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A Decision Support System for Optimizing Vegetable Crop Production Considering the Effects of Climate Change

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Abstract—This paper describes the development of a decision support system in order to address some of the problems identified in vegetable crop production in the Philippines. These problems include the excessive use of some agricultural inputs and the effects of climate change in agricultural production. Traditionally, farmers tend to increase agricultural inputs in the hope of getting higher production yield without realizing that the quality of the crop might be reduced and the increase in inputs may not significantly increase the production yield. Moreover, due to the changes in the weather patterns, farmers can no longer rely on the traditional planting calendars.

In this paper, a model is formulated to optimize vegetable crop production considering the negative effects of climate change by restructuring the traditional planting calendars of certain vegetable crops according to the changing trends of important climate parameters such as temperature and rainfall. Intercropping is also integrated into the system to further optimize the use of some agricultural inputs. This is implemented through developing a web-based decision support system to provide a tool for farmers to simulate the production given the necessary inputs.

The results were evaluated by local agriculturists, experts, and farmers and they have agreed on the usability and reliability of the results. The accuracy of the model was also evaluated by comparing the predicted values and actual values which results to a low RSME (root mean square error) value of 0.6. A lower RSME value means higher accuracy.

Keywords—Decision Support System, Vegetable Crop Production, Climate Change Adaptation, Web-Based System

I. INTRODUCTION

Vegetable crop production contributes approximately 30% of the total agricultural production in the Philippines and contributed a large portion of GDP (UNDP, 2006). Production is based on highland and lowland cropping in dry and wet seasons. Major production of highland vegetables is in Northern Mindanao and Cordillera and most lowland vegetables are grown in Luzon (Johnson, 2008). Vegetables are short-season crops in which several crops can be grown in a year and are suitable for temporary and small-area of agricultural land. Thus, vegetable crops can be grown using crop rotation and intercropping systems.

Key issues affecting vegetable production are excessive pesticide use, concentration of production in dry season, low export of fresh and processed vegetables and low per capita vegetable availability (BAR, 2003). Problems that affect farm productivity include high rainfall, poor soils and land fragmentation, and fertilizer use tends to be excessive in Mindanao (Murray-Prior et al., 2006).

The negative effects of climate change have greatly affected agriculture since its production is dependent on climatic conditions (Highlights, 2009). Climate change refers to observable changes of temperature and amount of rainfall and occurrence of extreme climate events such as typhoons, La Niña, El Niño, and drought. In the Philippines, there is an increase occurrence of extreme rains causing floods and landslides in 1990, 2004, 2008, and 2009, droughts normally associated with El Niño have caused massive crop damage in various parts of the country, and there is an increase of 4.2 in the frequency of typhoons entering the Philippine area of responsibility during the period of 1990-2003 (Lasco et al., 2011). Reduction of crop yields due to crop damage and crop failure brought by the negative effects of climate change has been reported. Now farmers can no longer rely on the traditional planting calendars because the weather patterns have changed (Lansingan, 2009). In addition, the El Niño and La Niña phenomena added to the stress of agricultural production. From year 2005-2009, adverse effects of typhoons resulted to lower yields on most crops based on the crop statistics gathered by Bureau of Agricultural Statistics (BAS). In the province of Bukidnon, due to its geographical location, typhoon was not a major problem. However, drought and pests were considered the major causes of crop damage in the province of Bukidnon (Highlights, 2009).

These evidences show that there are existing problems in the vegetable crop production in the Philippines. Farmers also tend to increase inputs such as fertilizer and pesticide in the hope of achieving greater yield which is in fact does not significantly increases yield but only increases toxicity to the crop. Thus, the use of its agricultural inputs is not optimized. In addition, the negative effects of climate change have significant impact on the crop production and an adaptation strategy should be implemented. It is therefore essential to enhance the decision-making strategy to various production options. This would help ensure profitable performance of the farmers and the agricultural sector (Singh, 2008).

Most of the existing decision support systems for agriculture are crop specific and does not consider cropping systems like intercropping which have been practiced recently to enhance farm productivity (Arihara, 2000).

Intercropping is the practice of growing two or more crops together in order to maximize beneficial interactions while minimizing competition. The resulting beneficial interactions help lower the need for external inputs. Intercropping of compatible plants encourages biodiversity and therefore creating a crop environment that could limit the outbreaks of pest infestation (Kantor, 1999). For example, crops in the onion family especially garlic have been used for centuries in intercropping with crops that are prone to pests because of its ability to repel insects. With the advantages of intercropping, using the cropping system would really contribute on the yield increase. A study on intercropping conducted at Horticultural Research Farm, Malkander, NWFP Agricultural University, Peshawar (Pakistan) during 1998-2000 evaluates the yield performances of different vegetable crops when planted as a single crop and planted with various combinations. Results showed that the right combinations of vegetable crops yielded more than being planted alone (Syed, 2003).

The purpose of this study is to create a decision support system that can help optimize crop production amidst the negative effects of climate change by restructuring the traditional planting calendars of certain vegetable crops according to recent weather forecast and optimizing the use of some agricultural inputs. Intercropping is also integrated into the system to further optimize the crop production.

II. METHODOLOGY

A. *Restructuring of the Planting Calendar of Crops Due to Climate Change*

In considering the effects of climate change in the study, the temperature and rainfall data of year 1971-2000 (climatological normals) and that of year 2000-2010 are gathered from PAG-ASA (Philippine Atmospheric, Geophysical and Astronomical Services Administration). Predictions of some important climatic parameters generated from a climate modeling system are also gathered. These will be the basis for the restructuring of the planting calendar of each crop due to climate change.

B. *Model Formulation for the Optimization Problem of Vegetable Production*

The Law of the Maximum states that the total growth or yield of a crop is proportional to aggregate values of the growth factors. The magnitude of response to an input increases as more and more limiting factors are corrected (Wallace, 2003). In this study, the growth factors considered are the water stress, soil fertility, and land equivalent ratio (for intercropping) factors. These factors which consider the climatic parameters, crop, soil type, fertilization, intercrop combination and other important parameters ensures that optimized yield will be achieved. This also ensures that the production inputs used are minimized.

B.1 Identification of Parameters and Variables

The following are the identified parameters considered in the study:

a.) The individual *crop* in an intercrop to be planted in a particular period in a year

The set of all crops considered in the study is denoted with $I = \{1,2,3,4,5,6,\ldots,N\}$, where 1 may represent a particular crop such as tomato, and so on.

b.) The *intercrop combination* of two crops to be planted in a particular period in a year

The set of all intercrop combinations considered in the study is denoted with $J = \{1,2,3,4,\ldots,N\}$, where 1 may represent a particular intercrop combination such as okra-tomato, and so on.

c.) Every *crop cycle* at which crop i can be planted within the specified planting date (T_2-T_1)

The set of crop cycle is denoted with $K = \{1,2,..,N\}$, where 1 represents 1^{st} cycle, 2 for 2^{nd} cycle, 3 for 3^{rd} cycle, and so on.

d.) The *planting period* in a year at which the crop will be planted

The planting period will be based on climate change scenarios and the corresponding climatic parameters such as temperature and amount of rainfall that would optimally contribute to the requirements of the crop. The set of planting period is denoted with $L = \{1,2,3,4,\ldots,12\}$, where 1 represents January, 2 for February, 3 for March, 4 for April, …, and 12 for December.

In the succeeding discussions, the following notations are used.

A_T = total land area (in ha) where to plant
A_i = land area (in ha) where a particular crop i will be planted
I_J = the set of crops to be planted in an intercrop combination j
L_{IK} = set of planting periods for every crop cycle k of crop i
CT_i = crop cycle (no. of months) of particular crop i

T_2 = End Date of planting
T_1 = Start Date of planting
T_K = starting planting date for every crop cycle at which the crop can be planted within the specified planting date $(T2 - T1)$
pH_S = soil pH of the area where the crop will be planted
$pHmax_i$ = maximum soil pH required for particular crop i
$pHmin_i$ = minimum soil pH required for particular crop i
NOF_i = amount of nitrogen that is present in an Organic fertilizer
POF_i = amount of phosphorous that is present in an Organic fertilizer
KOF_i = amount of potassium that is present in an Organic fertilizer
NIF_i = amount of nitrogen that is present in an Inorganic fertilizer
PIF_i = amount of phosphorous that is present in an Inorganic fertilizer
KIF_i = amount of potassium that is present in an Inorganic fertilizer
NRF_i = required amount of nitrogen for a particular crop i
PRF_i = required amount of phosphorous for a particular crop i
KRF_i = required amount of potassium for a particular crop i
$Temp\_min_i$ = the minimum temperature requirement of crop i
$Temp\_max_i$ = the maximum temperature requirement of crop i
$Temp_k$ = the value of temperature at period k
$Rain_k$ = the amount of rainfall (mm) at period k
$Wloss_{et}$ = the amount of water loss during evapotranspiration
Wt_i = water tolerance factor of crop i
RW_i = the amount of water required for a particular crop i
YP_i = yield of crop i $\left(\frac{\text{ton}}{\text{ha}}\right)$ in the intercrop
YM_i = yield of crop i $\left(\frac{\text{ton}}{\text{ha}}\right)$ as a sole crop
RD_i = rooting depth of crop i
VF_i = vegetable family of a certain crop i
IPD_j = incidence of pests and diseases in an intecrop combination
RD_i = rooting depth of crop i
VF_i = vegetable family of a certain crop i
IPD_j = incidence of pests and diseases in an intecrop combination

The decision variables for the model are represented by

$$x_{i,j,k,l} \in \{0,1\} \quad i \in I, j \in J, k \in K, l \in L$$

Where I represents the set of crops; J represents the set of intercrop combinations; L the set of crop cycles at which crop i can be planted within the specified planting date (T_2-T_1); and K the set of planting dates for each crop cycle.

Each $x_{i,j,k,l}$ takes the value 1 when crop i in an intercrop combination j is scheduled to be planted at a crop cycle k and planting dates l; and 0 otherwise which means the candidate solution is not feasible. Each variable $x_{i,j,k,l}$ also takes a value of 1 if it does not violate any given constraints.

B.2 Problem Constraints in the Model

The following constraints are considered in the study.

a.) For each planting period l in every crop cycle with starting date k, the sum of the land areas planted for the two crops in an intercrop combination j should be less than or equal to the total land area allocated for planting.

For each period l of crop cycle k and for each intercrop combination j,

$$\sum_{i \in I_j} x_{i,j,k,l}\,(A_i) \le A_T$$

b.) Each crop cycle k of crop i should be scheduled at a starting date which is same or later than T_1 and the planting ends on or earlier than T_2.
For each crop cycle of crop i scheduled at starting date k,

$$x_{i,j,k,l}\,(T_k) \ge T_1$$

$$x_{i,j,k,l}\,(T_k + CT_i) \le T_2$$

c.) The crops in the intercrop combination j should be planted in the soil that satisfies the required soil pH for each crop.
For each crop i, each starting date k, and each planting date l,

$$x_{i,j,k,l}\,(pHmin_i) \le pH_S$$

$$x_{i,j,k,l}\,(pHmax_i)\,) \ge pH_S$$

If the soil pH is lesser than the required pH, lime application is needed.

d.) The application of fertilizer (organic and inorganic) should meet the nutrient requirement of each crop i for every nutrient.
For each crop i,

Nitrogen (N):

$$\sum_{l \in L_{IK}} x_{i,j,k,l} (NOF_i + NIF_i) = NRF_i$$

Phosphorous (P):

$$\sum_{l \in L_{IK}} x_{i,j,k,l} (POF_i + PIF_i) = PRF_i$$

Potassium (K):

$$\sum_{l \in L_{IK}} x_{i,j,k,l} (KOF_i + KIF_i) = KRF_i$$

e.) Each crop *i* in an intercrop combination *j* should be planted on periods at which the temperature requirement is satisfied.
For each period *l* of every crop cycle *k*,

$$x_{i,j,k,l} (Temp\_min_i) \leq Temp_l$$

$$x_{i,j,k,l} (Temp\_max_i) \geq Temp_l$$

f.) Each crop *i* in an intercrop combination *j* should be planted on periods at which the water requirement is satisfied.

$$x_{i,j,k,l}(Rain_l + Irrig_l - Wloss_{et}) = RW_i$$

g.) To ensure that there is efficiency in the land use in an intercrop combination *j*, the value of the *Land Equivalent Ratio (LER)* should not be less than 1.

$$\sum_{i \in I_j} x_{i,j,k,l} (YP_i / YM_i) \geq 1$$

LER is calculated using the equation *LER= Σ (Ypi/Ymi)*, where *Yp* is the yield of each crop *i* in the intercrop and *Ym* is the yield of each crop *i* as a sole crop. A value of *LER* above 1 ensures that planting the intercrop combination *j* is better than planting each crop as a monocrop.

h.) To determine the right combination of crops in an intercrop, it must satisfy at least one from the given constraints below.

$$\frac{x_{1,j,k,l}CT_1}{x_{2,j,k,l}CT_2} > 2 \text{ or } \frac{x_{1,j,k,l}CT_2}{x_{2,j,k,l}CT_1} > 2$$

CT_1 and CT_2 represents the number of months for planting crop 1 and crop 2 respectively. If the planting time of a certain crop exceeds a year then it is considered a long-term crop and a crop that can be planted several times in a year is considered a short-term crop. Planting a long-term crop and a short-term crop in an intercropping system is an economic strategy of farmers in which they can harvest and produce income from planting the short-term crop while waiting for the harvesting of the long-term crop.

$$x_{1,j,k,l}VF_1 = x_{2,j,k,l}VF_2$$

VF_1 and VF_2 represents the vegetable family of crop 1 and crop 2 respectively. Intercropping two crops that belongs to the same crop family reduces the labor cost since the treatment of the two crops such as applying fertilizers is similar in which it makes it easier for managing the crops.

In addition a deep-rooted crop is best intercropped with a shallow-rooted crop in which the nutrients that was not absorbed by the shallow-rooted crop can be absorbed by the deep-rooted crop since the flow of nutrients is affected by leaching. Crops which have a high demand of nutrients should not be intercropped because they will tend to compete with each other.

i.) To reduce the incidence of pests and diseases during the planting period, the crops in the intercrop combination *j* should not be on the same plant family. A value of 0 for IPD_j means that the intercrop combination has a reduced incidence of pests and diseases.

$$x_{i,j,k,l}(IPD_j) = 0$$

B.3 The Mathematical Model for Vegetable Crop Production Optimization

In this study, the objective function aims to achieve maximum yield which is profitable to the farmers.

$$Maximize \ \sum_{i \in I_j} \sum_{k \in K_i} x_{i,j,k} \left((Yo_i)(g_i)\right) \quad \dots (1)$$

where,

$$Yo_i = Base\ Yield\ of\ Crop\ per\ hectare$$
$$g_i = growth\ factors\ of\ a\ crop$$

Subject to the following constraints:

$$\sum_{i \in I_j} x_{i,j,k,l} (A_i) \leq A_T \quad \dots.. (2)$$

$$x_{i,j,k,l} (T_k) \geq T_1 \quad \dots\dots (3)$$

$$x_{i,j,k,l} (T_k + CT_i) \leq T_2 \quad \dots.. (4)$$

$$x_{i,j,k,l} (pHmin_i) \leq pH_S \quad \dots\dots (5)$$

$$x_{i,j,k,l} (pHmax_i)) \geq pH_S \quad \dots.. (6)$$

$$\sum_{l \in L_{IK}} x_{i,j,k,l} (NOF_i + NIF_i) = NRF_i \quad .. (7)$$

$$\sum_{l \in L_{IK}} x_{i,j,k,l} (POF_i + PIF_i) = PRF_i \quad \dots (8)$$

$$\sum_{l \in L_{IK}} x_{i,j,k,l} (KOF_i + KIF_i) = KRF_i \quad \dots (9)$$

$$x_{i,j,k,l} (Temp\_min_i) \leq Temp_l \quad \dots.. (10)$$

$$x_{i,j,k,l} (Temp\_max_i) \geq Temp_l \quad \dots\dots (11)$$

$$x_{i,j,k,l}(Rain_l + Irrig_l - Wloss_{et}) = RW_i \quad \ldots (12)$$

$$\sum_{i \in I_j} x_{i,j,k,l} (YP_i / YM_i) \geq 1 \quad \ldots. (13)$$

$$x_{i,j,k,l} CT_i > 2x_{i+1,j,k,l} CT_{i+1} \quad \ldots. (14)$$

$$x_{i,j,k,l} VF_i = x_{i+1,j,k,l} VF_{i+1} \quad \ldots\ldots (15)$$

$$x_{i,j,k,l}(IPD_j) = 0 \quad \ldots\ldots (16)$$

Equation 1 is the objective function of the model. Equation 2 is the constraint for the land area to be planted for each crop *i*. Equations 3 and 4 are the constraints for the range of planting date to be within the specified planting start and end date. Equations 5 and 6 is the constraint to make sure if the soil pH is within the range required for both crops. Equations 7, 8, and 9 are the constraints for the applied fertilization to be equal to the required nutrient of the crops. Equations 10 and 11 are the constraints that the temperature of a period/month should be within the range of the required temperature for both crops. Equation 12 is the constraint for the water requirement of the crops. Equation 13 is the constraint for the Land Efficiency Ratio of the intercrop that should be equal or greater than 1. Equations 14 and 15 are the other conditions used to determine if the two crops are recommended as intercrop. Equation 16 is the constraint for the incidence of pest and diseases to be equal to zero in which value is based on the crops planted in a crop rotation.

The yield of a particular crop, Y_i, is dependent on growth factors which can affect in attaining maximum yield. The growth reducing and limiting factors considered in the study are the *water stress*, soil *fertility, and land equivalent ratio (for intercropping)* factors.

a.) *Water stress factor (WSf_i)* As the crop undergoes water stress, the water pressure inside the leaves decrease and the plant wilts, which is the common symptom of water stress. This condition will certainly reduce growth and in effect reduce crop yield or even crop failure. This growth factor is dependent on climate parameters such as temperature, rainfall, humidity, and wind speed and the absorption capability of the crop determined by its roots characteristics and the soil type.

b.) *Soil fertility factor (Sf_i)*. There are several factors that contribute to soil fertility. These factors are fertilization using organic and inorganic fertilizers, nitrogen fixation, and crop residues of previous crop. These factors are then evaluated if it satisfies the nutrient requirement of the crop.

c.) *Land Equivalent Ratio (LER).* The Land Equivalent Ratio (LER) is the sum of the fractions of the intercropped yields divided by the sole-crop yield. LER is calculated using the equation *LER= Σ (Ypi/Ymi)*, where *Yp* is the yield of each crop *i* in the intercrop and *Ym* is the yield of each crop *i* as a sole crop.

Considering the above mentioned growth factors in the model will ensure that the optimum yield will be attained and at the same time minimize production inputs used.

C. Implementation Through a Web-based System

A web-based system is developed to implement the optimization of the vegetable crop production. It provides a tool for farmers to simulate the crop production by inputting necessary inputs such as crops to be planted, total land area, soil type, soil pH, and soil test level. The system also provides necessary graphs for simulation to display visual presentations of the data. GIS mapping is also used to graphically display the statistics of crops by municipality in the province of Bukidnon which is the data used in this study. The web technologies used to implement this system are WAMP server, MySQL - for the database, CSS and HTML - for the webpage layout, PHP, Javascript, and AJAX - for scripting, Google Maps API - for the GIS mapping, and RGraph – for creating the graphs for visual representation of data.

III. RESULTS AND DISCUSSION

A. Restructured Planting Calendar due to Climate Change

Figure 1 shows a sample of a restructured planting calendar generated from the system. The planting calendar is generated through comparing the prediction data of Bukidnon such as temperature and rainfall to the requirements of the crop to achieve optimal growth. The prediction data used were generated from a climate modeling system called PRECIS. PRECIS which stands for Providing Regional Climates for Impact Studies is developed to generate high-resolution climate change information for as many regions of the world. It generates climate scenarios that can be used in impact, vulnerability and adaptation studies, and to aid in the preparation of National Communications, as required under Articles 4.1, 4.8 and 12.1 of the United Nations Framework Convention on Climate Change (UNFCCC).

The output from PRECIS such as temperature and rainfall are used to generate the restructured planting calendar while the climatological normals of temperature and rainfall which is the mean value from 1971-2000 are used for the traditional calendar.

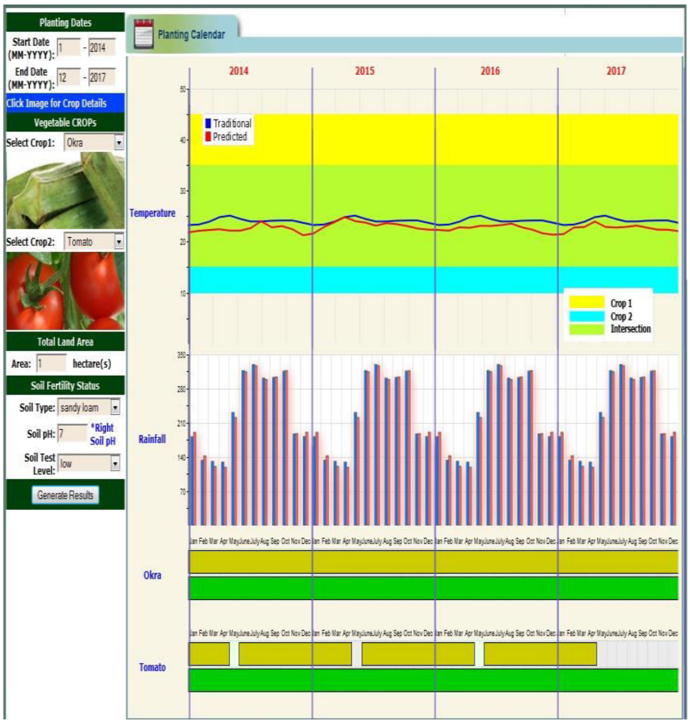

Fig. 1 Generated Planting Calendars for the Crops Selected Due To Climate Change

To better illustrate the effect of climate change to the parameters such as temperature and rainfall, the interface of the system displays graphs for these parameters as shown in Figure 1, in which the normal values are in blue and the prediction values are in red. The graph shows that there is a change of values in these parameters in which it also affected the planting calendar of a crop. The graph for the temperature in Figure 1 shows that the monthly temperature values for 2014-2017 satisfies the temperature requirements for Okra and Tomato since the values of the line graph is within the intersection horizontal bar colored yellow-green. The graph for the seasonal rainfall also shows the predicted changes. The interface also displays the traditional calendar of the crop to compare with the restructured one. The traditional planting calendar is generated based on the climatological normals of temperature and rainfall while the restructured one is based on the prediction of temperature and rainfall generated from PRECIS.

B. Validation of the Intercropping Combinations Generated From the System

Deciding whether a combination of crops is efficient as intercrop will be based on the set conditions given as constraints to the model. To test whether these intercrops are based on real farm situations, a survey about these intercrops were conducted. The respondents composed of agriculturists and experts in the field of agriculture. Figure 2 shows the results of the survey.

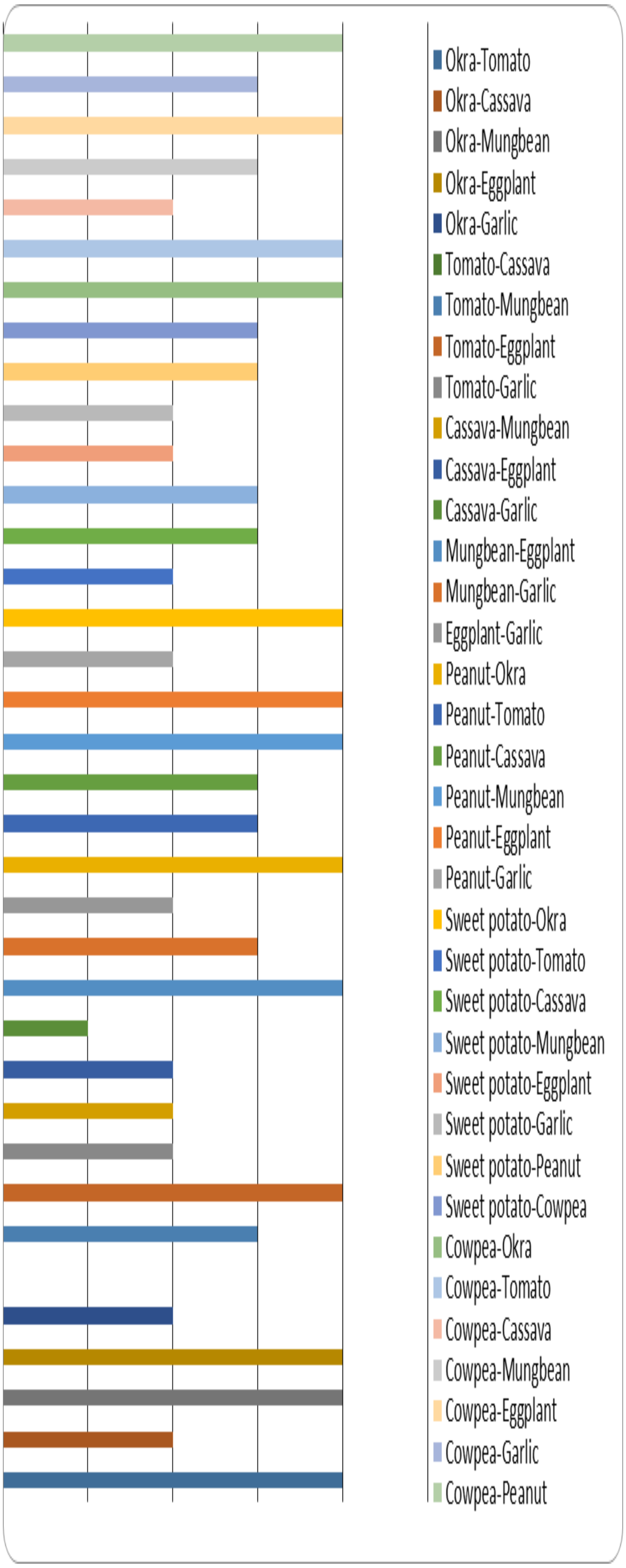

Fig. 2 Results of Survey to Determine Whether the Combination Can Be Intercropped or NotThe results are then compared to the intercrop combination generated from the system as shown in Figure 3.

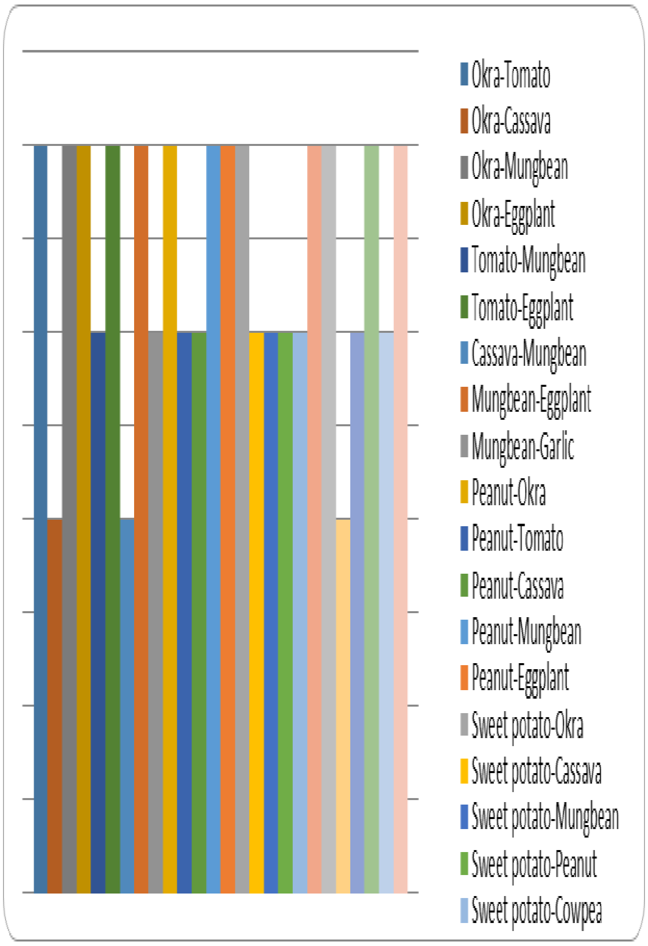

Fig. 3 List of Intercrop Combinations Generated from the System and the Expert's View Whether These Combinations Can Be Intercropped Based on the Survey

Based on the results, 34 out of 36 intercrop combinations generated by the system scored 75% to 100% in the survey. Only 2 out of 36 intercrop combinations scored 50% in the survey and these are the Eggplant-Garlic and Cassava-Garlic combinations. These combination were recommended by the system because it satisfies one condition considered in the study which is the intercropping of a long-term crop with a short-term crop. These two combinations only scored 50% in the survey because they commented that garlic is usually planted on lowland areas and not suitable on elevated areas such as Bukidnon and Claveria, Mis. Oriental. While the combinations that cannot be intercropped as generated by the system scored 50% and less in the survey.

C. Usability of the System

Figure 1 show the crop scheduling of the crop generated to help farmers decide what time to plant. The scheduling of the two crops that are chosen for the intercrop combination is placed adjacent to each other so as to readily visualize the cropping cycle.

The system provides necessary information about the crops and its production. The user can view information about a certain crop by clicking the image of the crop as shown in Figure 4.

Fig. 4 Sample Crop Profile of the Selected Crop

The Geographical Information System (GIS) map generated by the system provides an informative graphical presentation about the crop statistics in Bukidnon which includes the number of farmers in a municipality, the volume of production of a particular crop, the area planted, and the average yield per hectare produced for each crop by municipality. Figure 5 shows a sample GIS map generated by the given selected parameters at the right side of the webpage.

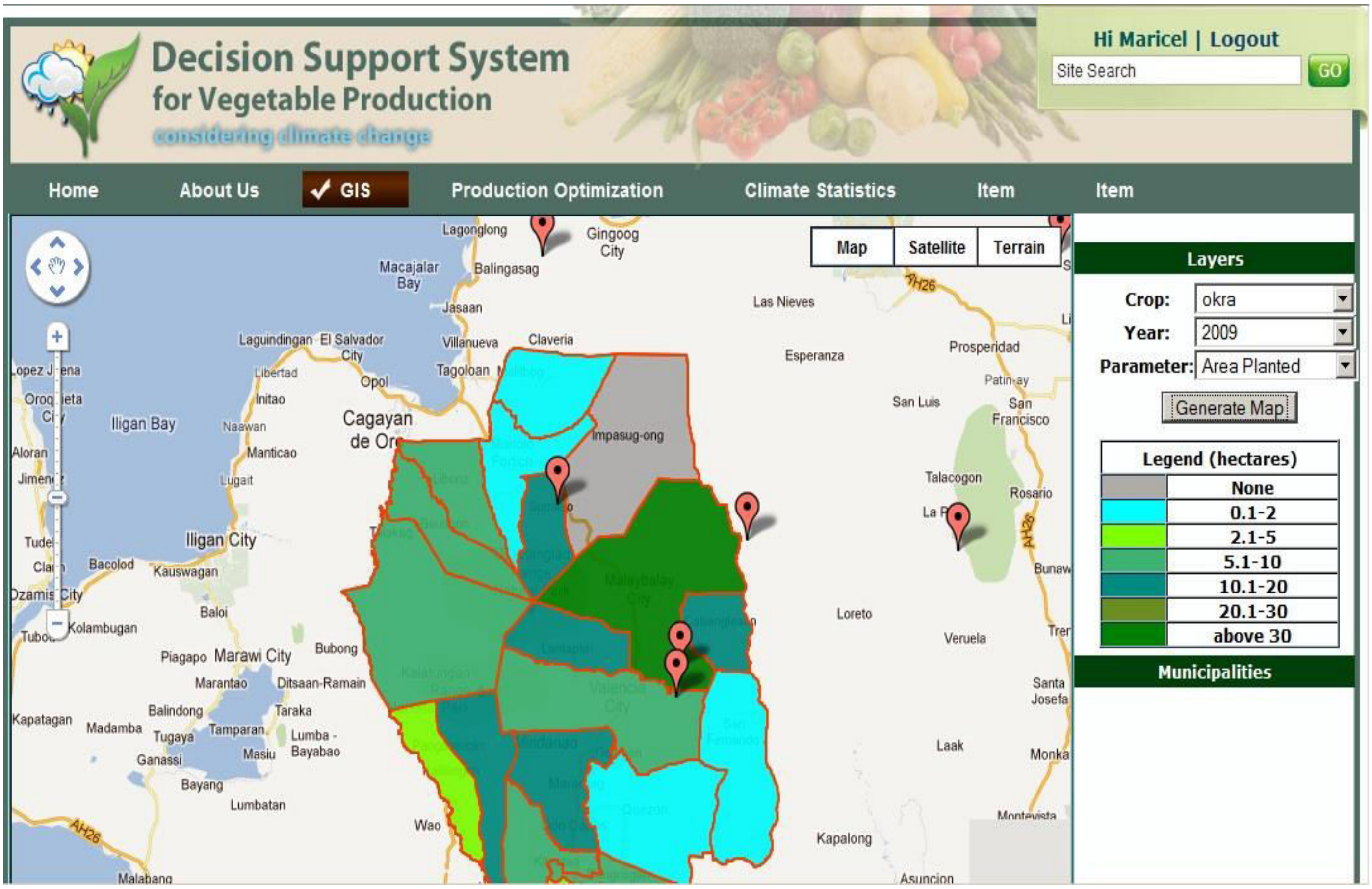

Fig. 5 Sample Generated GIS Map

The system also generates recommendations on planting the crops as shown in Figure 6. These include the recommended fertilization, whether soil needs lime application or suitable for the crops and remarks on intercrop combination. The system also generated outputs such as the estimated crop yield and income.

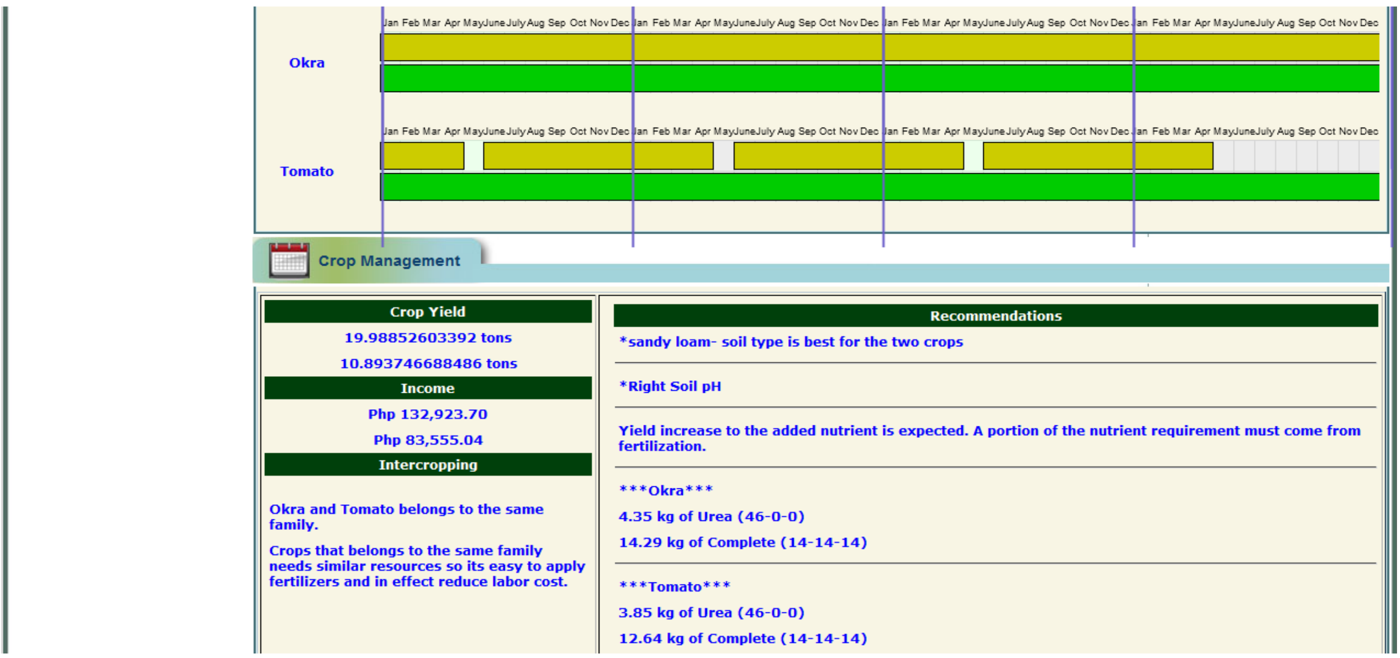

Fig. 6 Sample Recommendations Generated From the System

D. Results of Model and User Evaluation of DSS Model Validation

Results of RSME (Root Mean Square Error) of comparing the predicted values of the system and the actual values gathered by BAS in the same year showed good agreement. The result RSME depicted in the graph shown in figure 7 is approximately 0.6. A lower RSME value means higher accuracy.

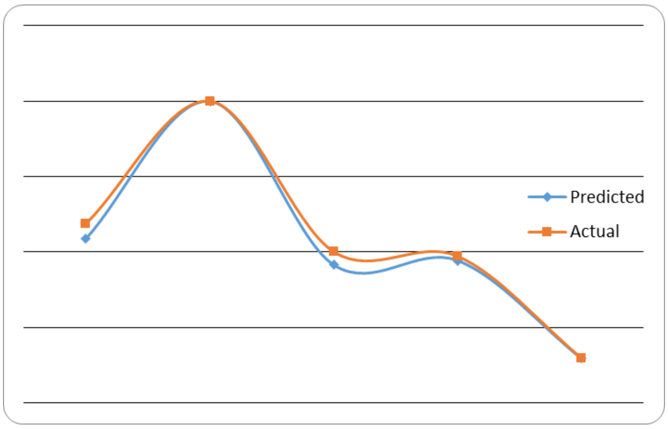

Fig. 7 Graph That Compares the Predicted Values with the Actual Values Recorded From Bureau of Agricultural Statistics

D.1 User Acceptability

The system was evaluated by the users through answering a survey questionnaire. These users include agriculturists and farmers. The results were shown graphically in Figures 8 and 9. The results shows that 77% of the respondents who are farmers agree that the system is usable, 80% agree that the system is easy to use, and 65% agree that the results are based on real farm situations. The results also shows that 100% of the respondents who are agriculturists and experts agree that the system is usable, 53% agree that the system is easy to use, and 83% agree that the results are based on real farm situations.

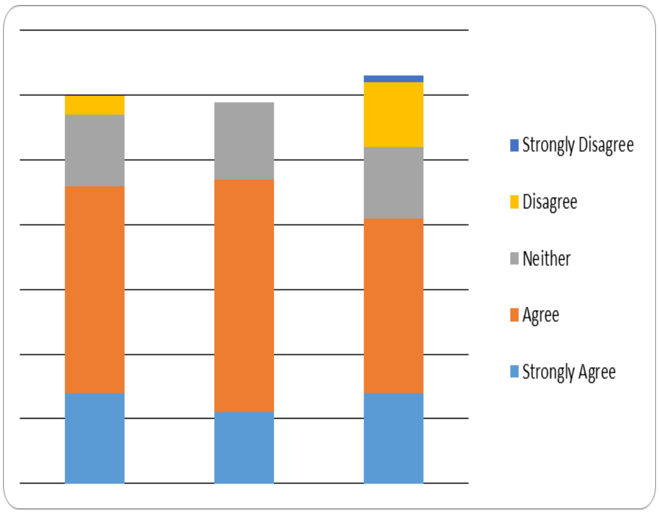

Fig. 8 Results of User Evaluation (farmers)

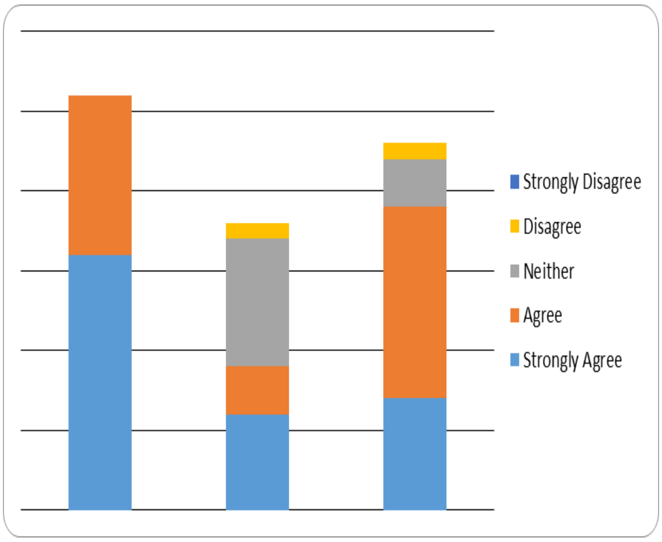

Fig. 9 Results of User Evaluation (agriculturists)

The results shows that the agriculturists believes on the capability of the system in terms of its usability, ease of use, and reliability of results because they have knowledge on the existence of this kind of technologies. There is a positive response from the experts in evaluating this system based from the interview conducted. They commented that this study is very promising because it would help them in their planning to ensure the good crop production of farmers. They evaluated the outputs such as yield and income and commented that these were really based on real farm situations since the calculation of these outputs are based on data from reliable sources such as Department of Agriculture and Bureau of Agriculture Statistics. The survey conducted on the farmers also shows that majority of farmers are in favor of the system in terms of its usability, ease of use, and reliability of results.

IV. CONCLUSION

From the results of the study, it can be concluded that:

i. Based on the user evaluation, they agreed on the usability and reliability of the results generated from the system.
ii. Agriculturists, experts, and farmers agreed that considering climate change to restructure planting calendars is helpful in optimizing crop production which would reduce the risk of crop failure.
iii. An RSME value of 0.6 shows that the predicted yield output of crops to the actual yield value of crops are in good agreement.
iv. The development of the web-based system is very helpful since it would provide a tool for the farmers to simulate the crop production rather than relying on “planting at their own risk”

V. ACKNOWLEDGMENT

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