ISSN 2234-3075(Print)
ISSN 2288-7806(Online)
Http://dx.doi.org/10.14771/AIM.10.2.2

Developing a decision support system for selecting new crops

Guhyun Jung[1], Myounghee Jeon[2], Jinhong Lee[3], Heundong Park[4], Seyong Lee[5], Joonyong Kim[6]

Abstract

Due to changes in the agricultural market environment and both overseas and domestic farming conditions, uncertainties in agricultural production and management are becoming greater. Hence, there is a stronger need for farmers to choose crops in the optimal condition. This research aims to introduce the result and process of developing a decision support system for selecting crops, aimed to assist farmers in selecting the optimal crops most suitable in the given situation.

There are basically three main factors to consider in the decision-making process for farmers when selecting a crop to introduce to their lands. First of all, one must consider how much profit crop A will produce when it is cultivated. Secondly, one must consider which crop to cultivate in order to earn a certain amount of profit. Thirdly, one must consider what is the best way to maximize Farm A's business profit. For instance, a farm may have land as its resource, and one must research which location, type of crop, level of technology, and so forth, to maximize profit.This research creates a database of the profitability of a total of 180 crop types by analyzing Rural Development Administration's survey of agricultural products income of 115 crop types, small land profitability index survey of 53 crop types, and Statistics Korea's survey of production costs of 12 crop types. Furthermore, this research presents the result and developmental process of a web-based crop introduction decision support system that provides overseas cases of new crop introduction support programs, as well as databases of outstanding business success cases of each crop type researched by agricultural institutions.

Article history

Received 23 October 2018
Received in revised form 6 November 2018
Accepted 10 November 2018

1. Introduction

Farming households are increasing each year in South Korea. When examining by each year, it can be perceived that farming households have increased from 10,202 in 2013 to 10,758 in 2014, reaching up to 11,959 in 2015. When examining in terms of each province, Gyeongsangbuk-do Province holds 2,221, Jeollanam-do Province 1,869, and Gyeongsangnam-do 1,612 farming households. Most of the farming household heads are in their fifties, which is 40.3 percent. The farming household heads in their fifties to sixties covers 64.7 percent. When considering the survey on educational programs and information-provision systems concerning those who have returned to farming and rural areas, particularly focusing on those with less than three years of farming experience, it shows that agricultural product marketing was 2.61, business management 2.77, and business review/planning 2.85 points. In sum, it was theoretically under the average of 3 points. This shows that in comparison to the level of need, the related information is insufficiently provided (Ways to improve

* This research was supported by Rural Development Administration's Agenda Program (Project number PJ01355102).

[1] Gyeonggi-do Institute of Agricultural Technology, Crop Research Department Team Leader
jgh1324@gg.go.kr
[2] Gyeonggi-do Institute of Agricultural Technology, Crop Research Department Researcher
jeon6474@gg.go.kr
[3] Gyeonggi-do Institute of Agricultural Technology, Crop Research Department Researcher
jinhong5@gg.go.kr
[4] JINONG Corporation, CEO
phd516@jinong.co.kr(✉)
[5] JINONG Corporation, Head of Management Division
ace@jinong.co.kr
[6] Seoul National University, Department of Biosystems and Biomaterial Science and Engineering, PhD in Agricultural Engineering
tombraid@snu.ac.kr

educational programs and information-provision systems concerning those who have returned to farming and rural areas, Korea Rural Economic Institute Seminar Sourcebook, May 2012).

Furthermore, changes in the agricultural products market environment and domestic/foreign agricultural conditions have increased uncertainties in agricultural production and management. Due to this, an increasing number of farmers are seeking to change their crop types. Return-farmers and farmers seeking to select new crops have insufficient information regarding target income, input cost, necessary amount of labor, and so forth. As a result, they face difficulty in the management of farmlands and settling down to farming.

In response to this trend, Rural Development Administration conducts research on farming income each year. The subjects of study reach up to 115 different types of products, including apples, tomatoes, and roses. Farming technology institutes in each province conduct studies on management conditions, focusing on the specialized crop in each location and a number of crops in small areas. In addition, Statistics Korea executes income studies on 12 crop types including rice, garlic, onions, Korean native cattle fattening, dairy cattle, etc. and other regionally specialized crops, in addition to numerous crops in small areas. However, the analyzed information on the profitability index of each crop type is merely a list of statistics on each crop type. Hence, this data is deficient when it comes to utilization by farmers or those who wish to take up farming in rural areas (return-farmers).

As such, there is a need for a system that integrates and utilizes research materials on each crop that are provided by each institution, including farming income data, studies on management conditions of regionally specialized crops, and statistical research data on major crop production costs. Furthermore, this integrated system must be able to support the establishment and planning of farming for those who wish to change crops or introduce new crop types to their lands.

This research seeks to develop a program that supports the farmers' decision-making when introducing new crops to their lands. The first method of developing this program is to create a database of the profitability index analysis information of each crop type, focusing on a total of 180 crops, including Rural Development Administration's survey on 115 crop types, small land profitability index survey on 53 crop types, and Statistics Korea's survey of production costs on 12 crop types. Secondly, this research will collect databases of outstanding business success cases of each crop type researched by agricultural institutions and foreign cases of new crop introduction support programs. Thirdly, we will develop a management model that is able to conduct a simulation of possible management situations that may occur when introducing a new crop type under the current farming management situation, taking into consideration the constraints on the farmers and return-farmers, including one's current land holdings or arable land, labor, resources, and level of technology. Fourthly, this research will develop an analytical function for farm management planning support program (labor required in each stage of labor, control calendar, the amount and cost for elements of input, expected earnings, and so forth) development and management performance.

2. Literature Review

2.1. Studies on decision-making for crop introduction in South Korea

From 1977 and onward, Rural Development Administration has been annually presenting research and analyses on the gross income of each crop type, management cost, amount of labor spent, income, and so forth. The sample of survey are upper-middle level farming households that accommodate farming technologies of Rural Development Administration. National Agricultural Economic Institute researched and analyzed the average profitability index of agricultural and livestock products from 1970 to 1976. From 1977, Rural Development Administration researched and analyzed the profitability index of agricultural and livestock products. Livestock products were excluded from their surveys since 1998, in order to avoid overlapping with Ministry of Agriculture Food, and Rural Affairs' production cost survey on livestock products. Furthermore, the title of the published booklet was changed from 'Agricultural and livestock product average income' to 'Agricultural and livestock product income sourcebook'. In 2002, the researched data on 43 crop types was approved as general statistics by Statistics Korea. In 2010, the number of crop types were increased to 58, and the survey continues to be carried out today. In addition, Rural Development Administration examines the management efficiency of farming households and utilizes the results to develop management standard diagnosis tables, applying it to personalized consultations for farming households. The management standard diagnosis tables are developed according to 84 types of crops. Specifically, these include 7 food crop types such as rice, 6 special use crop types such as sesame

seeds, 11 types of facility-grown vegetables such as facility-grown chili, 13 types of outdoor-grown vegetables such as autumn cabbages, 10 types of fruits such as apples, 7 types of flowers such as gypsophila paniculate, 6 livestock products such as layer poultry. The management standard diagnosis tables are structured into four categories, which are general farming conditions, business outcome indicator, detailed evaluation diagnosis table, and general evaluation diagnosis table. Through the management diagnosis table, one is able to assess the particular farming household's management performance level such as business size, output, farming income, condition of cultivation facilities, and cultivation and management techniques. By creating a point-based system according to these cultivation and business management elements, the table is structured so that the particular farming household can receive an adequate diagnosis result of management.

Return Farm General Center (www.returnfarm.com) provides training, consultations, and book resources for those who wish to take up farming in rural areas, including information on the main crop types and most promising items of each city, county, and province. However, these crop types are limited, and the provided information is unspecific, presenting only five categories – family management size, average investment cost, annual management cost, average profit, and farmland price. Therefore, these resources are inadequate when deciding upon which crop to select.

Pyung-sik Park et al. (2001) used Rural Development Administration's management standard diagnosis table, 'rice management standard diagnosis table,' to assess the management of rice production of farming households. The researchers compared those results with Japan's management diagnosis methods. Hee-sook Lee et al. (2006) put together studies related to financial information systems of farming households to examine financial information systems for supporting agricultural decision-making of small-scale farming households. These researchers not only proposed detailed categories of financial management for farming households, but also structured and realized an information system structure for management.

Ministry of Agriculture, Food and Rural Affairs funded a business unit (supervised by NEWMA) of elevated supply, demand, and distribution of vegetables based on technology. The purpose of this unit was to conduct a study, in 2015 to 2017, on the predicted cost of five major vegetable types. In this study, Professor Choe Young-chan's research team at Seoul National University used an artificial neural network algorithm to improve the accuracy of predictions compared to the former econometric method.

In "Performances of Farm Management Consulting Project ('01)," Kyeong-ha Kang et al. (2001) analyzed the performance of systems related to Rural Development Administration's management analysis, including the establishment of farming management consulting promotion systems, consulting systems, the supply of management standard diagnosis table development according to each item, and the construction of consulting systems for farming households. In "Farm Management Consulting Guide Using Benchmarking Technique ('99)," Rural Development Administration developed a system with the aim of constructing a network system that manages farming management objectives, as well as farming management consulting by benchmarking techniques. In "Korean Horticulture's Consulting Service," Hyun-bok Jung deducted a profitability analysis according to each crop type, scoring criteria of greenhouse economic feasibility analysis for consultation, and the scope and content of professional consultation.

2.2. Study for decision-making in choosing the optimal crop type and cultivation area

Rădulescu, M. et al. (2014) used the portfolio theory to propose the optimal model for various problem-solution situations such as maximum profit, minimal financial risk, minimal environmental risk, and so forth. They proposed a system architecture to apply a linear programming method on a program that uses the portfolio method. The analytical application structure which utilized actual data is presented in <Figure 1>.

Linear programming uses a suitable method to bring forth the optimal value under limiting situations. It deduces the scope of cultivation area and the list of crop types which can create maximum profit, considering constraining factors such as the amount of budget that a farming household can invest, the scope of labor, the scope of possible crop types that can be chosen, and so forth.

Yong-whan Kim et al. (2002) conducted a study to present the factors that a tiller may consider when selecting the crops for cultivation. The researchers were able to find that crop-selection choices are occasionally constrained by the particular area's traditional cultivating environment. At the same time, a farmer may consider the labor and area necessary for cultivation to decide the type and number of crops to grow. Most of all, the details of cultivation depend heavily on profit results.

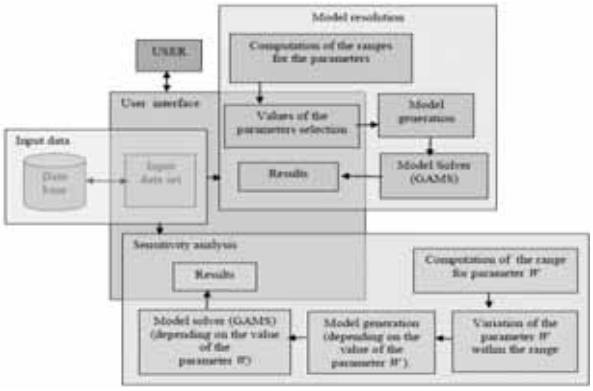

Figure 1 Linear programming model using the portfolio theory by Rădulescu, C.Z. et al. (2012)

2.3. The importance of information systems

An increasing number of farming and return-farming households are considering the possibility of changing their crop types due to changes in consumers' preference of agricultural products, changes in vegetation due to climate change, and fluctuations in agricultural product prices. When considering which crops to select – in instances where a farmer may change crop types or consider returning to farming – the manager will attempt to combine farmland, labor, resources, and so forth, in the most efficient way to maximize profit. Before selecting which crop to cultivate, the process of investigating management cost, input cost, and earnings for each produce type is critical.

Rural Development Administration developed an agricultural product earning analysis program and presented it to farmers. This program provided a research function for agricultural product earning analysis data, agricultural income prediction, management performance analysis, farming information, outstanding cases of agricultural businesses, and manuals. However, it was unable to reflect the recent changes in the revenues for each crop type, management costs, and management situations. Furthermore, the program was provided in Excel, creating the problem where farming households had difficulty in accessibility and application.

It is necessary to develop a management model that a returning-farmer or a farmer exploring new crops can use, to conduct simulations with the current land holdings, labor, and resource constraints, providing information on the scale of business, management cost, and profitability index for each crop type. The model should be created into a program and provided to farmers via the Internet. Furthermore, outstanding management cases for each crop types should be realized into a database so that farmers may refer to it. The information on management techniques from various agricultural institutions should be integrated into one. In doing so, returning-farmers and farmers will have direct access to the necessary information for crop selection and farm management planning, such as information on estimated income and management fees, amount of labor required for farming in each stage, and suitable time for cultivation and pest control. The development of such a model is a pressing need for farmers and return-farmers.

To go on further, the existing income analysis research is either narrowly focused on a single crop type or fails to consider the time series trend of multiannual data. As such, our research seeks to take into consideration the causes of income risk due to time series trends, as well as to deduce the optimal surface area when selecting a multiple of crops. By doing so, we will be able to develop a business management model necessary for farmers and returning-farmers to make decisions on crop types. It is vital to realize this into a web-based program and thus increase the level of research convenience and accessibility for farmers.

3. Decision support system model for selecting new crops

This research aims to make into a database the information held by Rural Development Administration and Statistics Korea, which can be referred by farmers and returning farmers when deciding upon which new crop types to select. In addition, we devised a research model that is able to conduct farm management simulations by using a farm work estimation model, income estimation model, and cost estimation model. When devised into a diagram, it appears as <Figure 2>.

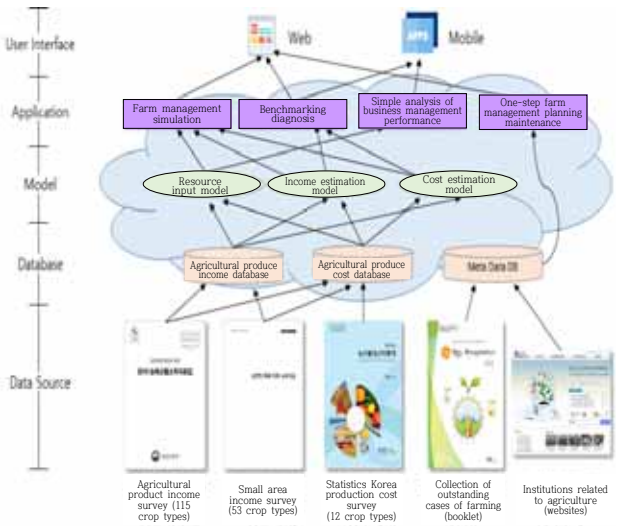

Figure 2 Decision support system model for selecting new crops

There are basically three main factors to consider in the decision-making process for farmers when choosing which crop to introduce to their lands. First of all, one must consider how much profit crop A will produce when it is cultivated. Factors that may affect the profits of each crop type include geographical location, facility, surface area of land, farming techniques, and so forth. With the income estimation model for each crop type, we can deduce the annual estimated income for the particular crop type. Secondly, one must consider which crop to cultivate in order to earn a certain amount of profit. In contrast to the first question, this second issue is a research method for identifying the required resources and crop type in order to gain the target income. Thirdly, one must consider what is the best way to maximize Farm A's business profit. For instance, a farm may have land as its resource, and one must research which location, type of crop, level of technology, and so forth, to maximize profit.

In order to identify the solutions to the three issues mentioned above, this research will utilize "Agricultural product income information by each region," a sample survey conducted annually by Rural Development Administration. This resource provides information on each region's gross income of 115 crop types (gross income), surveyed information on the amount and cost of each item of expenditure, and Statistics Korea's information on the cost and profit of rice. This information is surveyed every year by agricultural technology centers of cities and counties, as well as experts in agricultural business management of each area. Furthermore, these surveys are conducted through auditory interviews and visits with each surveyed farming household.

Table 1 Three main factors to consider in the decision-making process of selecting crop type

Inquiry	Entry and search condition	Result
How much profit will crop A produce when cultivated?	(Input value) crop type, geographical location, facility, surface area, level of farming technique ⇑ (Model analysis) crop type profit estimation model	· Estimated annual profit for crop A
Which crop should one cultivate in order to earn a certain amount of profit?	(Input value) target income, geographical location, facility, surface area, level of farming technique ⇑ (Model analysis) crop type profit estimation model	· Recommended crop type for increasing profit to more than 000 Korean won.
What is the best method of maximizing Farm A's business profit?	(Input value) target income, geographical location, facility, surface area, level of farming technique ⇑ (Model analysis) portfolio optimal solution (crop type, surface area) model	· Crop to cultivate, surface area of cultivation land for each crop type · Maximum estimated amount of farm profit

4. Explanation of Program Development

4.1. Outline of System Development

This research purports to realize the three situations in the above "<Table 1> Three main factors to consider in the decision-making process of selecting crop type" into a program. The whole system will be named "decision support system for selecting new crops". The submenus will be constituted of "predicted amount of crop profit," "yearlong farm plan," "comparison of the profit level of one's own farm," and "outstanding cases of farming businesses." In the menu, "predicted amount of crop profit," the analysis for the three main factors to consider when deciding upon a new crop will be made available. The first submenu of "predicted amount of crop profit" is the "estimated profit for the selected crop type" function. With this function, one may analyze the first inquiry, "How much profit will crop A produce when cultivated?" Secondly, the "possible crop for target profit" function analyzes the predicted crop for the target profit. This brings forth the answer to the question, "Which crop should one cultivate in order to earn a certain amount of profit?" Thirdly, the "possible surface area for target profit" function provides information on the predicted surface area and geographical location for the target profit". This presents the solution to the question, "What is the best method of maximizing Farm A's business profit?"

The entire menu structure for "decision support system for selecting new crops" is presented in the table below.

Table 2 Structure of menu for decision support system for selecting new crops

Name of menu	Submenu	Main function
Predicted amount of crop profit	Estimated profit for the selected crop type	· Analysis of predicted amount of profit for each crop type · This function finds the solution to "How much profit will crop A produce when cultivated?"

Name of menu	Submenu	Main function
	Possible crop for target profit	· Analysis of predicted crop type for target profit · "Which crop should one cultivate in order to earn a certain amount of profit?"
	Possible surface area for target profit	· Analysis of predicted surface area for target profit · This function analyzes the solution for "What is the best method of maximizing Farm A's business profit?"
Yearlong farm plan	Farm work schedule	· Detailed information on farm work schedule for each crop type
	Necessary amount of labor	· Information on the amount of labor necessary for cultivating each crop type
Comparison of the profit level of one's own farm	-	· This function informs the predicted level of the farming household after comparison with upper, average, lower level farming households and income data
Outstanding cases of farming businesses	-	· This function collects and provides information on outstanding cases of farming businesses for each crop type

4.2. Detailed explanation of the program

[Predicted amount of crop profit]

By creating the data collection on agricultural product profits into a database, we can predict the profit for each crop type cultivated by farming households. When we input the target profit, the program will provide the necessary information for producing that profit, such as crop type and amount.

4.2.1. Estimated profit for the selected crop type

The function, "estimated profit for the selected crop type," provides the predicted profit for the relevant crop type. After inputting the data for the farming household's geographical area, crop type, and surface area, one can select the appropriate profit, amount, and level of farming technique. In other words, it analyzes the solution for the inquiry, "How much profit will crop A produce when cultivated?"
By clicking the "add crop type" button, the user can add the desired crop type. By clicking the "analyze" button, the user may input the query conditions such as geographical location, crop type, and surface area, and thus receive the analyzed results.

① Display image of query condition input

Figure 3 Display image of predicted amount of crop profit input

In order to conduct a simulation on crop profit, the user must select the desired geographical location in terms of province. The user will then decide upon the type of crop and predicted surface area for cultivation. After doing so, the user will select the predicted cost of the crop for that year in terms of high, medium, and low. The user will go on to select the desired amount in levels of high, medium, or low. When this selection is complete, the user will finally distinguish one's production cost levels in terms of high, medium, or low. The analysis will then proceed.
As for the criteria for the relevant crop profit, we referred to the average value of five years provided by Rural Development Administration's average profit analysis data, based on the year analyzed.

② Display image 1 of the analyzed result

Figure 4 Display image showing results for the predicted amount of crop profit

The above display image presents the search results when a farmer cultivating apples on a 10,000㎡ orchard plans to reach high, medium, and high levels for price, amount, and cost, respectively. In other words, the simulation shows that the sale price predicted by the farmer is higher than the average farming household (weighted value of price is "high"); the amount of produce is average; and the production cost is higher than the average farming household (weighted value of cost is "high").
The simulation further shows that the predicted number of produced apples is 18,602kg; the gross income is 57,379,033 Korean won; the management cost is 19,155,033 Korean won; and the profit is 35,087,659 Korean won.

② Display image 2 of the analyzed result

Clicking the "view details" button will provide the following information: the gross income and management cost of the relevant crop type, results after distinguishing the profit, and details for each category. For a convenient analysis, the program provides the converted value for the cultivated surface area inputted by the farmer, with the basic surface area standardized to 1,000㎡.
For instance, the gross income of apples for each 1,000㎡ surface area is 5,795,935 Korean won; the management cost is 2,128,337 Korean won; and the profit is 3,544,208 Korean won. This value has been calculated according to the weight value of the "price/amount/cost" set for the analyzing the predicted amount of crop profit. The gross income is presented in detail since it is the added value of the main product price and secondary product price. Likewise, management cost is distinguished below as seed cost, inorganic fertilizer cost, organic fertilizer cost, pesticide cost, light and heat cost, repairment cost, and so forth.

Figure 5 Display image showing results for the relevant crop's gross income, production cost, and earnings

4.2.2. Possible crop types for target profit

For the function, "possible crop types for target profit," the farmer may input data on target profit, geographical location, surface area of land, and weighted value (price, amount, cost). When this is complete, the function presents a comparison analysis between the farmer's target profit and the relevant geographical location's crop profit.

① Display image of query condition input

Figure 6 Display image of target profit input

Unlike the "estimated profit for the selected crop type" function, the farmer may search for possible crop types for the desired target profit in the "possible crop types for target profit" function. This can be executed by inputting one's target profit according to the relevant geographical location and the weighted value of price, amount, and technique applicable to one's arable land.

② Display image of the analysis

Figure 7 Display image showing the results according to the target profit

The above display image presents the analyzed result when a user with 10,000㎡ of land in Gyeonggi-do Province sets the target profit as greater than 30,000,000 Korean won, under the following conditions: the target agricultural product's weighted value of price, amount, and technique is medium, high, and medium, respectively. The analyzed results show that apples, pears, outdoor grapes, peaches, and blueberries will bring forth the desired target profit.

As for the model used in the analysis, we used the five-year average value of management cost and income for each province and crop type, provided by Rural Development Administration's average profit analysis data.

By clicking the "view details on each crop type" button, the user will be provided with results on the relevant crop type's gross income, management cost, and profit. The displayed screen will provide results similar to "<Image 5> Display image showing the results for the relevant crop's gross income, production cost, and earnings."

4.2.3. Possible surface area for target profit

The function, "possible surface area for target profit," analyzes the result for the question, "Which crop should one cultivate in order to earn a certain amount of profit?" When the farmer-user selects one's target profit and geographical area, the function will provide relevant information on the crop type and adequate surface area of cultivation land necessary for achieving the target profit.

① Display image of query condition input

Figure 8 Display image of the possible surface area for target profit input

In order to analyze the results for "possible surface area for target profit," the user will input the conditions for one's target profit amount and geographical region, as presented in the display image above.

② Display image of the analysis

Figure 9 Display image of the results according to the possible surface area for target profit

The display image above presents the simulation results for the possible crop types and surface area of cultivation when the user wishes to make a profit of 100,000,000 Korean won in Gyeonggi-do Province.

The data used in the model is provided by Rural Development Administration's average profit analysis data for a five-year extent.

[Yearlong farm plan]

The menu, "yearlong farm plan," is a function that informs website links that provide farm work schedules proposed for each crop type, as well as information on the necessary amount of labor. Information on "farm work schedule" and "necessary amount of labor" will be provided for each crop type. By clicking on these buttons, the user will be given a monthly farm work schedule for the relevant crop type, provided by Rural Development Administration. As for "necessary amount of labor," the user will be provided with information on the necessary amount of labor required for each crop type, with details for each work category searched.

Figure 10 Display image of information on farm work schedule and necessary amount of labor for each crop type

[Comparison of the profit level of one's own farm]

This menu is a function that informs the predicted level of one's farming household after comparing it with upper, average, and lower level farming households and income data. Based on 42 crop types, the program compares the profit of the top 20 percent income-level farming households and bottom 20 percent income-level farming households. The standard income was calculated by using the arithmetic mean of five years provided by Rural Development Administration's average profit analysis data. However, since this value does not have statistical significance, it should be used as a reference to examine the farming household's income level.

Figure 11 Display image showing results of the profit comparison of upper, average, lower level farming households' income data

[Outstanding cases of farming businesses]

The function, "outstanding cases of farming businesses," collects and provides information on outstanding cases of farming businesses for each crop type. The manager will be provided with an accumulation of information on farming techniques and business management relevant to each crop type.

Figure 12 Display image of provided information on outstanding cases of farming businesses for relevant crop type

5. Conclusion

Due to changes in the agricultural market environment and both overseas and domestic farming conditions, uncertainties in agriculture production and management are becoming greater. Hence, there is a stronger need for farmers to choose crops in the optimal condition. This research aims to introduce the result and process of developing a decision support system for selecting crops, aimed to assist farmers in selecting the optimal crops most suitable in the given situation.

The following resources have been made into a database in order to increase searching and user convenience for farmers' agricultural decision-making: annual analyses on farming incomes provided by Rural Development Administration, studies on the management conditions of regionally specialized crops provided by farming technology institutes of each province, and statistical research data on major crop production costs provided by Statistics Korea.

There are basically three main factors to consider in the decision-making process for farmers when selecting which crop to introduce to their lands. First of all, one must consider how much profit crop A will produce when it is cultivated. Factors that may affect the profits of each crop type include location, facility, surface area, farming techniques, and so forth. With the income estimation model for each crop type, we can deduce the annual estimated income for the particular crop type.

Secondly, one must consider which crop to cultivate in order to earn a certain amount of profit. In contrast to the first question, this second issue is a research method for finding the required resources and crop type in order to gain the target income. Thirdly, one must consider what is the best way to maximize Farm A's business profit. For instance, a farm may have land as its resource, and one must research which location, type of crop, level of technology, and so forth, to maximize profit.

Befitting this process, the following functions have been developed: the "predicted amount of crop profit" function for searching crop types according to the predicted profit and target profit for each crop type; the "yearlong farm plan" function which provides information on farm work schedule and necessary amount of labor for each crop type; the "comparison of the profit level of one's own farm" function which compares the average income with upper/lower levels for each crop type; the "outstanding cases of farming businesses" subfunction, which collects and provides information on outstanding cases of farming businesses for each crop type.

The following points outline the desired effects expected from this program. Firstly, by using a decision support system, each farming household may easily analyze and decrease production costs, as well as analyze and construct financial structures. By doing so, one may focus management efforts on the areas where the reduction of production expenses is possible, thereby increasing production profitability. Secondly, one may easily detect where both the production costs and major farming management expenses are spent excessively. This may enable the farmer to reduce operation expenses as well as to create additional profit. Thirdly, crucial farming decisions have been made previously with inaccurate data. Through this program, however, these decisions may be made with more accuracy and safety, based on the comparative analysis by benchmarking other farming households. Furthermore, the program will be able to play a part in improving the management abilities of farming households.

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