility for fruits and foodstuffs and grain, we were able to find that in the case of vegetables, when the income variation of the group with decreased cultivated surface area is compared to the past, it rose by approximately two times. As such, it can be said that the cultivated surface area decreased for vegetables because it was difficult to acquire income stably.

For the analysis on whether direction corresponds for crop types with changed cultivated surface areas and the changes in portfolio component ratio, we found that it only corresponds for half the cases. It is assumed that this is because the criterion for crop type selection may be influenced by not only stable income, but also high-income achievement or cultivated area changes caused by productivity decrease. If expanded in the socioeconomic perspective, it may be because there is a difference of market competitivity by region resulted by the scaling and systemization concerning the major crop types of each region, or due to crop change policy by local governments. Since it is difficult to consider various limiting variables and the constraints of data, it is difficult to state that the results of analysis of this research influenced changes in the cultivated surface area. Since this study is not an empirical study based on scientific methods, but has the characteristic of an exploratory study to examine the possibilities of several factors that can explain the phenomenon of cultivated area changes by region and by crop type, there is a limitation in that it cannot statistically prove the relation between the phenomenon and cause. However, this study has a differentiation in that we linked the whole income data from Rural Development Administration and the cultivated surface area data by each year from Statistics Korea, so that all regions and crop types can be viewed at one glance. Furthermore, since it deals with all regions and crop type items, it may act as a map which allows one to grasp the changes in specific regions and crop types in a comprehensive view. In this sense, this study may be utilized as a preliminary resource for studies conducting empirical analysis for understanding the phenomenon in specific regions and crop types and find which factors led that phenomenon to occur.

National institutions collect and publish various data by region and crop type annually in order to understand the situation of the agricultural industry and farming areas. Since these data are dispersed even up until now, the utilization may be inadequate. However, if one links various data in terms of region and crop type, it will be connected to enormous information, thus acquiring the personality of big data. In cases where a specific crop type's cultivated surface area rapidly decreased at a certain year, it is necessary to link dispersed data so that one may grasp at once whether it was due to the preceding year's income, that year's abnormal change, or due to the influence of another region. For this to be realized, it is important for preliminary studies to be conducted.

If farmers can select the optimal crop through the portfolio analysis, the economic performance may be improved. As such, it is important to have a decision-making support system which assists the optimal crop type selection for each region. In this sense, the crop introduction decision-making system co-developed by the Gyeonggi-do Agricultural Technology Center and the Rural Development Administration is well-timed, in that it provides information that can be referred to by farmers or returning farmers when changing their crop type or selecting a new crop type (Guhyeon Jeong et. al., 2018). Although the tables provided in this study have only extracted information on major crop types due to the limit of paper, the total data used in the actual analysis is useful in understanding various conditions. As such, if the results calculated from this study are used to make a sharing system that can be utilized by numerous researchers and the changes of main crop types in Korea are monitored within the sharing system and the related research results are accumulated, we anticipate that it will be conducive to future studies in the agriculture field.

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