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Extraction of Farming Work Rules to Improve Crop Quality with Multiple Regression Analysis

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ABSTRACT : Japanese farmer typically cultivate crop relying on such as their intuition and experience. In this case, the farmer sometimes fails the cultivation of high quality crop. For this reason, the farmer needs quantitative farm work rules. The rule makes from quantitative information of fields, crop and farming works. In this paper, we propose a system to assist the farmer to show the farming work rule for improving crop quality. The system extracts the farming work rule by multiple regression analysis and step wise stepwise regression. Response variable includes farming work information and explanatory variables include field and crop information. The system calculates a weight to compare the extracted rules based on standard rule which improves high quality crop. The quantitative farming rule enables the farmer to reduce a risk of the failure and cultivate high quality crop. We experimented cultivation of Japanese mustard spinach to extract watering, fertilization, culling, earth upping and pesticide spraying rules. The result shows that the coefficient of determination of farming work rule is high if the subjects have clear farming work rule. We considered the explanatory variables and the weight to confirm that these are correct or not.

KEYWORDS -agriculture, machine learning, multiple regression analysis, ICT, data mining

1 INTRODUCTION

Japanese farmer typically cultivate crop, relying on such as their intuition and experience [1]. The farmer performs farming works based on subjective decision of the field and crop information. For example, the farmer decides information of crop by observing leaf color. The farmer does not perform a watering when they feel humid air. The farmers learn through long experience to consider information of field and crop. He is able to cultivate high quality crop with subjective decision of farm work. In this case, the farmer sometimes fails the cultivation of high quality crop. If the farmer reviews the fail for cultivating in next year, it enables him to cultivate high quality crop. However, he repeats same failure because he does not measure quantitative information such amount of watering and fertilizer. For this reason, the farmer need quantitative farm work rules. The rule makes from quantitative information of fields, crop and farming works. In this paper, we propose a system to assist the farmer to show the farming work rule for improving crop quality. The system extracts the farming work rule by multiple regression analysis and step wise stepwise regression. Response variable includes farming work information and explanatory variables include field and crop information. The system calculates a weight to compare the extracted rules based on standard rule which improves high quality crop. The weight shows that which factor is important for the farmer to perform farming work to improve crop quality. The quantitative farming rule enables him to reduce a risk of the failure and cultivate high quality crop. We experimented cultivation of Japanese mustard spinach to extract watering, fertilization, culling, earth upping and pesticide spraying rules. The result shows that coefficients of determination of farming work rule is high if the subjects have clear farming rule. We considered the explanatory variables and the weight to confirm that these are correct or not. Chapter 2 describes about using ICT to support agriculture. Chapter 3 describes showing farm works quantitatively with rules. Chapter 4 describes the experiment to extract farming work rule and its result and the consideration. Finally, chapter 5 describes future works to solve the problem.

2 USING ICT TO SUPPORT AGRICULTURE

2.1 Obtaining farming work information

The farmer decides with rules among cultivation. The rules are proper each characteristic of their fields. The farmer performs subjectively the farm works as usual. However, he fails in cause of weather variation. For reducing failure, the farmers have to record farming information and check whether their decision is correct or not. It needs quantitative information such temperature, humid, state of crop and so on. For quantitative acquisition, the existing research get quantitatively field information of crop from pictures with image sensor [2], [3]. Other researches use such as PC [4], RFID [5] or acceleration sensors [6]. In addition, other researches propose a system that show collected information to farmer [7],[8].The existing researches show the recorded information directly to the farmer. It is difficult for the farmer to understand the information. If the farmer get understandable information, it is very benefit for him.

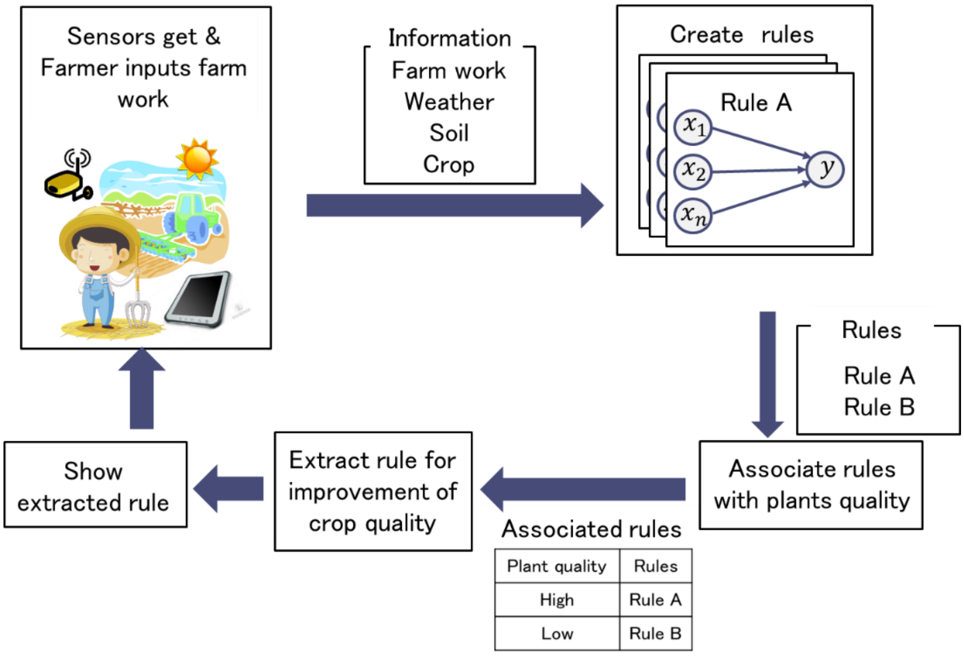
2.2 Support of farming work decision

The farmer decides performing farm works considering past, present and future information. The existing researches provide big recorded information about field such soil and weather, crop states and farming work. It is difficult for farmer to choose necessary information form a lot of information. In the research, we define a rule based on quantitative information as a farm work rule. The farm work rules which have clear standard enables to perform appropriate farming work. Another existing research analyzes relation crop and environment and create a rule by data mining in agriculture [9]. However, the research does not create farming work rule because it does not focus farming work. Another research extracts greenhouse sidewall control rules for raising rice seedlings with RFID [10].However, the research does not evaluate the good or bad rule to improve crop quality. If the farmer obtains a farming work rule to improve crop quality, it enables farmer to perform appropriate farming work for crop quality.

3 EXTRACTING FARMING WORK RULES TO IMPROVE CROP QUALITY

3.1 Extraction of farming work rules to improve crop quality

We propose a system showing effective farming work rule based on quantitative rule to thefarmers. The system is described in figure 1.



Plant quality	Rules
High	Rule A
Low	Rule B

Figure 1: Showing rule to improve crop quality

Sensors get quantitative information of the field. The sensors include temperature, and humidity. The farmer inputs quantitative information of farm works, such the amount of water, and amount of a specific fertilizer into the system. He also inputs the crop growth such as how many leaves, and the length of the crop. When he harvests the vegetable, he inputs his opinions about the product as good or bad. The system makes farming work rules of the input information. The farming work rule is associated the crop quality. The effective rules, which result in good product, are recommended to the farmer when he makes a new crop of the vegetable. The farmer refers to the effective rules to achieve high quality crop.

3.2 Farmer Subjectivity and quantitative information

For extraction of the quantitative rules, the subjective information of the farmers should be obtained quantitatively. Farmers have subjective opinions about the cultivation condition. For example, opinions about the soil are wet, or dry. Opinions about weather are hot, cold, or humid. The opinions are just about qualitative. We use sensors to measure the opinions. The sensors get soil information such as water potential, soil temperature and water potential along the cultivation. Since the sensors get quantitative information, it enables us to know what farm task, when, and how much of the farm task the farmer has done to the field. In addition, the system gets temperature, humidity and sunshine duration quantitatively from weather forecast sites as input.

3.3 Extraction of farming work rule

Figure 2 shows a method to extract the quantitative farm work rules.

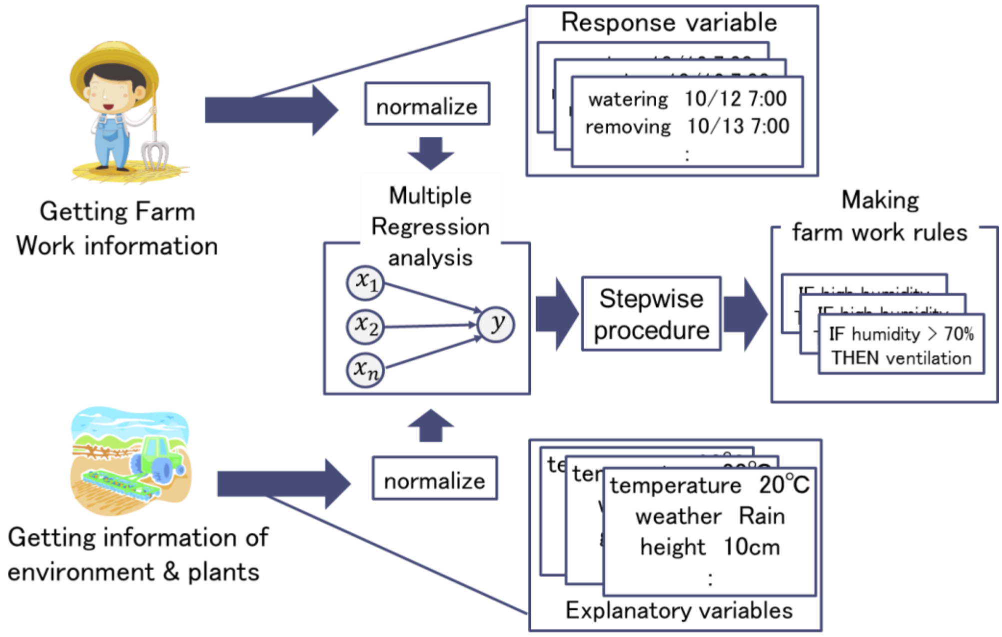


Figure 2: Extracting farm work rules

The rules are extracted using a multiple regression analysis. Explanatory variables represent field and growth information including temperature, weather, and growth of crop. Response variable includes the amount of water, the amount of fertilization and the number of elimination. The explanatory variables and the response variables are normalized by equation 1 when the system performs the multiple regression analysis.

$$s_i = \frac{x_i - \bar{x}}{SD_x} \tag{1}$$

The x_i means data before normalization, and the s_i means data after normalization. The $\mathrm{SD_x}$ means a standard deviation of data the x, and the $\bar{x}$ means an average of the data. The system chooses important explanatory variables for a decision of farming work with stepwise regression. Stepwise regression chooses acombination of explanatoryvariable which AIC(Akaike information criterion) of the combination is the lowest in all combinations. The coefficient of the explanatory variables represents a farming work rule which includes quantitative conditions such information of growth, weather and soil. The extracted rule is easy for the farmer to understand because the rule represents important information for cultivation.

3.4 Extraction rules to improve crop quality

The system extracts a rule which improves crop quality to compare extracted rules. If the coefficient of the explanatory variables is similarly, the explanatory variable is weighted as important explanatory variable. A standard rule is a rule that is the biggest crop size in the extracted rules. The t means a number of extracted rules, and the k means a number of the explanatory variables. The $a_{t,k}$ means coefficients of the explanatory variables, and g_t means a size of crop. The equation 2 calculates a weight $w_{t,k}$.

$$w_{t,k} = \sum_{i=1}^{t} \frac{1}{(a_{0,k} - a_{i,k})^2} \cdot \frac{g_i}{\sum_{j=0}^{t} g_t} \tag{2}$$

This equation calculates a distance of the rule coefficients. The important explanatory variable is in close distance and high weight. The equation calculates a crop quality ratio of a total of all crop qualities to a crop quality. Then it multiplies the reciprocal of the distance and the crop quality ratio together. The ratio of a better rule is large, so $w_{t,k}$ is large. The equation 3 calculates a normalized weight $p_{t,k}$.

$$p_{t,k} = \frac{w_{t,k}}{\sum_{j=0}^{t} w_{j,k}} \tag{3}$$

The farmer understands important explanatory variables for improving crops quality by the calculated weights. The farmer performs effective farming work to show the weight.

4 EXPERIMENT OF EXTRACTING FARMING WORK RULE

4.1 Experiment Outline

We experimented cultivation of Japanese mustard spinach to extract farming work rule and examine the rule quality. The subjects are two people who have experience of farming work and five students who have no experience. Experiment term is 20 days without Saturday and Sunday. The experiment was performed at a field. Figure 3 shows the arrangement of ridges in the farm.

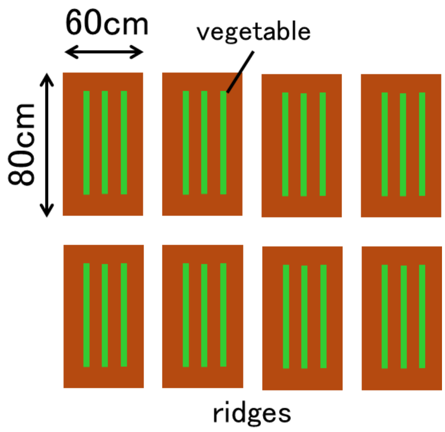


Figure 3: The arrangement of ridges

We made eight ridges and each ridge is 60 cm high and 80 cm long. The performed farming works include watering, fertilization, culling, earth upping and pesticide spraying. We divided the seven subjects (A, B, C, D, F, G, H) into following groups.

1. First group : Three students (A,C,F)
2. Second group : Two students (B,D)

3. Third group : Two experienced people (B,D)

The first group only waterings and performs others farming works at same time. The second group and the third group perform all farming works. The subjects A, B, C, D, F and G performed farming works in the morning, and the subject H performs in the afternoon. The second group checks value of water potential before farming work to examine a difference of extracting rules. Water potential shows a soil condition. If water potential is low, soil is wet. If water potential is high, soil is dry. The subjects of the second group know the exact soil condition to check the value. The subjects of the second group watering if the value is over 20 kPa in the experiment [11].All subjects check past weather, present weather and weather forecast on web page [12] before every farming work. The subjects observe soil and crop condition and decide performing the farming works. We recorded farming work information at Table 1 as response variable.

Table 1: Farming work information

Farming Work	Information
Watering	Amount of watering, Liter
Fertilization	yes or no
Culling	Number of plants
Earth upping	yes or no
Pesticide spraying	yes or no

We also recorded explanatory variables according to Table 2.

Table 2: Explanatory variables

Variables	Contents
soil	Water potential (kPa)
rain_48	Precipitation between 48 hours and 24 hours before the work (mm)
rain_24	Precipitation between 24 hours and time of the work (mm)
sun_48	Sunshine hours between 48 hours and 24 hours before the work (min)
sun_24	Sunshine hours between 24 hours and time of the work (min)
sun	Sunshine hours for 6 hours at the work
sun_d0	Weather forecast at the day is sunny (yes or no)
cou_d0	Weather forecast at the day is cloudy (yes or no)
sun_d1	Tomorrow's Weather forecast is sunny (yes or no)
cou_d1	Tomorrow's Weather forecast is cloudy (yes or no)
sun_d2	Weather forecast of day after tomorrow is sunny (yes or no)
cou_d2	Weather forecast of day after tomorrow is cloudy (yes or no)
height	Crop size (cm)

We extracted farming work rule using the recorded data by the method.

4.2 Examination of coefficients of determination

Table 3 shows a result of rule extraction for each farming work and subject.

Table 3: Coefficients of determination of farming works and subjects

	Watering		Fertilization		Pesticide spraying		Culling		Earth upping	
	W_R	W_p	F_R	F_p	P_R	P_p	C_R	C_p	E_R	E_p
A	0.679	1.24%								
B	0.966	0.62%			0.833	1.32%	0.990	0.01%	0.891	0.06%

C	0.792	8.45%								
D	0.953	0.99%			0.879	0.23%	0.949	0.02%	0.489	3.65%
F	0.449	2.97%								
G	0.944	1.26%	0.904	7.76%	0.901	7.97%	0.876	1.56%	0.732	11.65%
H	0.942	17.68%	0.082	47.65%			0.092	46.99%	0.934	5.31%

The coefficients of determination which mean degree of model fit are W_R, F_R, P_R, C_R and E_R in the order of Watering, Fertilization, Pesticide spraying, Culling and Earth upping. If the coefficients is over than 0.8, the model fit is very high. The p values are W_p, F_p, P_p, C_p and E_p in the order of Watering, Fertilization, Pesticide spraying, Culling and Earth upping. If the p value is less than 5%, the coefficient has a significant difference.In the table 3, the columns of pesticide spraying of the subjects B, D and H are blanks because they did not perform tithe columns of fertilization of the subjects B and D are also blanks because of same reason. We consider the model fit of watering rule. The coefficients of the third group are over than 0.9, so the model fit is very high. The subjects G and H are confident about their watering rule because they have farming work experience. As a result, the model fit is very high. The coefficients of subject A, C and F about watering are lower than the others one. They do not have confident about own watering rule because they do not experience farming work. As a result, their model fit is low. The coefficients of the subjects B and D are very high and similar to the third group. They also do not have confident about own watering similar to the subjects A, C and F.However, they could perform watering in order to a rule by observing the sensor value. In summary, if the subjects have confident of own rule, the model fit is high.

4.3 Result and Examination of explanatory variable

We consider the coefficients of explanatory variable for each farming work. The coefficients show important factor for the subjects when they performed the farming work. Table 4 shows coefficients of explanatory variable of watering rule. The explanatories is chosen by Stepwise regression. The p values in the table 2 is less than 10%.

Table 4: Coefficients of explanatory variable of watering rule

Variables	A	B	C	D	F	G	H
soil	-0.73	1.59		1.93		-0.57	
rain_48				0.64			
rain_24	-0.73	1.26		1.91	-0.46	-0.68	
sun_48	-0.49	0.3		0.87			
sun_24		-0.54		-0.65		0.82	
sun		-0.26				0.62	
sun_d0	0.5			-1.28			
cou_d0							
sun_d1		-0.23					
cou_d1							
sun_d2		-0.29		0.76		-0.88	
cou_d2							
height		-1.59		-2.1			

The chosen variables of the subject A are explanatory variable about soil moisture and weather. The coefficient of the soil and the sun_48 is a negative. It means incorrect coefficients because the subject A reduces amount of water when soil is dry and weather is sunny. The coefficient of the soil of the subjects B and D is high because the subjects checked the sensor value when they watering. The absolute values of the coefficient about weather and weather forecast are large in the subject G.It means the subject G decides amount of watering based on weather and weather forecast.The number of the explanatory variables which their p values are less than 10 % is 0 or 1 in the subjects C, F and H.The subject F performed watering based on precipitation before 24 hours.The subjects C, H performed watering based on no information or other information.

Table 5 shows coefficients of explanatory variable of fertilization rule.

Table 5: Coefficients of explanatory variable of fertilization rule

Variables	G	H
soil	-2.33	-3.93
rain_48	9.14	5.66
rain_24	3.16	
sun_48	-2.25	-1.71
sun_24	1.8	3.13
sun	1.58	
sun_d0	11.12	7.38
cou_d0		
sun_d1	-0.87	1.6
cou_d1		
sun_d2	0.62	
cou_d2		
height	-3.77	

The subjects G and H performed fertilization only.The coefficient of the sun_d0 is the largest of the others. The rule means they perform fertilization if weather is sunny today. Since the fertilizer is drained by rain after fertilization, the rule was extracted. That the coefficient of rain_48 is high shows that they performed fertilization when precipitation of two days ago is a lot.

Table 6 shows coefficients of explanatory variable of pesticide spraying rule.

Table 6: Coefficients of explanatory variable of pesticide spraying rule

Variables	B	D	G	H
soil				
rain_48	-0.5	-1.2	10.49	
rain_24	-0.72		3.04	
sun_48	0.33		-2.43	
sun_24	-0.42			
sun	-0.35	-0.73	1.27	
sun_d0	-1.2	-1.14	12.06	
cou_d0				
sun_d1			-1.06	
cou_d1				
sun_d2			0.94	
cou_d2				
height	0.45		-4.06	

The coefficients of the subject G shows he performed in sunny and there is precipitation on two days and day before. The coefficient sun_d0 of the subject G is the largest. He performed pesticide spraying in sunny because the pesticide is drained by rainfall. The subjects B and D are also, however, the coefficient of the sun_d0 is a negative. It is an incorrect rule because the rule means they perform pesticide spraying in rainy.

Table 7 shows coefficients of explanatory variable of culling rule.

Table 7: Coefficients of explanatory variable of culling rule

Variables	B	D	G	H
soil		0.71		-3.94
rain_48	-0.74		-2.49	5.67
rain_24	-0.87	0.88	-0.63	
sun_48	-0.76			-1.71
sun_24	0.66		-1.4	3.14
sun	0.53		-0.35	
sun_d0	0.69		-2.06	7.39
cou_d0				
sun_d1	0.12		-1.46	1.6
cou_d1				
sun_d2	-0.6		0.4	
cou_d2				
height	1.88	0.4		

The result shows the subject B reduced the number of culling as growing the plant because the coefficient of the height is large. He performed culling considering weather because the chosen coefficients include coefficients about weather. The coefficient shows subject D considered soil condition and past precipitation. It also shows he reduced the number of culling as growing the plant. The subject G considered weather before and after while culling because the root is weak after culling. The coefficient of the subject G is a negative and large. It means he reduces the number of culling if weather is sunny at culling before and after. The coefficient of the subject H shows also that he perform culling considering soil condition and weather.

Table 8 shows coefficients of explanatory variable of earth upping rule.

Table 8: Coefficients of explanatory variable of earth upping rule

Variables	B	D	G	H
soil			-5.32	-3.89
rain_48			3.57	5.31
rain_24	0.34		-4.36	
sun_48	-0.3	-0.5	-1.18	-1
sun_24	-0.44		-0.96	3.08
sun	-0.22		1.56	
sun_d0	0.41	0.56	4.5	6.07
cou_d0				
sun_d1			-1.71	1.85
cou_d1				
sun_d2			0.92	0.69
cou_d2				
height	0.29	0.71	-2.23	-1.76

The rules of the subjects B and D show that they performed earth upping considering weather and the height. The rules are correct because earth upping is performed as growing plants and in sunny. The subjects G and H considered protecting from soil dry to perform earth upping. As a result, the subject’s absolute values of the soil and the sun_d0 are large. It means the subjects performed earth upping when weather was sunny and soil was wet.

4.4 Result and Examination of The Weight

We describe weighted coefficients. Table 9 shows the weight each farming work rule.

Table 9: Weight each farming work rule

Variables	Watering	Fertilization	Pesticide spraying	Culling	Earth upping
soil	0.079	0.083			0.361
rain_48		0.017	0.013	0.056	0
rain_24	0.898		0.118	0.715	0.361
sun_48		0.73	0.23		0.006
sun_24	0.003	0.119		0.015	0
sun	0.009		0.554	0.116	0.271
sun_d0		0.015	0.01	0.009	0
cou_d0					
sun_d1		0.035		0.018	0
cou_d1					
sun_d2	0.011			0.071	0.001
cou_d2					
height			0.076		0

The weight is calculated on basis of the rule of the subject G. The crop size of the subject G was the largest in all subjects. If a distance between the basis rule and another rule is near, the weight is large. The large weight of an explanatory variable is important to improve crop quality. The weight of rain_24 of watering and culling was large. It means that the subjects performed considering precipitation the day before. The subjects considered the weather at farming work because the weight of sun of pesticide spraying is large. The weight of earth upping shows the soil moisture and precipitation the day before is important. The weight of fertilization shows the precipitation 48 hours before is important.

5 DISCUSSION

A model fit does not correspond to a crop quality in the result. The coefficients of determination of the subject A and C are higher than the subject F. However, the crop size of the subject F is larger than the subject A and C. It means that the crop grew well by chance although the subject F did not perform based on clearly rule. For this reason, the system should decide good farming work rule to improve crop quality by the model fit. It enables to extract exactly farming work rule considering the model fit. We consider the result of the coefficient of explanatory variables. The coefficient of explanatory variables is not exactly because the subjects did not think that the explanatory variables is not important. For this reason, the system should adjust the farming work rule by using interview and questionnaire.

6 CONCLUSION

In this paper, we proposed a system to assist the farmer to show the farming work rule for improving crop quality. The system extracts the farming work rule by multiple regression analysis and step wise stepwise regression. Response variable includes farming work information and explanatory variables include field and crop information. The system calculates a weight to compare the extracted rules based on standard rule which improves high quality crop. The weight shows that which factor is important for the farmer to perform farming work to improve crop quality. We experimented cultivation of Japanese mustard spinach to extract watering, fertilization, culling, earth upping and pesticide spraying rules. The result shows that coefficients of determination of farming work rule is high if the subjects have clear farming rule. We considered the explanatory variables and the weight to confirm the result. Future work is correction the farming work rule by using interview and questionnaire to improve mode fit accuracy.

REFERENCES

[1] H. Mineno, et.al, Development of a wireless sensor network for visualizing agricultural knowledge, *Intelligent Decision Technologies, 4(4)*, 2010, 277-284.

[2] S. Tsubota, S. Yamamoto, T. Teshina, S. Hayashi, Estimation of the Number of Strawberries for a Movable Bench System, *Shokubutsu Kankyo Kogaku, 27(3),*152-161, 2015,

[3] S. Kazunori, Plant and Vegetation Monitoring Using Laser-Induced Fluorescence Spectroscopy, *Industrial Applications of Laser Remote Sensing*, 99-114, 2012,

[4] A. Matese, S.F. Di Gennaro, A. Zaldei, L. Genesio, F.P. Vaccari, A wireless sensor network for precision viticulture: The NAV system, *Computers and Electronics in Agriculture, 69(1)*, 51-58, 2009

[5] P.K.S.C. Jayasinghe, et.al., Development of a Fieldwork Reminder System to Help Field Management, *World Conference on Agricultural Information*, Atsugi, Tokyo, 1095-1099, 2008

[6] T. Nanseki, K. Sugahara, T. Fukatsu, Farming Operation Automatic Recognition System with RFID, *Japanese Society of Agricultural Informatics, 16(3)*, 132-140, 2007

[7] Y. Saito, et.al., AGRISERVER: A Real-time Sensing Network for Farms with Applications for Agriculture and Related Industries, *Japanese Society of Agricultural Informatics, 22(1)*, 1-11, 2013

[8] T. Nanseki, Y. Fujii, T. Ezoe, Development of a Farming Visualization System "FVS-PC Viewe": Support for Agricultural Skills Succession, *Japanese Society of Agricultural Informatics 22(4)*, 201-211, 2013

[9] D. Savvas, C. Goumopoulos, Applying machine learning to extract new knowledge in precision agriculture applications, Panhellenic Conference on. IEEE, 100-104, 2008

[10] H. Sekiguchi, et.al., Data Mining to Extract Greenhouse Sidewall Control Rules for Raising Rice Seedlings, Japanese Society of Agricultural Informatics , 22(4), 212-227, 2013

[11] Douglas C. Sanders, VEGETABLE CROP IRRIGATION, Department of Horticultural Science, Horticulture Information Leaflet 33-E, 1993

[12] http://www.jma.go.jp/jma/indexe.html,Japan Meteorological Agency