3. RESEARCH METHODOLOGY

3.1 The Study Area

The study area is in Phrao district, Chiang Mai province. Phrao district lies between latitudes 19°00′ N to 19°35′ N and longitudes 99°05′ E to 99° 20′ E. It is about 97 km. Northeast of Chiang Mai City. The district covers an area of about 1,284 km^2 (about 850,000 rai). It consists of flat areas in the center surrounded by mountainous areas. Figure 3 shows the location of Phrao district within the Chiang Mai Province boundary.

The main river in the district is the Mae Ngud river that is a tributary of Mae Ping river. The river runs from north to south and is very important for being source of irrigation and drinking water (Wangchuk, 1992). The total number of the population in the district is about 49,000 (9,800 households). It consists of 11 sub-districts and 100 villages of which most households are involved in agricultural activities (Ali & Dissanayake, 1990).

There are three distinct seasons, the rainy season is from July to October with an average rainfall of about 1,100 mm. The cool season is from November to February and the summer is from March to June. The annual average minimum and maximum are temperature 13°c to 35°c, respectively.

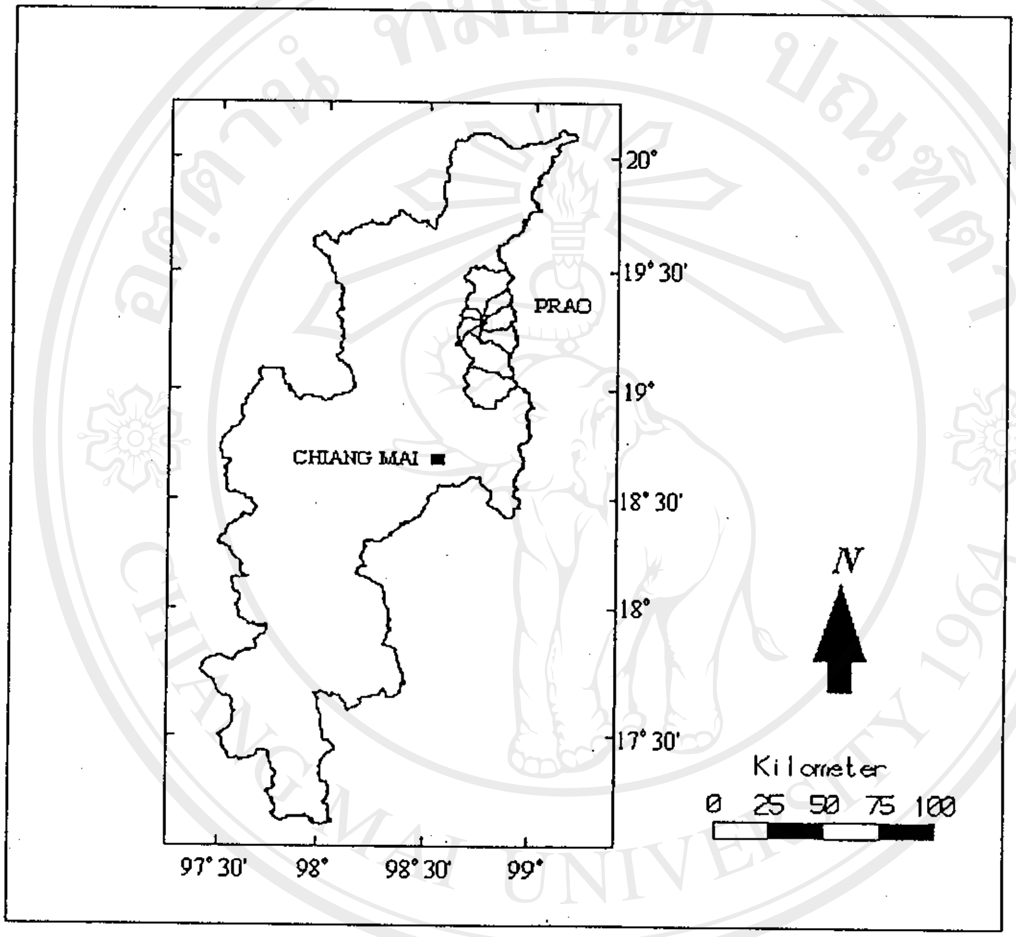

Figure 3. The location of Phrao district in Chiang Mai Province.

About 78% of Phrao district total area is classified as sloping complex as defined by DLD. The remaining area is the agricultural land (Figure 4). Less than 10% of total area is classified as lowland, some 20% as upland and 70% as highland.

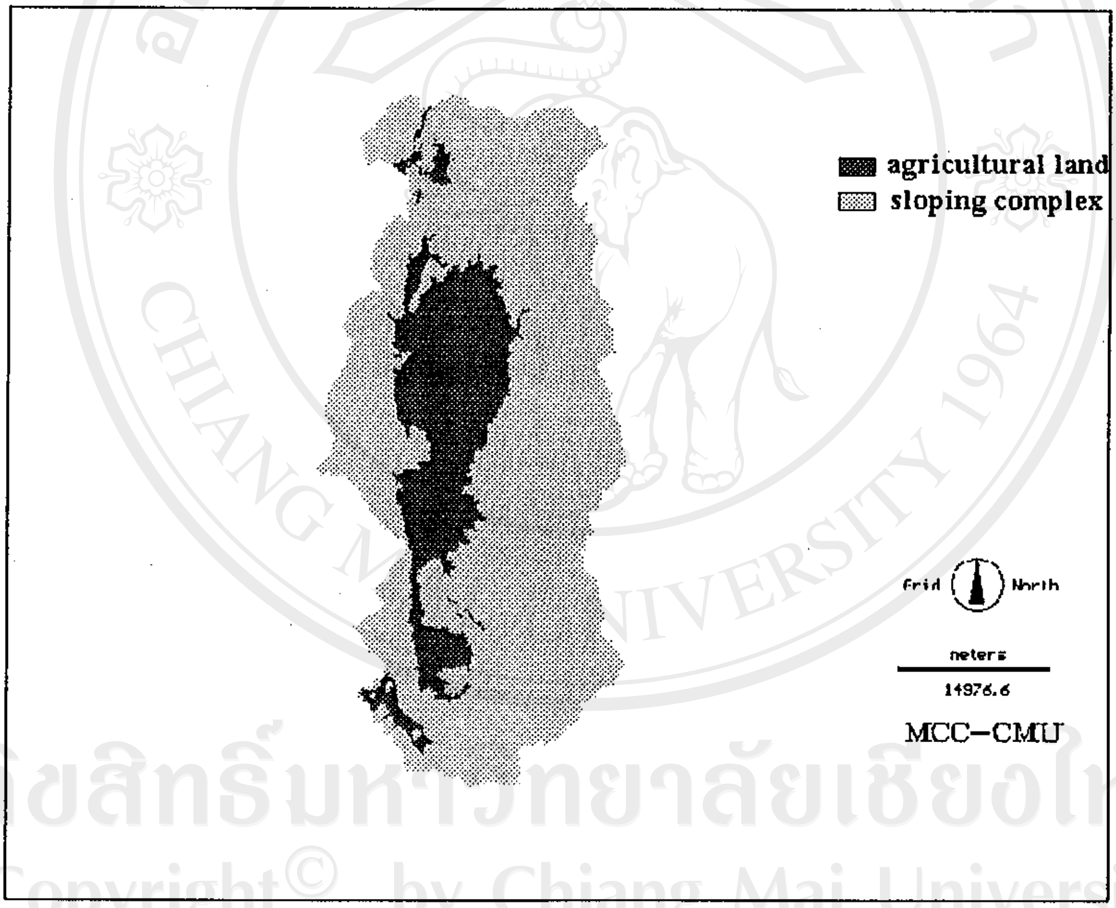

Figure 4. Distribution of agricultural land in Phrao district.

There are 6 land settlement project areas in the upland zone named "*Phrao Cooperative Land Settlement Project*". The project area covers 51,000 rai, or about 6%, of the total area in the central part of the district. The agricultural land is allocated to the poor and landless people through land settlement cooperative society to improve their standard of living (Schapink, 1992).

3.2 Framework of the Study

There are three main parts as reflected by different information technologies used in this study (Figure 5). The first part is the input and output of spatial data which is facilitated by the Geographic Information System (GIS) package. The DLD soil unit maps at the scale of 1:50,000 were digitized by the PC ARC/INFO package, or a vector based software, to provide land mapping unit (LMU) boundaries for further evaluation. Land characteristics (LC) of each LMU were entered as attribute values of each LMU polygon in PC ARC/INFO. Conversion and grouping of LC into land quality (LQ) for matching with the requirements of the specific crop were achieved by the ALES -- the expert system. At this point, the results were the physical suitability classes and subclasses. Only lands that have potential for agriculture will be subjected to further assessing for the economic suitability class.

Crop yield data using for estimating the proportional yields of each LMU were generated by the DSSAT model as shown in the last part of the framework.

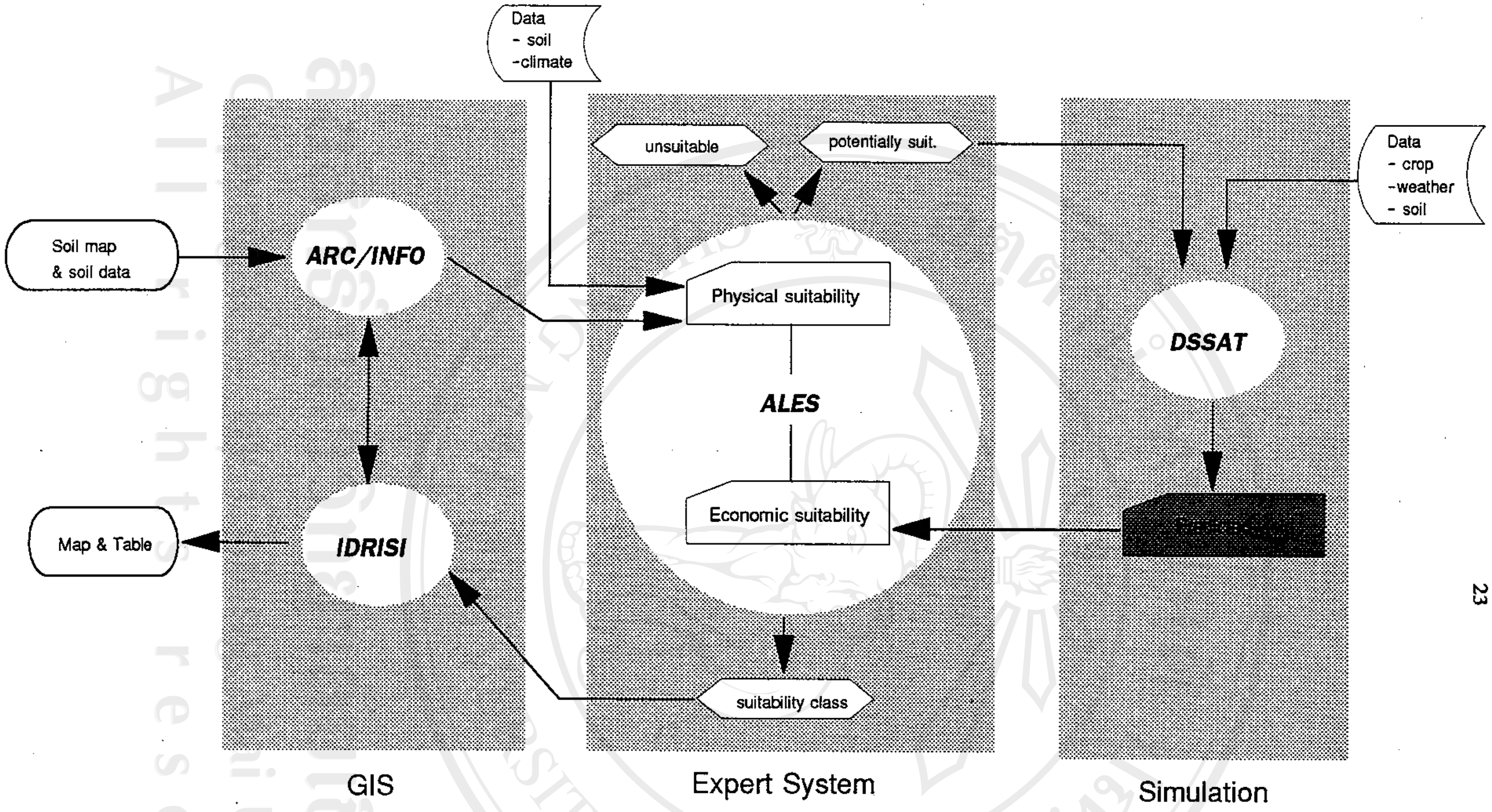

Figure 5. Framework of land evaluation procedure

The predicted yields from the model were used due to the lacking of published data on the yield of different crops in the study area.

The evaluation results, both physical and economic suitability classes, and the ALES database from the expert system were used to reclassify an existing raster image that represents the map units in that evaluating area. The ALES has an optional module, the ALIDRIS, to implement an interface from ALES software to the IDRISI software. GIS system can do the conversion from vector base by the PC ARC/INFO program into the raster base of the IDRISI program. Hence, this can produce many interpretative maps both of the ALES databases (i.e., land characteristic maps) and the land evaluation results.

3.3 MODEL CONSTRUCTION

3.3.1 Land Mapping Unit (LMU) and Land Characteristic (LC)

All agricultural lands in Phrao district were evaluated by the FAO Framework for Land Evaluation using ALES model. LMUs were digitized from soil maps of the district with the scale of 1:50,000 which was produced by DLD. Soil characteristics for all soil units were also obtained from DLD with additional field observations for verifying the characteristics of LMUs (Appendix Table 1). There were 15 soil units comprising 12 homogeneous soil units and 3 compound soil units. Field check was done for 3 sites per soil unit spreading over the district. Soil units that have different slope ranges were defined into different land mapping units for its limitation on growing some crops. Altogether 25 land mapping units were evaluated. Land characteristics identified as diagnostic factors were used to estimate the land qualities. The continuous values of land characteristics were classified into discrete land characteristics to be used as the decision criteria in the ALES decision trees (Appendix Figure1).

3.3.2 Land Utilization Type (LUT) Condition for Each Land Use

The first step in evaluating land starts with the decision about the alternative LUTs that were separately evaluated. Land Utilization Type is a technical term used to represent common term '*land use*' (Rossiter, 1990). It is a kind of land use described or defined in a degree of detail greater than that of major kinds of land use (FAO, 1976). It consists of set of technical specifications within a given time incorporate with environment or some major land improvements (FAO, 1983; FAO, 1984). This relates to the land use requirement and limitations of land for a specified use.

The information needed for constructing the model were the factors and their levels that affect or limit crop production, the data on yields and some socio-economic data for adjusting the model. In this study, the land utilization types (LUTs) were selected based on existing cropping systems in the area (AIT, 1984; OAE, 1987; FSRD, 1987; Shinawatra et al., 1990; Planning and Special Projects Division, 1990; DOAE et al., 1991; Schapink, 1992). They were identified as rainfed corn (RCorn), rainfed peanut (RPea), rainfed peanut-peanut (RP-P), rainfed rice (RRice), rainfed soybean (RSoy), and irrigated rice-soybean (IR-S).

Different LUTs have different land use requirements and limitations that are likely to be relevant to assessing its suitability within the area. Tables 2-7 illustrate each component of LUTs. Climatological data were collected from the weather stations distributed in or near Phrao district. Those are the Meteorological Observing Station at Phrao district, Northern Station Weather Forecast Center and Agroclimatological Data at Chiang Mai Field Crop Research Center.

S1 yields were assessed from DSSAT crop model simulation at the optimum condition in Phrao district. Those are the maximum yields of all soil unit in Phrao district with optimum fertilizers for rainfed or optimum irrigated conditions. Information on soil factors, management levels, inputs and outputs (Table 2-7) were obtained from farmer practices and the guideline for growing crop by DOAE and DOA. This document has been used as guidelines to manage crops for farmers by the extension agents. Annual reports by Chiang Mai Field Crop Research Center (CMFCRC, 1988-1992), Chiang Mai Field Crop Research Center News, Annual Report on Research Results by Field Crop Research Institute (FCRI, 1989-1991) and others literature were consulted. Cultural practices of the farmers in the district were extracted from Wiboonpongsa & Thani (1980), AIT (1984), Shinawatra et al. (1987), CMFCRC (1991b), Schapink (1992) and Insompan (1990).

Table 2. Attributes of Land Utilization Types considered for rainfed corn (RCorn) in Phrao district.

Variety : Suwan 1
Growing Period : 100 - 110 days
S1 Yield : 1107.71 kg/rai

CULTURAL PRACTICE
Farm Power : only land preparation mechanized (tractor)
Planting Practice : spacing 75 * 25 cm, 5 cm depth, 1 seed/hill
: fertilizer - banding before planting and side dressing 3 wks. after planting
Weeding : pre-emergence spraying and hand weeded 1 month after planting
Crop Protection Practice : 3 times spraying

MATERIAL INPUTS
Capital Intensity : seed 4 kg/rai
: fertilizer - 30 kg/rai of 16-20-0
: farm chemical - Lasso 600 cc/rai, Apron 35 S.D. 30 gm/rai and
- Lannate 90% 75 gm/rai
Labor Intensity : 7.35 m-day

ECONOMIC DATA
Market Orientation : cash generation
Price : 2.5 ฿/kg

Table 3. Attributes of Land Utilization Types considered for rainfed peanut (RPea) in Phrao district.

Variety : Tainan 9
Growing Period : 110 - 120 days
S1 Yield : 595.39 kg/rai

CULTURAL PRACTICE
Farm Power : only land preparation mechanized (tractor)
Planting Practice : spacing 30 * 20 cm, 5 cm depth, 2-3 seeds/hill
: fertilizer - banding before planting and side dressing 15-20 days after planting
Weeding : hand weeded 15, 30 & 45 days after planting
Crop Protection Practice : spraying

MATERIAL INPUTS
Capital Intensity : seed 15 kg/rai
: fertilizer - 25 kg/rai of 12-24-12 and 200 gm/rai of Rhizobium
: farm chemical - Captan 50 gm/rai, Furadan 5 kg/rai, Azodrin 450 cc/rai, and Dithane M-45 200 gm/rai
Labor Intensity : 9.79 m-day

ECONOMIC DATA
Market Orientation : cash generation
Price : 5.50 ฿/kg

Table 4. Attributes of Land Utilization Types considered for rainfed rice (RRice) in Phrao district.

Variety : San Pa Tong, RD6
Growing Period : 120 - 150 days
S1 Yield : 853.63 kg/rai

CULTURAL PRACTICE
Farm Power : only land preparation mechanized (tractor)
Planting Practice : nurseries - seeded bed 1.5-2 m.
: transplanting - 30 days after sowing
: spacing 25 * 25 cm
: fertilizer - broadcasting before transplant & before panicle initiation
Weeding : hand weeded 2 times
Crop Protection Practice : spraying

MATERIAL INPUTS
Capital Intensity : seed 6 kg/rai
: fertilizer - 30 kg/rai of 16-20-0 and Urea 6 kg/rai
: farm chemical - Sevin 85 250 gm/rai, and Furadan 6 kg/rai
Labor Intensity : 5.56 m-day

ECONOMIC DATA
Market Orientation : subsistence
Price : 3.5 ฿/kg

Table 5. Attributes of Land Utilization Types considered for rainfed soybean (Rsoy) in Phrao district.

Variety : SJ4, SJ5
Growing Period : 95-100 days
S1 Yield : 474.11 kg/rai

CULTURAL PRACTICE
Farm Power : only land preparation mechanized (tractor)
Planting Practice : spacing - 75 * 25 cm., 5 cm. depth, 2-3 seeds/hill
: fertilizer - banding before planting
Weeding : spraying 5 days before planting and hand weeded 15 & 30 days after planting
Crop Protection Practice : spraying

MATERIAL INPUTS
Capital Intensity : seed 15 kg/rai
: fertilizer - 50 kg/rai of 12-24-12 and Rhizobium 200 gm/rai
: farm chemical - Azodrin 500 cc/rai, Lasso 600 cc/rai, and Captan 50 gm/rai
Labor Intensity : 8.31 m-day

ECONOMIC DATA
Market Orientation : cash generation
Price : 8.0 ฿/kg

Table 6. Attributes of Land Utilization Types considered for rainfed peanut-peanut (RP-P) in Phrao district.

Variety : Tainan 9
Growing Period : 100 - 110 days
S1 Yield : 595.39 kg/rai of early rain peanut and 482.56 kg/rai of late rain peanut

<u>CULTURAL PRACTICE</u> : the same as rainfed peanut

<u>MATERIAL INPUTS</u>
Capital Intensity : seed 30 kg/rai
: fertilizer - 50 kg/rai of 12-24-12 and Rhizobium 400 gm/rai
: farm chemical - Captan 100 gm/rai, Furadan 10 kg/rai, Azodrin 900 cc/rai, Dithane M-45 400 gm/rai
Labor Intensity : 19.73 m-day

<u>ECONOMIC DATA</u>
Market Orientation : cash generation
Price : early rain peanut 5.5 ฿/kg and late rain peanut 6.5 ฿/kg

Table 7. Attributes of Land Utilization Types considered for irrigated rice-soybean (IR-S) in Phrao district.

Variety : rice - NSPT, RD6
: soybean - SJ4, SJ5
Growing Period : rice - 120-150 days
: soybean - 90-110 days
S1 Yield : rice 856.3 kg/rai
: soybean 409.15 kg/rai

<u>CULTURAL PRACTICE</u>
the same as rainfed rice for rice
Farm Power: no mechanized for soybean
Planting Practice : soybean ; spacing - 50 * 25 cm., 3 seeds/hill
; fertilizer - banding
Weeding : spraying before planting and hand weeded 15 & 30 days after planting for soybean
Crop Protection Practice : spraying 3-4 times

<u>MATERIAL INPUTS</u>
Capital Intensity : seed - 6 kg/rai for rice and 11 kg/rai for soybean
: fertilizer - 20 kg/rai of 16-20-0, Urea 5 kg/rai, 12-24-12 25 kg/rai, and Rhizobium 200 gm /rai
: farm chemical - Sevin 85 250 gm/rai, Furadan 6 kg/rai, Lasso 600 cc/rai, Captan 50 gm/rai, and Dithane M45 900 gm/rai
Labor Intensity : 14.36 man-day

<u>ECONOMIC DATA</u>
Market Orientation : subsistence & cash generation
Price : rice 3.5 ฿/kg and soybean 8.0 ฿/kg

Input prices were documented from interviewing the agricultural chemical stores in Chiang Mai for the price of fertilizers and pest control chemicals. The prices of seeds were obtained from Seed Division Region 7, Department of Agricultural Extension. Output prices were taken as the average farm gate price reported by the Office of Agricultural Economics Region 13.

3.3.3 Land Use Requirement (LUR)

Land use requirements are used to describe the requirement for a successful and sustained practice of a given land utilization type that are expressed in term of land qualities. These are later matched with the qualities of soil unit to determine the suitability of each land unit for a specific land use type. These requirements and limitations were determined from the literature review such as CSR/FAO (1983) and based on the experience adapted for this area.

The following qualities were used to construct LUR for various suitability classes.

t	--	temperature regime,
w	--	water availability,
r	--	rooting condition,
f	--	nutrient retention,
n	--	nutrient availability,
s	--	terrain,
fl	--	flood hazard.

The LUR for each LUT in different suitability ratings are presented in Appendix Table 2 to Appendix Table 7. The requirement of temperature regime, rooting condition, nutrient retention, nutrient availability and terrain were similar to what appeared in CSR/FAO (1983). However, the water availability, one of the LUR, was modified by assessing from the length of growing period instead of using average annual rainfall and dry months. Growing period is a continuous period during the year when precipitation is greater than half of the potential evapotranspiration (0.5 PET), calculated by Penman's method, plus a number of days required to evaporate an assumed 100 mm. of soil water stored at the end of the rain (Kowel, 1978).

The growing period around Phrao weather station estimated by Penman's method was 203 days (Figure 6). The values for different suitability ratings for growing period were estimated from Kassam (1984). Another land use requirements, the flood hazard was considered for rainfed field crops. The flooded areas were determined from the areas whose slope range between 0-2 %.

Land characteristics of each LMU were traversed through the severity level decision trees of a particular LUT to achieve the land quality values. Decision procedures were developed for each LUT based on requirements derived from above. The results are the qualities of each LMU for a particular crop grown (see Appendix Table 8).

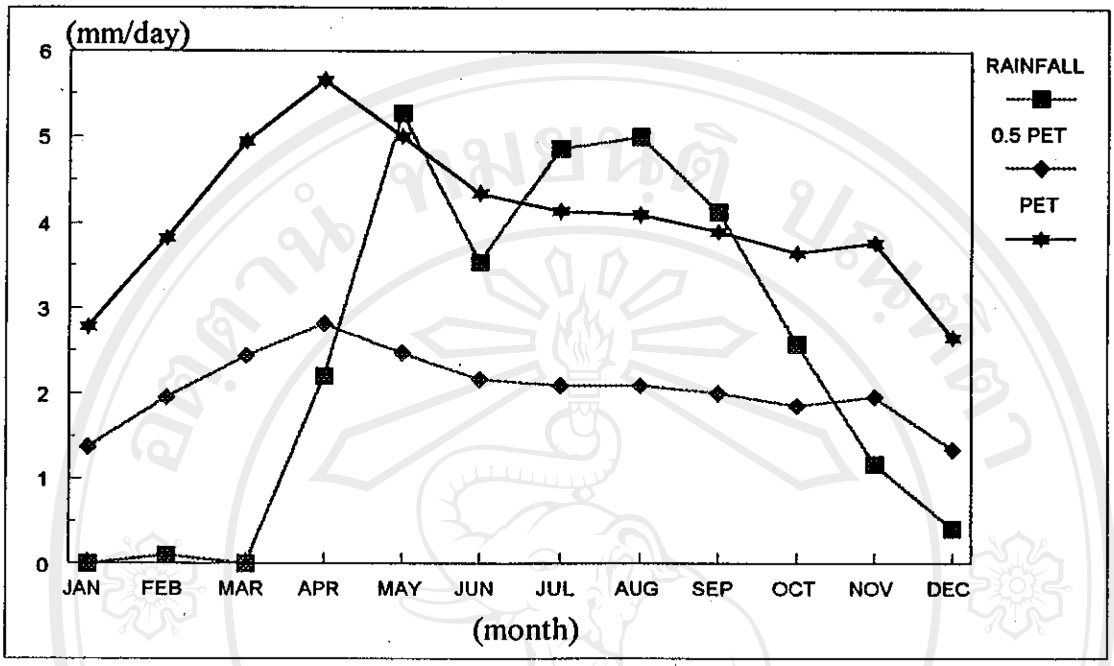

Figure 6. Climatic data used for determining the growing period in Phrao district.

3.3.4 Determination of Physical Suitability Class

The process of matching land use requirements with land characteristics or land qualities without respect to any economic conditions resulted in physical suitability for a land use. Rossiter and Van Wambeke (1989) stated that if a use is too risky or physically impossible, no economic analysis can justify it. ALES always computes physical suitability prior the economic suitability. The physical evaluations were used to eliminate completely unsuitable land for further consideration. As mentioned before, if the physical suitability is worst, the economic suitability is permanently not suitable. This corresponds to FAO suitability class 'N2' (permanently not suitable) and it is indicated by the highest-number of physical suitability class designed by the evaluator in the ALES program.

The designated physical suitability classes were allocated into 4 classes. Class 1 determines the most suitable land with no limitation for growing any specified crop. Class 4 determines the permanently not suitable class. Class 2 and class 3 represent moderately and marginally suitable classes by some limiting condition, respectively.

ALES has two ways to decide those physical classes. The general way is to construct the "*physical suitability decision tree*" by combining severity level of land qualities. The constructed decision procedures were used as the matching process among LURs and LQs traversed the physical suitability decision trees to identify the physical suitability subclasses. Another way is the use of "*maximum limitation method*". The physical suitability class was designated from the maximum value or highest-number of one or more severity levels of specified LQs (Rossiter & Van Wambeke, 1989). Both can be combined by determining some LQs using the decision tree and then explore other specific severity levels of the maximally limiting LQs.

In this study, both methods were used to perform the suitability classification. The first method represented the potential suitability classification, the other represented the current suitability classification. The examples of building decision trees (Rcorn, Rrice and Rpea) are presented in Appendix Table 9.

3.3.5 Determination of Proportional Yields

ALES uses land quality values of each LMU to traverse the proportional yield decision trees, and/or limiting yield factors (percentage of optimum) and/or proportional yield factor (percentage of optimum). The proportional yield factor is expressed as decimal fraction on the interval [0...1], with '0' representing complete crop failure, and '1' representing the optimum.

Three methods can be used in predicting the proportional yield. The first method uses severity levels of LQs as decision entities in a decision tree called "*proportional yield decision trees*". The evaluator can define proportional yield for each combination of severity levels of LQs. The second method involves the use of "*proportional yield factors*" for some LQs that affect yield in a multiplicative fashion. The percentages of each severity level are multiplied together. This can be used instead of proportional yield decision trees or they can also be used in combination. The last method utilizes "*limiting yield factors*" that influence yield according to the agricultural "*law of minimum*". The maximum yield of certain land could not be higher than percentage of the most severity level LQs. This method can partially or completely replace proportional yield decision trees. The proportional yield decision trees and limiting yield factors were used to estimate the yield for intermediate use of input in this study. The types and level of input used are described in Table 1 to 6 for each LUT.

The proportional yield used in the decision trees were derived from the DSSAT model. The strategy evaluation in DSSAT model can be modified to suit the conditions of crop variety, soil type, planting date, spacing, timing and amount of irrigation and/or fertilizer applications. The selected LURs for establishing the proportional decision trees including nutrient retention, nutrient availability and rooting condition are shown in Appendix Table 10. Other LURs that can not be identified from to simulation model were handled by limiting yield factors.

The limiting yield factors were determined for individual land quality according to FAO method (Dent & Young, 1981; FAO, 1983). The range of crop yields as a percentage of yield under optimal condition for each suitability class rating are shown in Table 8.

Table 8. Guideline for definitions of classes for factors rating. The classes refer to a single land quality rated concerning a specified crop or land utilization type.

Class	Definition in term of yields*
S1	> 80 %
S2	40 - 80 %
S3	20 - 40 %
N	< 20 %

* expected crop yields, as a percentage of yields under optimal conditions. (adapted from Dent & Young 1981 and FAO, 1983).

3.3.6 Determination of Economic Suitability Class

This represents the overall suitability rating classified from with the predicted gross margins. ALES assigned land into four classes according to FAO suitability classes: S1 (highly suitable), S2 (moderately suitable), S3 (marginally suitable), and N1 (economically unsuitable or currently not suitable). The limits of each economic suitability class were achieved from the multiplicative of estimated yield with output price then subtracted by S1 cost. Estimated yield was obtained from S1 yield multiplied by the proportional yield factor of each suitability class.

The lands were differentiated into different physical suitability classes based on the severity level of their land qualities by proportional yields. The proportional yields were multiplied by the optimum yield (S1 yield) to obtain the predicted yield and multiplied by the output price to estimate the predicted return (Appendix Figure 2). The predicted cost per annum of each LMU for a specific LUT is composed of S1 cost (the most suitable class cost) and the additional cost (Appendix Figure 3). To obtain the cost for the most suitable LUT (S1 cost), it started from the estimate of the input requirement for S1 then multiplied those input by a specific input price. The additional cost was obtained from the estimated input that are required for each LQ severity level. For example, if LQ severity level of nutrient availability of corn for soil unit no. 6 is class 3, it requires additional nitrogen fertilizer. The product was the results of an input for S1 annual cost and input for addition cost. The sum of each input for S1 annual cost and each additional cost input gave us the annual cost of specific LUT for each LMU. The predicted cost was then subtracted from the predicted return to obtain the predicted gross margin of LMU for that LUT. This result was classified as the economic suitability subclass limits for each LMU and LUT (Appendix Figure 2).

3.4 THE LAND EVALUATION RESULTS

The result of the above can be displayed as the evaluation matrices for physical and economic suitability classes for each LMU and LUT used in this study. The land evaluation results were printed out as tables according to soil units and as raster images using ALIDRIS module in ALES. This module converted ALES database into the images of IDRISI program. The resulting raster images included the physical suitability subclass and economic suitability class (results of the use of proportional yield decision tree, the use of limiting yield factors, and the use of proportional yield decision tree in combination with limiting yield factors) for all LUTs.

The suitability ratings in form of IDRISI raster images were compared with the suitability maps produced by DLD (1990) and with the land use classified in 1992 in Phrao district. The comparisons were statistically tested with the KHAT statistic processed through the ERRMAT command in the IDRISI program. ERRMAT compares two images for the purpose of accuracy assessment. The output contains column and row marginal totals, errors of omission and comission, an overall error measure, confidence intervals for that figure and a Kappa Index of Agreement (KIA) both for all classes combined and on a per category basis (Carstensen, 1987; Eastman, 1993).