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CROP CHOICE SIMULATION MODEL FOR INTEGRATED WATER RESOURCE ASSESSMENT AND MANAGEMENT

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ABSTRACT

This paper is an extension of crop choice model made by Ekasingh et. al. (2005). Its aim is to simulate crop selection made by farmers in different IWRAM II's geographical areas. A simple computer programming running on Visual Foxpro was constructed using the existing decision tree and information. The model provided spatial information about farmers' crops selection and displayed them in geographic information system. It also extended to verify the influences of credit made available to farmers, one of the key policy variables, on their crop choice decision. Initially, rice, longan and maize were the top three crops preferred by these farmers. When more credit was available to them, they tended to grow more maize and longan. Interestingly, the model showed that farmers in some geographical areas changed their choices from longan to maize and from rice to maize and longan. The above information would be very useful and meaningful when integrated water resource assessment and management is in ordered

Keywords: crop choice model, simulation, credit, and integrated water resource assessment and management

1. Introduction

Integrated water resource assessment and management project (IWRAM project) has been introduced to Thailand since 1996. The aim of the project was to establish the decision support system in order to aid better water resource management in the watershed area. The project's main concept was to integrate crop, hydrological, erosion and socio-economic models into the decision support system. During the first phase (1996-2000), Mae Jaem watershed was selected as the study area. The approach used in the first phase was the resource management unit (RMU) where household interacted with land unit (The Royal Project Foundation, 2001). On the other hand, the second phase continued to explore in three sub-watersheds of Mae Rim, Mae Ping Part II and Mae Kuang. Land modeling unit (LMU) where crop interacted with land unit instead of RMU was the integration among four different models. This paper deals with part of the socio-economic model in conjunction with IWARM decision support system (IWRAM DSS) (see the shaded area of Figure 1).

Figure 1 shows the framework applied in socio-economic model building. The surveyed data used were divided into two parts. The first part dealt with crop production cost and returns form the data based for socio-economic impact assessment sub-model in the IWRAM DSS. The second part was used to derive farmers' crop choice or decision tree. Details on building the farmers' crop choice rules can be found in Ekasingh at al. (2005). In order to feed valuable information based on farmers' socio-economic characteristics into IWRAM DSS, crop choice simulation was designed. The processes included translating the decision tree made available by Ekasingh at al. (2005) into a computer algorithm to predict crop selection by farmers living in the different geographical areas and display the information in the geographic information system format (see the shaded area of Figure 1). The information produced by this model would be useful for the IWRAM DSS to provide meaningful option on water resource management when accounted for the socio-economic conditions of the farmers.

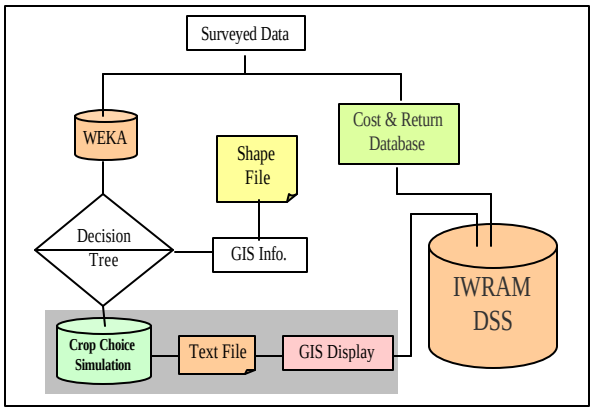


Figure 1. Conceptual framework for socio-economic model building and the linkage to IWRAM DSS

The main purpose of this paper is to build up the crop choice simulation model as well as to use it to test some policy factors affecting the farmers' crop choice. This paper tested the effects on farmers' crop choice as result of a possible change in government policy on agricultural credit made available to the farmers.

2. Objectives

This paper aims at providing geographic information reflecting socio-economic conditions of the farmers in the area for the IWRAM DSS. More specifically, the paper had the following objectives:

1) to build a simple computer program and simulate farmers' crop choice
2) to evaluate the influences of a government policy i.e. credit availability on farmers' crop choice

3. The study area

This study covers three sub-watersheds of the Ping river basin i.e. Mae Rim sub-watershed, Mae Ping Part II sub-watershed and Mae Kuang sub-watershed. These sub-watersheds are in the Chiang Mai and Lamphun provinces of Thailand. The Ping River is one of four main rivers in Northern Thailand. The other three rivers are the Wang, Yom, and Nan rivers. All these four rivers join in Nakornsawan to form the Chao Phraya River, the most important river in Thailand, cutting through the Central Plains through Bangkok, the capital of Thailand. Changes in these rivers would significantly affect majority of the Thai citizens. As such, the Ping Basin is an important watershed in Thailand.

In the Chiang Mai - Lamphun areas, elevation is around 400 meters above sea level (msl) along the river beds and rising to 600-700 msl in the upper slopes. It is at 1000-1300 msl in the higher slopes of the watershed. Annual rainfall is approximately 1200 mm.

The study area is rich in irrigation systems. Local and traditional weirs are abundant, with approximately 2,000 weirs in the area. There are also government irrigation projects e.g. reservoirs and surface water irrigation projects. Irrigation water is sourced from both surface and ground water systems. The two main surface irrigation projects are Mae Tang and Mae Kuang. The Mae Tang irrigation project covers most of Mae Ping Part II sub-watershed while Mae Kuang irrigation project serves North-west part of Mae Kuang sub-watershed. The rest of Mae Kuang and Mae Rim sub-watersheds are under rainfed system where part of them being covered by local and traditional weirs.

The main cropping patterns are rice in the wet season and followed by some dry season crops, such as soybean, garlic, shallot, tomatoes, potatoes and onion. Recently, land is increasingly being converted to fruit tree production, including longan, mango and oranges, because of good profitability. Markets for these fruit trees are sometimes volatile. Their capital needs are also high.

In the middle and upper slopes of the study area, farm land is not usually irrigated and water is scarce especially in the dry season. Farmers are also much poorer than those in the lowlands. Many of them are from ethnic minorities, including Karen, Hmong, Akha and Lisu. These people largely depend on vegetables and fruit production. (These people have largely migrated from Laos, Myanmar and China over the last century.)

The three sub-watersheds of the study area have also been classified into a series of 66 Land Units (LUs)[1] by the IWRAM's research team from the Department of Land Development. This approach defines the land unit according to the given yield of a crop for a particular land unit (or land suitability class) based on the FAO land evaluation procedures (FAO, 1976). A single land unit reflects a combination of soil class and topography. This biophysical classification concept has been incorporated in the socio-economic analysis to simplify integration between the socio-economic and biophysical components of the IWRAM project (Ekasingh et al., 2005).

4. The farmers' decision model

Based on the findings from Ekasingh et al. (2005), farmer decisions were able to be classified on the basis of four key biophysical and socioeconomic variables: land unit, estimated cost of production, the land-labor ratio, and the estimated profit level. Separate decision trees were developed for wet and dry season crop choices (see Figure 1 and 2 in Appendix A). Both decision trees were shown to fit the data with a high degree of accuracy (96 and 86 percent respectively). These decision trees was used to simulate farmers' land use decisions on a land unit basis given scenarios relating to the three socio-economic variables.

[1] The 66 land units are referred to as LU1, LU2, …, LU65 and LU100.

5. Programming approach and algorithm

This paper made use of Visual Foxpro's algorithm to construct a program for farmers' crop choice simulation. The "if … the …. else … endif" command was frequently used to represent the decision tree. The program consisted of 6 consecutive sections as follows (see Figure 2 and also Appendix B for more detail of the program code).

The first section deals with commands to set up format of output and read necessary data for the program. These necessary data is in the form of database. Detail of this database would be discussed in section 6.

The second section deals with commands to generate farmer's expected profit level and generate farmers' level of investment that incorporated the credit availability. This absolutely depended on farmer's behavior. Detailed information needed to generate the expected profit level is in section 6. The commands for eliminating land units those were not agricultural areas (i.e. resident areas, forest, and water bodies) were also include in this step.

The third section is the collection of commands to represent the farmers' decision tree for the wet season where the "if … the ... else … endif" command plays a vital role. The appropriate crop based on the wet season decision tree would be assigned on the running LU and then skipped to the forth section.

The forth section deals with the commands to check for non-agricultural areas and crop choice in the wet season. If it found non-agricultural areas and farmers' crop choice of fruit trees, it assigned the same value for the dry season crop choice. For the agricultural areas not planted with fruit trees, the program would also check water availability, the necessary condition for dry season crop. If it did find irrigation on the non-fruit tree areas of any LU, the blank (no crop) was assigned on that LU. If it found irrigation on the LU, the program followed commands in the fifth section.

The fifth section is again the collection of commands to represent the farmers' decision tree for the dry season where the "if … the … else … endif" command plays a vital role. The appropriate crop based on the dry season decision tree would be assigned on the running LU and then skipped to the sixth section.

The sixth section composes of the commands to draw the land use output produce from sections 2, 3, 4 and 5 and save them in the "text file" format. This output format was suitable to read into the GIS software for an appropriate GIS display. Last part of this section also included commands to terminate the program.

Since the program has been designed on Visual Foxpro, this program source code has to be written in this programming language. With the availability of the prepared database, the program is ready for use.

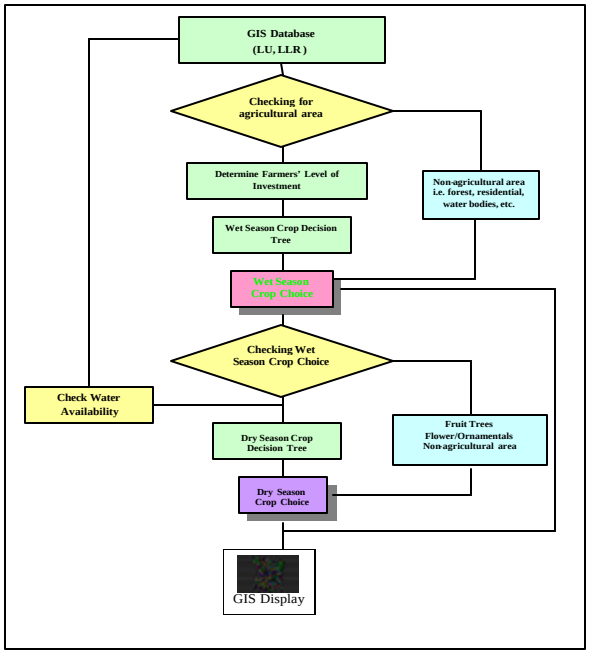


Figure 2. Framework for crop choice simulation model

6. Inputs used in the program

To run the above program and algorithm successfully, there are some needed data. Besides the wet and dry decision trees, the program also needs data on LU number and location[2], investment level (included credit availability), expected profit level, and land labor ratio. The information on LU number and location was made available by the biophysical team. The data on land-labor ratio was computed from the average land holding and labor of a farm household at the sub-district level. These needed data were collected from the Provincial Office of Agricultural Extension in Chiang Mai and Lamphun Provinces. This forms the database that is necessary for the program (Table 1).

Table 1. Sample of database required by the simulation program

lu_tam_amp	LU	irr_code*	Land/labor ratio
1- Khee-lek, Mae Taeng	1	I2	4.2737
1- Buak-kang, Sankampaeng	1	I2	0
1- Baan Thi, Mae Thi	1	I2	5.5304
1- Paa Pong, Doi Saket	1	I2	5.6395
1- Paa Oai, Sansai	1	I1	4.5305
1- Muang Le, Sansai	1	I1	4.5305

Table 1. (cont.)

[2] The information about location of each LU is necessary for displaying the output on the map. This is because there are number of the same LU located at different places.

lu_tam_amp	LU	irr_code*	Land/labor ratio
1- San Paa-sak, Maung	1	I2	4.5569
1- San Mahapon, Mae Tang	1	I2	4.2737
1- Huay Yarb, Mae Thi	1	I2	5.5304
10- Khee-lek, Mae Rim	10	I2	4.3996
10- Tha-tum, Paa Sang	10	R	3.0738
10- Nam Dip, Paa Sang	10	R	3.0738
10- Baan Klang, Muang	10	I2	4.5569
10- Baan Paen, Muang	10	R	4.5569
10- Baan Rauen, Paa Sang	10	R	3.0738
10- Pra-tu Paa, Muang	10	I1	4.5569
10- Pak Pong, Paa Sang	10	R	3.0738
10- Paa Sang, Paa Sang	10	R	3.0738
10- Paa Pong, Doi Saket	10	I2	5.6395
10- Mae Ka, San Pathong	10	I2	0
10- Mae Pong, Doi Saket	10	I2	5.6395

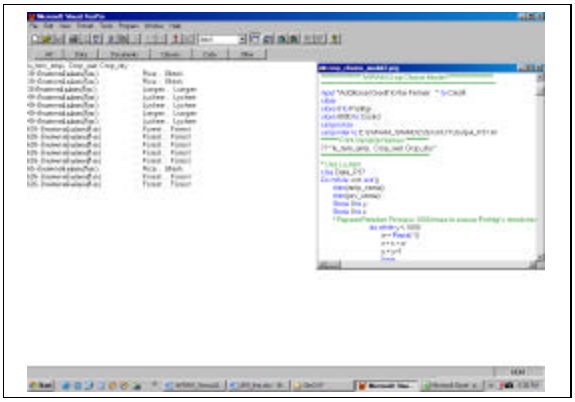
Note: * I1 or I2 demonstrates the availability of irrigation water while R is none.

On the other hand, the investment level was initially assumed to be 20,000 baht per household. The investment per rai is thus obtained by dividing the 20,000 baht by the average land holding of that LU. Additional credit was treated a variable (to be determined by the user) and add to the initial investment of the household. Meanwhile the expected profit level depend farmers' behavior according to their risk attitudes. If they were risk takers, they would expect high profit level. In the contrary, the risk averse farmers would expect lower profit level.

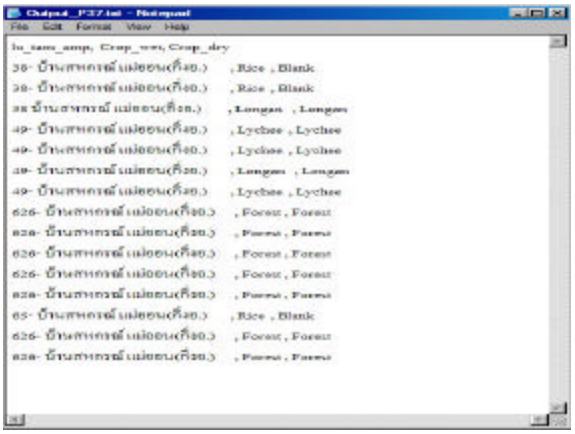
Nobody knew exactly a representative farmer in the LU would be risk taker or risk averse farmer. Based on the experiences working closely with northern farmers in the fields, It appeared that rich farmers were risk takers while the poor farmers were usually risk averse. Piece of additional information from the field survey revealed that there were more poor farmers than the rich ones. At the same time, the decision tree required 5 levels of expected profit.[3] Hence, the assigned probabilities for these 5 levels of expected profit were 0.70, 0.10, 0.10, 0.05 and 0.50 respectively. This information was needed to feed in section two of the program commands in combination with the random process for generating the expected profit of the representative farmer on the LU.

7. Results and discussions

When the program is executed, the amount of additional credit is requested. For the basic execution, it is not necessary to add any credit since each household was given 30,000 baht for the investment.[4] Supplying 0 (for the basic run or any level of additional credit, the program would be running and generate land utilization on each LU (Figure 3) based on farmers' decision which incorporated their socio-economic conditions.



(a) Output on screen preview



(b) Output file viewed in MS Notepad

Figure 3. Output of the simulation program using information form P37, one of a small sub-watershed in the study areas

This simulation program was then applied for the whole IWRAM II's area. The output in Appendix Table 1 (on the last column) shows that more farmers prefer to grow wet rice, wet and followed by dry rice or bean (especially soybean) and longan. While maize in wet season and mango were also popular among farmers in the study areas. These simulated crop choices were similar to the existing crop pattern of the areas where wet rice and wet rice

[3] The value of expected profit levels were 1 for less than 3,000 baht/rai, 2 for 3,001-6,000 baht/rai, 3 for 6,001-12,000 baht/rai, 4 for 12,001-15,000 and 5 for more than 15,000 baht/rai (see more details in Ekasingh et al., 2005).

[4] Note that this program should run without printer turning on. Otherwise the output would also be printed. Upon terminating the program (existing from Visual Foxpro) the program will generate output in a text file format. This out put file could be accessed by MS Notepad, any text editor or any word processing program. It can also be directly accessed by the well-known GIS software called "ArcView" for the GIS display.

followed by dry rice or soybean as well as longan and maize were the main crops in these study areas. This demonstrated that the program had high predictability of farmers' crop selection.

When a scenario of a farm household having additional 10,000 and 20,000 baht of credit the simulation program predicted that farmers in the areas would grow more maize and in the wet season and longan (the last rows of Appendix Table 1 and 2). Many of them converted rice areas to maize and longan and maize to longan or vice versa in the different locations (see Appendix Table 1 and 2). These predicted shifts in crop choices were witnessed by the actual trend in the recent development of cropping pattern in the areas. The farmers were able to accumulate their own investment or access to additional credit.

For better view of the information obtained from this program, we directly imported its output into the existing GIS database using ArcView 3.1 and combined the wet and dry season crop choices in to one variable call "wet_dry." This new variable is then used to display the farmers' wet-dry crop choices in the map (the popular format of GIS display (Figure 4).

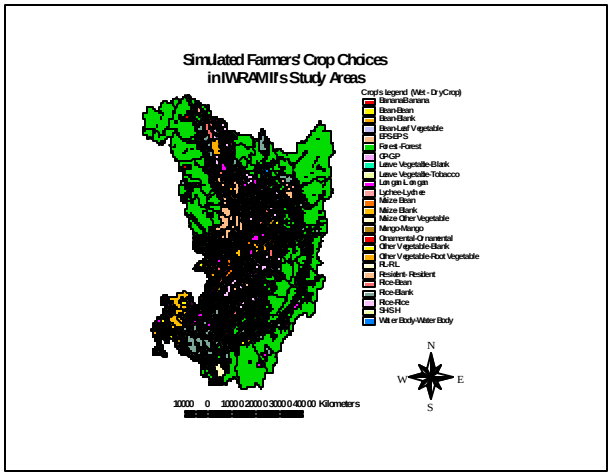


Figure 4. Map of IWRAM II's study areas showing simulated farmers' crop choices in the wet and dry season (without additional credit available to the representative farmer on each LU)

8. Conclusions

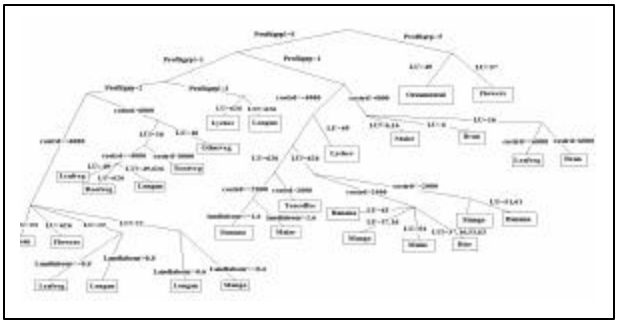
As a continuation from the paper presented by Ekasingh et al. (2005), this paper has presented the building of farmers' crop choice simulation program. The programming algorithm was the Visual Foxpro. Hence, running this program was dependent on this programming language. The program was also flexible to perform policy scenario based on credit availability to the representative farmer in a particular land unit.

The program was applied to the IWRAM II's study areas. Initially, rice, longan and maize were the top three crops preferred by farmers in the study areas. When more credit was available to them, they tended to grow more maize and longan. The simulation results confirm the existing cropping pattern in the areas. Interestingly, the model showed that farmers in some geographical areas changed their choices from longan to maize and from rice to maize and longan. These predicted shifts of the farmers' crop choices are similar to the actual trend in the recent development of cropping pattern in the areas. These information would be very useful and meaningful when integrated water resource assessment and management is in ordered.

9. Acknowledgement

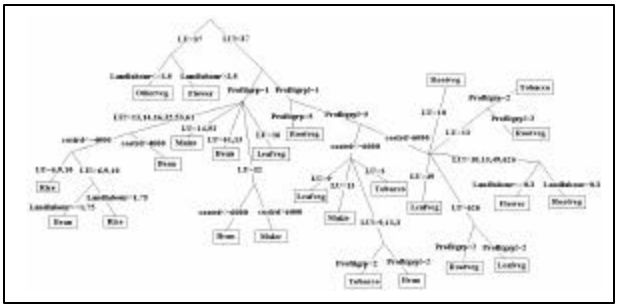
The research work outlined in this paper is part of a larger integrated project, IWRAM. The authors would like to acknowledge all their project partners and previous researchers who have been involved in the project. In addition, the Royal Project Foundation of Thailand and the Australian Centre for International Agricultural Research (ACIAR) should also be acknowledged for their on-going financial support of the project.

APPENDIX A: FARMERS' DECISION TREES IN MAE RIM, MAE PING PART II AND MAE KUANG SUB-WATERSHEDS



Source: Ekasing et al. (2005)

Figure 1. Wet season decision tree



Source: Ekasing et al. (2005)

Figure 2. Dry season decision tree

APPENDIX B : SIMPLIFIED AND BRIEF VERSION OF VISUAL FOXPRO'S PROGRAMMING SOURCE CODE

```
********** **********IWRAM Crop Choice Model ****************************************

************** SECTION ONE: Setting Necessary conditions and reading data file **************
input "Additional Credit to the Farmer:  " to Credit
clear
store 0 to Profitgr
store 0 to Costrd
set print on
set printer to E:\IWRAM_SIMMOD\SimOUT\Output_P37.txt
******* Print Variable Names *********
?? "lu_tam_amp,  Crop_wet, Crop_dry"
************************************************ ***********
Use Lu_tam
*Use Data_P37
*************** SECTION TWO: Generating the farmer's expected profit level
                                        and their investment level ***************
Do While .not. eof ()
        rtrim(amp_name)
        rtrim(prv_name)
        Store 0 to y
        Store 0 to x
   ***** Generating the farmer's expected profit level (repeat random process
         for 1,000 times to ensure stability *********************************
              do while y < 1000
                 w = Rand(-1)
                 x = x + w
                 y = y+1
              loop
              enddo
                    z = x/1000
                     If z <= 0.7 then
                           Profitgr = 1
                     else
                           if z <= 0.8 then
                                 Profitgr = 2
                           else
                                 if z <= 0.9 then
                                 Profitgr = 3
                             else
                                 if z <= 0.95 then
                                       Profitgr = 4
                                 else
                                       Profitgr = 5
                                 endif
                             endif
                           endif
                     endif
   ***** Generating the investment level *********************************
                     if land = 0 then
                           Costrd = 5000 + Credit/15
                     else
                           Costrd = (30000 + Credit)/land
                     endif
                           if irr_code = "R" then
                                 Irrigation = 0
                           else
                                 Irrigation = 1
                           endif
   ***** Commands for screening the none agricultural areas *****
       If LU = 625 then
            Crop_wet = "EPS"
       else
           If LU = 626 then
              Crop_wet = "Forest"
           else
              If LU = 627 then
                 Crop_wet = "GP"
              else
              If LU = 628 then
                    Crop_wet = "Resident"
              else
                 If LU = 629 then
                       Crop_wet = "RL"
                 else
                    If LU = 630 then
                    Crop_wet = "SH"
                    else
                    If LU = 631 then
                          Crop_wet = "Water Body"
                    else
************** SECTION THREE: Starting wet season decision tree

                    If profitgr = 5 then
                          If LU = 37 then
                                Crop_wet = "Flower"
                          else
                                If LU = 49 then
                                      Crop_wet = "Ornamental"
```

```
*****SECTION FORTH: Eliminating none agricultural areas and check fruit tree and irrigation water *****

   ***** Eliminating none agricultural areas *********************************
       If LU = 625 then
            Crop_dry = "EPS"
       else
            If LU = 626 then
                 Crop_dry = "Forest"
            else
                 If LU = 627 then
                  Crop_dry = "GP"
                  else
                  If LU = 628 then
                       Crop_dry = "Resident"
                  else
                       If LU = 629 then
                       Crop_dry = "RL"
                       else
                        If LU = 630 then
                             Crop_dry = "SH"
                        else
                             If LU = 631 then
                             Crop_dry = "Water Body"
                              else

   *****Assigning Perennial Crops ***************************************
       If Crop_wet ="Ornamental" then
            Crop_dry = "Ornamental"
       else
            If Crop_wet ="Lychee" then
                 Crop_dry = "Lychee"
             else
                  If Crop_wet ="Banana" then
                       Crop_dry = "Banana"
                  else
                  If Crop_wet ="Tea_coffee" then
                       Crop_dry = "Tea_coffee"
                  else
                       If Crop_wet ="Mango" then
                       Crop_dry = "Mango"
                       else
                       If Crop_wet ="Longan" then
                            Crop_dry = "Longan"
                        else

   ***** Checking availability of irrigation in the dry season and assigning "blank"  for non-irrigated area **
       if irrigation = 0 then
          Crop_dry = "Blank"
       else

************** SECTION FIFTH: Starting dry season decision tree ***************
       If LU = 37 then
            If landlabor <= 3.5 then
                 Crop_dry = "Other Vegetable"
             else
                 Crop_dry = "Flower"
             endif
       else
            If Profitgr = 1 then
                 If LU = 16 then
                 If costrd <= 6000.00 then
                       Crop_dry = "Leaf Vegetable"
                 else
                       Crop_dry = "Bean"
                 endif
                 else
                 If LU = 13 then
                      Crop_dry = "Bean"
                 else
       .                                                                                .
       .

************** SECTION SIXTH: Draw out the output and terminating the program *****

      ? lu_tam_amp, ",", Crop_wet, ",", Crop_dry,

      ***** Assigning next LU ***************************************
       skip
       loop
     ***** Termination of the program ***********************************************
Enddo
set printer off
*close all
Use
************** PROGRAM TERMINATION ***************************************
```

APPENDIX C: APPENDIX TABLES

Appendix Table 1 Number of LUs classified by simulated crop choice based on without and with 10,000 baht additional credit made available to each farm household.

Wet-dry crop choice without additional credit made available to farm household	Wet-dry crop choice with 20,000 baht additional agricultural credit						
	1[1]	2[1]	3[1]	4[1]	5[1]	6[1]	7[1]
1 Banana - Banana	1						
2 Bean - Bean		10					
3 Bean - Blank			15				
4 Bean - Leaf Vegetable				6			
5 EPS - EPS					1		
6 Flower - Blank							
7 Forest - Forest							68
8 GP - GP							
9 Leave Vegetable - Blank							
10 Leave Vegetable - Tobacco							
11 Longan - Longan	1			5			
12 Lychee - Lychee							
13 Maize - Bean							
14 Maize - Blank			2				
15 Maize - Other Vegetable							
16 Mango - Mango		3	2	3			
17 Ornamental - Ornamental							
18 Other Vegetable - Blank			1				
19 Other Vegetable - Root Vegetable							
20 Resident - Resident							
21 Rice - Bean							
22 Rice - Blank			1				
23 Rice - Rice		7					
24 RL - RL							
25 SH - SH							
26 Water Body - Water Body							
Grand Total	2	20	21	14	1	0	68

Note: The dark columns and rows remark the physical constraint.

[1, 2, ..., 26] These numbers represent crop choice corresponding to those are presented in the rows.

Appendix Table 1 (Cont.)

Wet-dry crop choice without additional credit made available to farm household	Wet-dry crop choice with 20,000 baht additional agricultural credit						
	8[1]	9[1]	10[1]	11[1]	12[1]	13[1]	14[1]
1 Banana - Banana							
2 Bean - Bean				1			
3 Bean - Blank				2			
4 Bean - Leaf Vegetable				2			
5 EPS - EPS							
6 Flower - Blank							1
7 Forest - Forest							
8 GP - GP	3						
9 Leave Vegetable - Blank							1
10 Leave Vegetable - Tobacco				1			
11 Longan - Longan		1		51	1	17	47
12 Lychee - Lychee				6	2		2
13 Maize - Bean			1	14		58	
14 Maize - Blank				17			70
15 Maize - Other Vegetable				1			
16 Mango - Mango				17		3	12
17 Ornamental - Ornamental					3		
18 Other Vegetable - Blank				6			13
19 Other Vegetable - Root Vegetable			1	5		4	
20 Resident - Resident							

Appendix Table 1 (Cont.)

Wet-dry crop choice without additional credit made available to farm household	Wet-dry crop choice with 20,000 baht additional agricultural credit						
	8[1]	9[1]	10[1]	11[1]	12[1]	13[1]	14[1]
21 Rice - Bean				16		6	
22 Rice - Blank		1		67			119
23 Rice - Rice				54		8	
24 RL - RL							
25 SH - SH							
26 Water Body - Water Body							
Grand Total	3	2	2	260	6	96	265

Appendix Table 1 (Cont.)

Wet-dry crop choice without additional credit made available to farm house	Wet-dry crop choice with 20,000 baht additional agricultural credit						
	15[1]	16[1]	17[1]	18[1]	19[1]	20[1]	21[1]
1 Banana - Banana							
2 Bean - Bean		2					
3 Bean - Blank							
4 Bean - Leaf Vegetable		4			1		
5 EPS - EPS							
6 Flower - Blank							
7 Forest - Forest							
8 GP - GP							
9 Leave Vegetable - Blank							
10 Leave Vegetable - Tobacco					1		
11 Longan - Longan		12		1	2		13
12 Lychee - Lychee			1				
13 Maize - Bean		3			4		
14 Maize - Blank		12		4			
15 Maize - Other Vegetable							
16 Mango - Mango		17					
17 Ornamental - Ornamental							
18 Other Vegetable - Blank		1		1			
19 Other Vegetable - Root Vegetable		1			2		2
20 Resident - Resident						130	
21 Rice - Bean					3		34
22 Rice - Blank				9			
23 Rice - Rice					4		
24 RL - RL							
25 SH - SH							
26 Water Body - Water Body							
Grand Total	0	52	1	15	17	130	49

Appendix Table 1 (Cont.)

Wet-dry crop choice without additional credit made available to farm house	Wet-dry crop choice with 20,000 baht additional agricultural credit					
	22[1]	23[1]	24[1]	25[1]	26[1]	Grand Total
1 Banana - Banana						1
2 Bean - Bean						13
3 Bean - Blank						17
4 Bean - Leaf Vegetable						13
5 EPS - EPS						1
6 Flower - Blank						1
7 Forest - Forest						68
8 GP - GP						3
9 Leave Vegetable - Blank						1
10 Leave Vegetable - Tobacco		2				4
11 Longan - Longan	24	39				214
12 Lychee - Lychee						11
13 Maize - Bean						80

Appendix Table 1 (Cont.)

Wet-dry crop choice without additional credit made available to farm house	Wet-dry crop choice with 20,000 baht additional agricultural credit					
	22[1]	23[1]	24[1]	25[1]	26[1]	Grand Total
14 Maize - Blank						105
15 Maize - Other Vegetable						1
16 Mango - Mango						57
17 Ornamental - Ornamental						3
18 Other Vegetable - Blank	4					26
19 Other Vegetable - Root Vegetable		8				23
20 Resident - Resident						130
21 Rice - Bean						59
22 Rice - Blank	67					264
23 Rice - Rice		138				211
24 RL - RL			2			2
25 SH - SH				1		1
26 Water Body - Water Body					83	83
Grand Total	95	187	2	1	83	1,392

Appendix Table 2 Number of LUs classified by simulated crop choice based on without and with 20,000 baht additional credit made available to each farm household

Wet-dry crop choice without additional credit made available to farm household	Wet-dry crop choice with 20,000 baht additional agricultural credit						
	2[1]	3[1]	4[1]	5[1]	7[1]	8[1]	10[1]
1 Banana - Banana							
2 Bean - Bean	10						
3 Bean - Blank		12					
4 Bean - Leaf Vegetable	9						
5 EPS - EPS				1			
6 Flower - Blank							
7 Forest - Forest					68		
8 GP - GP						3	
9 Leave Vegetable - Blank							
10 Leave Vegetable - Tobacco							
11 Longan - Longan	3		5				
12 Lychee - Lychee							
13 Maize - Bean							
14 Maize - Blank							
15 Maize - Flower							
16 Maize - Maize							
17 Maize - Other Vegetable							
18 Mango - Mango	2	3	15				
19 Ornamental - Ornamental							
20 Other Vegetable - Blank		1					
21 Other Vegetable - Root Vegetable							
22 Resident - Resident							
23 Rice - Bean							
24 Rice - Blank		2					
25 Rice - Rice	15						1
26 RL - RL							
27 Root Vegetable - Blank							
28 SH - SH							
29 Water Body - Water Body							
Grand Total	39	18	20	1	68	3	1

Note: The dark columns and rows remark the physical constraint.

[1, 2, ..., 29] These numbers represent crop choice corresponding to those are presented in the rows.

Appendix Table 2 (Cont.)

Wet-dry crop choice without additional credit made available to farm household	Wet-dry crop choice with 20,000 baht additional agricultural credit						
	11[1]	12[1]	13[1]	14[1]	15[1]	16[1]	17[1]
1 Banana - Banana				1			
2 Bean - Bean	1						
3 Bean - Blank	4						
4 Bean - Leaf Vegetable	1						
5 EPS - EPS							
6 Flower - Blank				1			
7 Forest - Forest							
8 GP - GP							
9 Leave Vegetable - Blank				1			
10 Leave Vegetable - Tobacco	1		2				
11 Longan - Longan	50		49	72	1	2	
12 Lychee - Lychee	3	2		6			
13 Maize - Bean	25		50			2	
14 Maize - Blank	21			78			
15 Maize - Flower							
16 Maize - Maize							
17 Maize - Other Vegetable							1
18 Mango - Mango	11		5	14	2		
19 Ornamental - Ornamental				3			
20 Other Vegetable - Blank	6			16			
21 Other Vegetable - Root Vegetable	5		14				
22 Resident - Resident							
23 Rice - Bean	9		45				
24 Rice - Blank	66			167			
25 Rice - Rice	46		112				
26 RL - RL							
27 Root Vegetable - Blank							
28 SH - SH							
29 Water Body - Water Body							
Grand Total	249	2	277	359	3	4	1

Appendix Table 2 (Cont.)

Wet-dry crop choice without additional credit made available to farm household	Wet-dry crop choice with 20,000 baht additional agricultural credit						
	18[1]	19[1]	20[1]	21[1]	22[1]	23[1]	24[1]
1 Banana - Banana							
2 Bean - Bean				2			
3 Bean - Blank		1					
4 Bean - Leaf Vegetable			2	1			
5 EPS - EPS							
6 Flower - Blank							
7 Forest - Forest							
8 GP - GP							
9 Leave Vegetable - Blank							
10 Leave Vegetable - Tobacco							
11 Longan - Longan	2	5		9		2	5
12 Lychee - Lychee							
13 Maize - Bean				3			
14 Maize - Blank		6					
15 Maize - Flower							
16 Maize - Maize							
17 Maize - Other Vegetable							
18 Mango - Mango	4			1			
19 Ornamental - Ornamental							
20 Other Vegetable - Blank		1					2

Appendix Table 2 (Cont.)

Wet-dry crop choice without additional credit made available to farm household	Wet-dry crop choice with 20,000 baht additional agricultural credit						
	18[1]	19[1]	20[1]	21[1]	22[1]	23[1]	24[1]
21 Other Vegetable - Root Vegetable				2		2	
22 Resident - Resident					130		
23 Rice - Bean				1		4	
24 Rice - Blank		8					21
25 Rice - Rice				10			
26 RL - RL							
27 Root Vegetable - Blank							
28 SH - SH							
29 Water Body - Water Body							
Grand Total	6	21	2	29	130	8	28

Appendix Table 2 (Cont.)

Wet-dry crop choice without additional credit made available to farm household	Wet-dry crop choice with 20,000 baht additional agricultural credit					
	25[1]	26[1]	27[1]	28[1]	29[1]	Grand Total
1 Banana - Banana						1
2 Bean - Bean						13
3 Bean - Blank						17
4 Bean - Leaf Vegetable						13
5 EPS - EPS						1
6 Flower - Blank						1
7 Forest - Forest						68
8 GP - GP						3
9 Leave Vegetable - Blank						1
10 Leave Vegetable - Tobacco	1					4
11 Longan - Longan	8		1			214
12 Lychee - Lychee						11
13 Maize - Bean						80
14 Maize - Blank						105
15 Maize - Flower						0
16 Maize - Maize						0
17 Maize - Other Vegetable						1
18 Mango - Mango						57
19 Ornamental - Ornamental						3
20 Other Vegetable - Blank						26
21 Other Vegetable - Root Vegetable						23
22 Resident - Resident						130
23 Rice - Bean						59
24 Rice - Blank						264
25 Rice - Rice	27					211
26 RL - RL		2				2
27 Root Vegetable - Blank						
28 SH - SH				1		1
29 Water Body - Water Body					83	83
Grand Total	36	2	1	1	83	1,392

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