3. MATERIALS AND METHODS

3.1 Study Area

The study area covers the entire area of Prao district, Chiang Mai province which lies between latitudes 17° 15′ N to 20° 10′ North and longitudes 98° 05′ E to 99° 40′ East. The province is bounded by Mae Hong Son to the West, Myianma to the North, Chiang Rai, Lampang and Lamphun to the East, and Tak to the South. Prao district lies between latitudes 19° 00′ N to 19° 35′ North and longitudes 99° 05′ E to 99° 20′ East. It is located about 90 km Northeast from Chiang Mai city (Fig. 4). The mean temperature of Prao ranges from 21°C in November to 31°C in March. The average annual rainfall is 1090 m.m. (1979-1992). The most of flood plain areas in Prao are low terrace. The flood plain was used for wetland-rice. Field crops and orchards were used the upland area around the Prao district.

3.2 Framework of the Study

Four major components constitute the spatial information system for land evaluation in this study, spatial database, non-spatial database, fuzzy land evaluation and the system shell to link each component (Fig. 5).

The input, output and analysis of spatial data were managed by two GIS softwares namely IDRISI and PC ARC/INFO. Non spatial databases consist

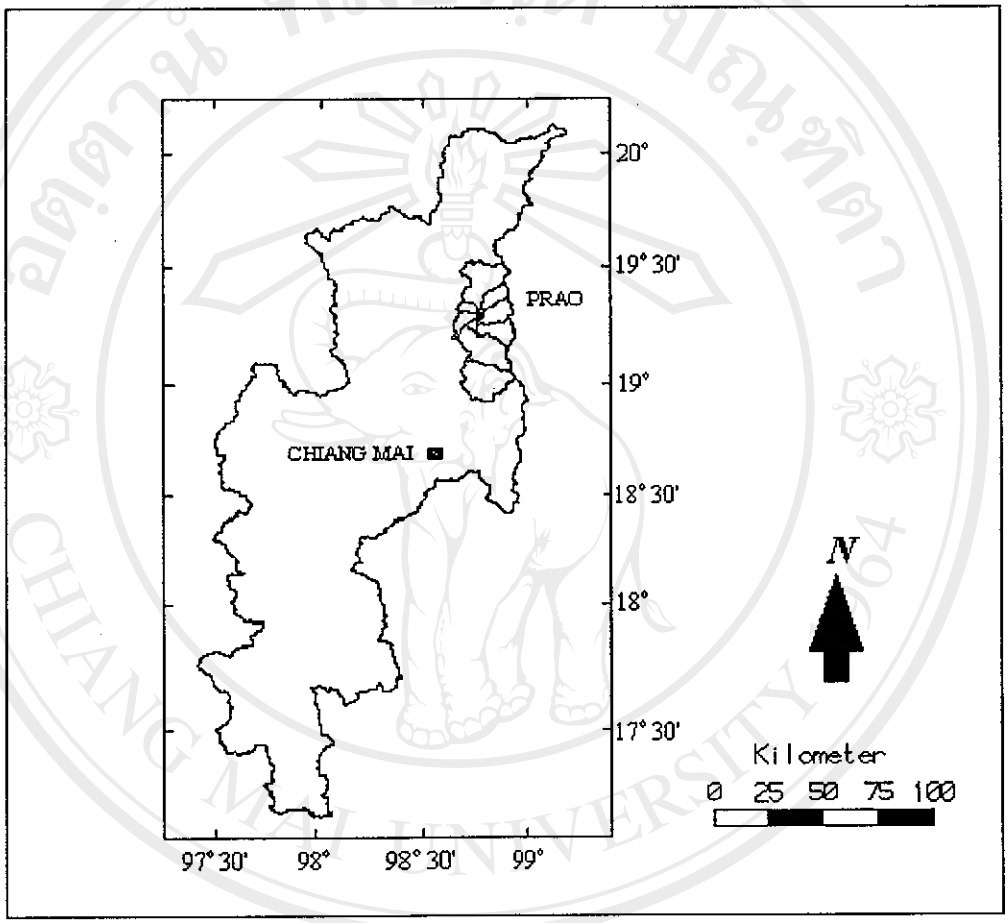

Figure 4. Chiang Mai province and Prao district.

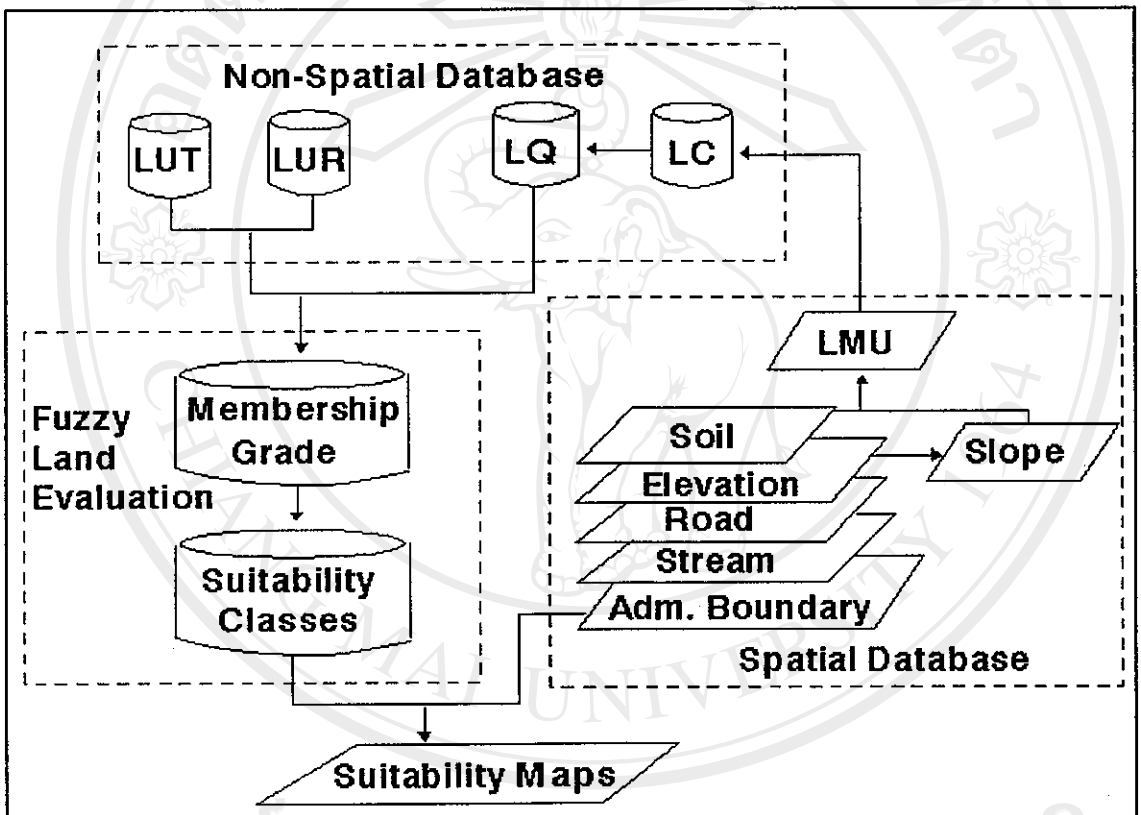

Figure 5. Framework of the study.

of land characteristics (LC) of the land mapping unit (LMU) created from GIS analysis and spatial database. The land characteristics were converted into land quality (LQ) according to FAO (1976). Other non-spatial databases include land utilization types (LUT) and land use requirements (LUR) for each LUT. All non-spatial databases were created and managed by using a commercial database management software called FoxPro version 2.0.

A computer program was written in the FoxPro source codes in order to evaluate each LMU according to Fuzzy land evaluation method by Wang et al. (1990), Law of Minimum and the Multiplication method FAO (1983), and a Modified Multiplication method used in Elbersen et al. (1983) . The results of the evaluation were stored in the databases as membership grades and suitability classes. These can be retrieved and displayed as suitability maps using IDRISI or PC ARC/INFO.

The system shell was designed to link all components together and was written as FoxPro's source codes. The shell is displayed as a menu both in Thai and English languages to facilitate different types of users.

3.3 Database Design and Implementation

3.3.1 Spatial Database

The objects in the spatial database are polygon and line. The soil series map, soil unit, and landuse maps were obtained from the Department of Land Development (DLD) and stored as polygons. The administrative boundaries were

extracted from the Royal Thai Survey Department (RTSD) and also stored as polygons. Line objects represent the roads, elevation and stream in the topographic map of RTSD. The above features in the maps were digitized in PC ARC/INFO at the scale 1:50,000. The contour lines were digitized at 200 meters interval with additional points of known elevation included. PC TIN software was used to generate the digital elevation model and later converted into slope map by the IDRISI program in raster format. The slope map in IDRISI format were also converted into vector format in PC ARC/INFO. The LMU were derived from the overlay in PC ARC/INFO using slope and soil coverages. The information on soil map, land use map, administrative boundary, road map, river map and contour map were described in data dictionary and source description in the Appendix Table 1-8. Appendix Figure 1 shows the spatial databases of the study area as organized and stored in the harddisk.

3.3.2 Non-Spatial Database

All spatial entities are described by their non-spatial attributes. These attributes data are land characteristic (LC), land quality (LQ), land utilization types (LUT) and land use requirement (LUR), they were stored in .DBF files format which can be updated, retrieved and managed by dBASE or FoxPro. They were used with lookup tables in PC ARC/INFO which can be related to polygons by using common key attributes.

The LC are the attributes of land that can be measured or estimated and the LQ are the attributes of the land that directly influence its suitability for one or more uses. Land utilization types can be defined as a specific way of using the

land. Land use requirements are the conditions of land necessary for the successful and sustained practice of a given LUT.

For the purpose of comparison between different description of LUR, the LUR of seven crops from CSR/FAO (1983) and DLD (1992) were stored in the database and shown in Appendix Table 9-15 and Appendix Table 16-22. The file structures in .DBF format of LUR and LUT are shown in Appendix Table 23 and 24 respectively . The LMU and LC file structure in .DBF format are shown in Appendix Table 25 and 26 respectively. These databases can also be used as attribute values in IDRISI by invoking ASSIGN commands in IDRISI. Appendix Figure 2 shows organization of non-spatial databases and the land evaluation programs as stored in the harddisk.

The procedure for Fuzzy, the Law of Minimum, the Multiplication, and the Modified Multiplication methods of land evaluation to be described in the next section would retrieve data on LUR and the LMU to produce suitability rating of each LMU. The membership grades estimated by the fuzzy method and suitability ratings were separately stored as databases which can be assessed by IDRISI or PC ARC/INFO commands to display as suitability maps.

3.4 Land Evaluation

Four methods of land evaluation are included in the system, Fuzzy land evaluation (Wang, 1990), Law of Minimum method, Multiplication method (FAO, 1983), and Modified Multiplication method (Elbersen, 1988). These methods were evaluated using two sets of LUR from CSR/FAO (1983) and DLD (1992).

3.4.1 Fuzzy Land Evaluation; Wang's Method

The first step of the evaluation process is to select the LUR. A computer program was written to convert textual values of LQ into the numeric values. For example, textual values of very low, low, medium, high, and very high were converted to the values of 2, 4, 6, 8, and 10 respectively. The soil drainage and soil texture were converted to 4 classes. Suitability classes of S1, S2, S3 and N were converted to 8, 6, 4 and 2 respectively. This process of conversion was defined by the procedure DEF_VAL in Appendix Table 27. The other land characteristics, i.e. temperature, rainfall, root depth, pH, salinity, and slope were normalized into the values ranging from 0 to 10 using the range between maximum and minimum value of these characteristics (Appendix Table 28). The maximum and minimum values were defined by the procedure CONSTANT in Appendix Table 27. The LUT was selected from the database (Appendix Table 24) and the LUR (Appendix Table 23) of that LUT was called by the procedure DEF_LUR in Appendix Table 27. The membership grades of each LMU was calculated according to equation (6). This could be done by the process of calculating Euclidian distance in Appendix Table 27. The result of membership grades of each LMU was assigned to the harden suitability class based on the class which has the highest value of membership grade and stored in the database called EVALUATE.DBF (Appendix Table 29). The membership grade of class S1 for each LUT was stored in EVALUATE.DBF and was used to calculate the relative suitability class based on equation (8). The results of fuzzy evaluation for absolute and relative suitability were stored in the database called WANG_F.DBF and WANG_F1.DBF (Appendix Table 30 and 31) for LUR defined by FAO (1983). The WANG_D.DBF and WANG_D1.DBF (Appendix Table 32 and 33) was stored the results of evaluation for LUR defined by DLD (1992). The values can be retrieved for displaying in IDRISI or PC ARC/INFO.

3.4.2 Law of Minimum

In this method, the LUT from the database (Appendix Table 24) and LUR (Appendix Table 23) of that LUT were called by the program EVALUATE.PRG (Appendix Table 34). The program asks for the source of LUR to be processed and defined the LUR by the procedure LUR_DLD or LUR_FAO (Appendix Table 34). The land quality for each LMU in Appendix Table 9-15 and Appendix Table 16-22 were converted to the values 1.0, 0.8, 0.5, and 0 (S1, S2, S3, N) by the procedure in the DEF_VAL. The minimum values among those indicated the suitability class for that LMU. The results of suitability rating were stored in the database called MIN_FAO.DBF or MIN_DLD.DBF (Appendix Table 35 and 36).

3.4.3 Multiplication Method

The LUT was selected from the database (Appendix Table 24) and LUR of that LUT was called by the program EVALUATE.PRG (Appendix Table 34). The description of LUR was requested by program in Appendix Table 34. The land quality for each LMU in Appendix Table 9-15 and Appendix Table 16-22 were converted to the values 1.0, 0.8, 0.5, and 0 (S1, S2, S3, N) by the procedure in the DEF_VAL. These values were multiplied for all LQ of each LMU according to equation (1). This could be done by the procedure DLD_CAL in Appendix Table 34. The results of the calculation were transformed into suitability classes defined as follows;

suitability class		calculated value
S1	=	> 0.80
S2	=	0.80 - 0.40
S3	=	0.40 - 0.20
N	=	< 0.20

The suitability classes were stored in the database called DLD_FAO.DBF or DLD_DLD.DBF (Appendix Table 37 and 38).

3.4.4 Modified Multiplication Method

Similarly, the LUT was selected from the database (Appendix Table 24) and LUR of that LUT was called by the program EVALUATE.PRG (Appendix Table 34). The other processes were the same as the Multiplication method. The values of LQ were multiplied for all LQ of each LMU according to equation (2). This could be done by the procedure ITC_CAL in Appendix Table 34. The results of calculation were transformed into suitability classes defined as above. The suitability classes were stored in the databases called ITC_FAO.DBF or ITC_DLD.DBF (Appendix Table 39 and 40).

3.5 System Shell

The purpose of the system shell is to provide a user friendly tool to display map and link different components of the land evaluation system. This was achieved by utilizing the capability of the FoxPro software to create the menu and link the relational database with GIS to produce the selected information. The hierarchical capability of database was used to create the system shell. Firstly, the main menu was designed to select location of the interested area. The selected location was organized in hierarchy starting from the province, district and subdistrict. The project area which does not coincide with administrative boundary can also be selected providing its boundary has been digitized and stored in the spatial database. Other menus include thematic map selection and land evaluation

method. The thematic maps menu was designed for the user to select the administrative boundary, soil, slope, present landuse, hydrology and road for displaying on the screen or printing out on the paper. The land evaluation menu allows the choices of the absolute and relative suitability. The absolute suitability was designed to list the names of LUT (crops) to be selected for land evaluation and contained three methods of evaluation namely Fuzzy, Modified Multiplication method, and manual suitability rating by DLD. The relative suitability evaluation follows Fuzzy land evaluation method to produce the suitability map. This system shell was written in FoxPro source codes that can be switched between Thai language and English language. The display in Thai language is possible through a public domained Thai driver called VTHAI version 2.01 developed by Faculty of Engineering, Chulalongkorn University. Appendix Figure 3 shows the system shell components which contain executable files of the shell, databases, and IDRISI images stored in the harddisk.

3.6 Outputs of Evaluation

3.6.1 IDRISI

The suitability classes from land evaluation were stored in the database with AREA_ID as the index variable to link with LMU images. These database (WANG.DBF, ITC.DBF) were converted into attributed value file (VALUE.VAL) in IDRISI through COPY command in FoxPro. To display the results as maps in the raster format in IDRISI, the system shell was used to call ASSIGN and COLOR commands in IDRISI. The ASSIGN command was used to link attribute value files (VALUE.VAL) to image files of LMU to create the maps

(OUTFILE.IMG) that show either absolute or relative suitability results. The COLOR command was used to display the map on the screen.

3.6.2 PC ARC/INFO

To display the similar result using PC ARC/INFO, different approach has to be used. In order to use the menu in the system shell to display the results of land suitability evaluation, plot files of the suitability maps for the selected area have to be created in ARCPLOT module of PC ARC/INFO and the DRAW command of PC ARC/INFO in the batch file was used to display maps on the screen. To facilitate the design of output maps, computer programs written in SML, a macro language of PC ARC/INFO was developed. Examples of SML to plot absolute and relative suitability output plot files are shown in Appendix Table 41 and Appendix Table 42.

3.7 Comparison of Outputs

Equation 9 was used to calculate the KHAT statistics for comparing the map outputs generated by different methods of evaluation. CONFUSE command in IDRISI was used to compute variance-covariance matrix and this matrix was later computed with LOTUS 1-2-3 to produce the KHAT statistics. The comparison of absolute suitability results was made among the Fuzzy land evaluation, Law of Minimum, Multiplication method and the Modified Multiplication method in each LUT. The relative suitability results comparison could be done only between the Fuzzy land evaluation and the present land use map.