3. MATERIALS AND METHODS

3.1 Study Area

The study area is located in the northwest of Chiang Mai Province, Thailand. It lies between 421900 mE, 2105550 mN to 428175 mE, 2110275 mN covers the area of about 2,970 ha, is about 150 km from Chiang Mai city (Figure 3.1). Its extent covers the area of 4 villages in Watchan subdistrict Mae Chaem district. The area is a mountainous landscape in the head of Mae Chaem watershed with elevations ranging from 950 to 1,500 m above sea level and the average elevation of 930 m. The people in Watchan are Karen, the largest ethnic group in northern Thailand. Paddy rice and swidden farming have been commonly practiced to produce staple food for the communities.

3.2 The Study Framework

The study framework shown in Figure 3.2 illustrates the major tasks to be achieved in order to examine and illustrate the situation of rice sufficiency and farmers' adaptive strategies for subsistent livelihood in relation to local natural resource use.

Since this study involved human and resource interaction, the biophysical and socio-economic components of the system have to be investigated. The three key components of this study are 1) average rice yield both paddy and upland rice, 2) rice cultivated areas and their changes over time, and 3) rice consumption needs, and farmers' adaptive strategies toward rice insufficiency problem. To obtain and analyze these information, integrated techniques were applied including crop cutting, aerial photographs interpretation, GIS tools and techniques, and formal interviewing.

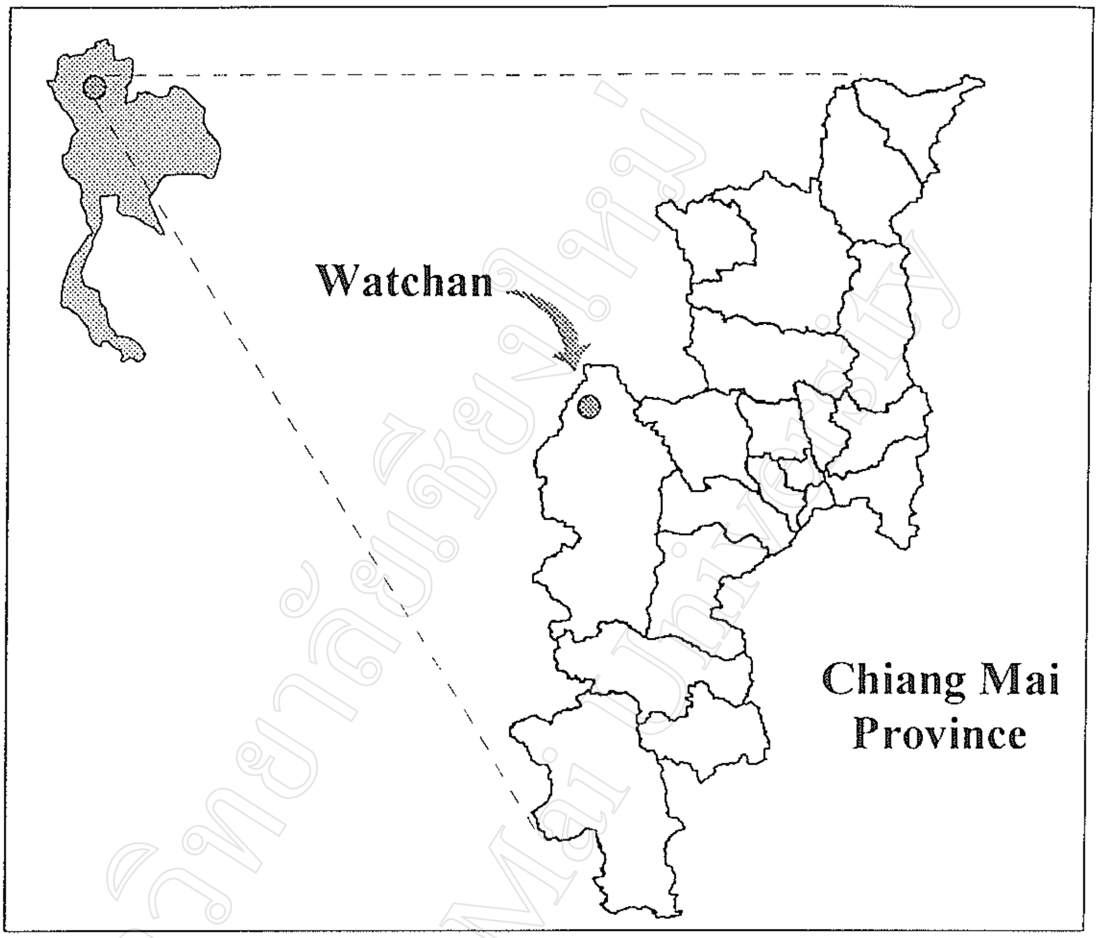

Figure 3.1 The study area.

3.3 Aerial Photograph Interpretation

To generate spatial data on size and location of rice cultivated areas and their changes over time, aerial photographs and a topographic map of the study area were employed. Aerial photographs available for the study area were obtained for 1954 (1:50,000), and 1983 (1:15,000). The interpretation of aerial photographs was undertaken by integration of ground survey, orthophoto and GIS techniques as illustrated in Figure 3.3. The technique produced land use maps which were classified into five land use categories. These were paddy, upland field, bush fallow, forest, village and other land uses.

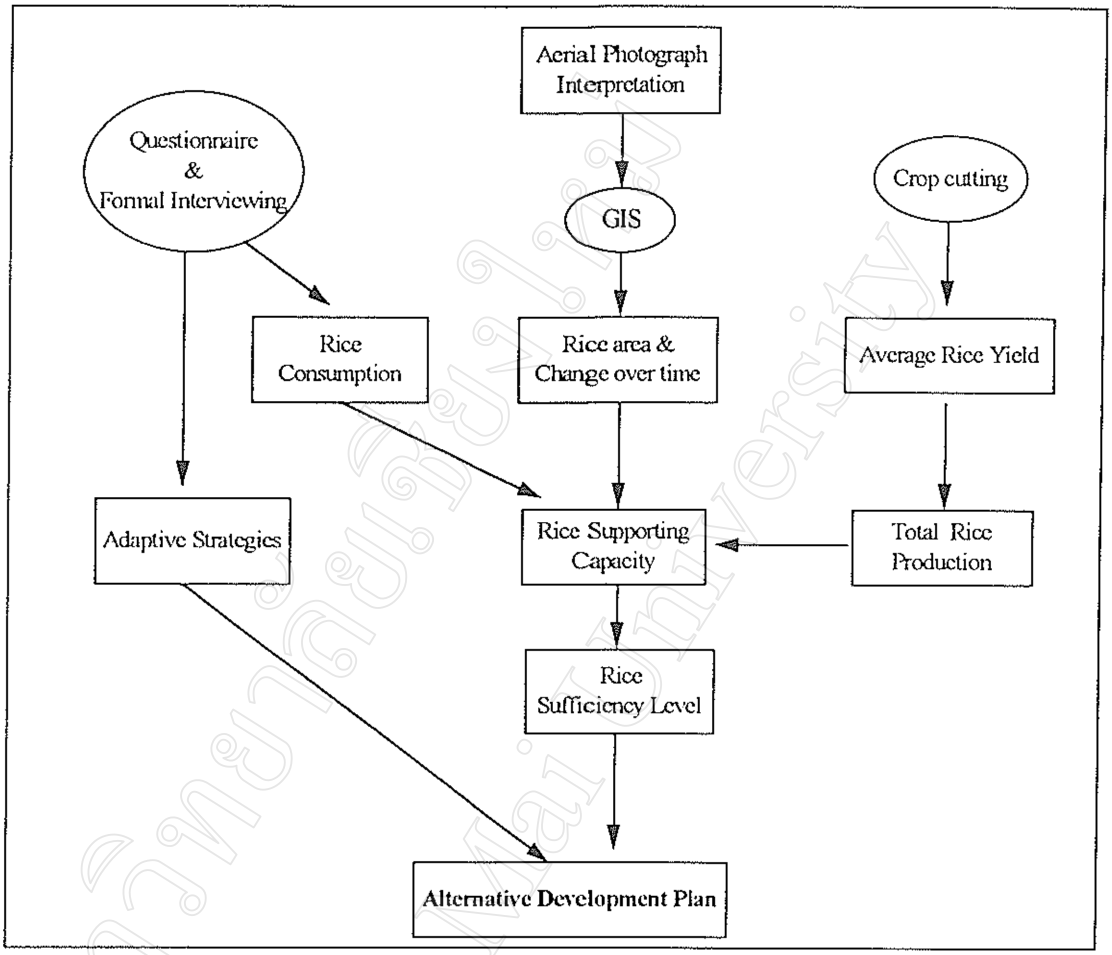

Figure 3.2 The study framework.

Aerial photograph, in general, does not present features true to scale because it is subject to tilt and relief displacement errors. Therefore geometric correction had to be done prior to conducting photo interpretation,. Steps and procedures to achieve these errors correction are described in the following sections.

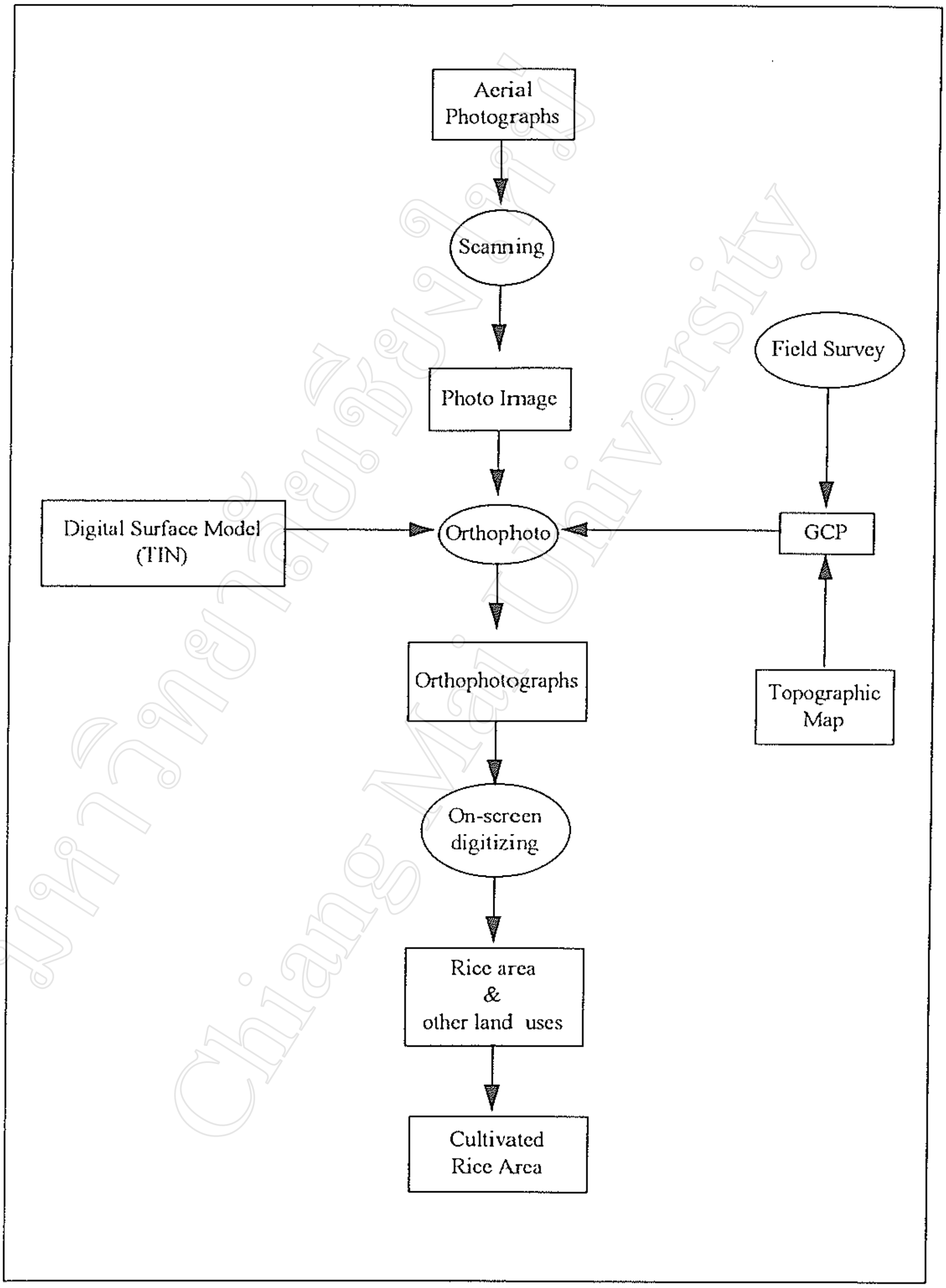

Figure 3.3 The process for estimating rice area and its change.

3.3.1 Scanning Aerial Photographs

The aerial photographs of the study area were scanned using a drum feed, black and white scanner. The scanner was attached to a personal computer (PC), with 80586 CPU, 16 MB RAM, 250 MB hard disk connected to Local Area Network (LAN) which was linked to TCP/IP networking. This networking provided communication and file transferring within and between PC and UNIX systems. The resolution of 200 DPI (dot per inch) was applied when scanning aerial photographs taken in 1954 due to its small scale, and 150 DPI was selected for the 1983 set of aerial photographs. After scanning process, digital photo images were created and stored in TIFF format files.

The number of aerial photographs which were selected for 1954 and 1983 were 4 (2 strips) and 16 (3 strips) respectively. The total number of scanned aerial photo images were 20 (Table 3.1).

Tables 3.1 Selected aerial photographs number for 1954 and 1983.

Date	Strip	Photo number	Number of Photos	Scale
4 Dec 1983	1	8601, 8602, 8603, 8604, 8605, 8606	6	1:15,000
	2	8653, 8654, 8655, 8656, 8657	5	
	3	9035, 9036, 9037, 9038, 9039	5	
18 Jan 1954	1	13297, 13298	2	1:50,000
	2	13260,13261	2	
Total			20	

3.3.2 Geocoding Digital Photo Image

Digital photo image files then were transferred to a SUN Sparc 20 workstation for creating orthophotographs using PhotoGIS Version 2. This software was developed by Salamanca Software Pty Ltd (Salamanca Software Pty Ltd., 1994) and run on UNIX Workstation environment with ARC/INFO Version 7.0.4 (ESRI, 1995).

There were 4 main steps which were necessary to generate orthophotograps. The first step was to select Ground Control Points (GCPs) and determine their coordinates. The second step was to create an empty ARC/INFO coverage that represented the extent of each aerial photograph by using four aerial photograph's fiducial marks as reference (TIC) points. The third step was to resection the photo image to obtain the adjusted camera parameters to be applied in the final geocoding step. The last step was orthophotograph to correct the error caused by relief displacement. This operation required a TIN of the study area and the parameter file retrieved from the resection operation.

3.3.2.1 Collecting Ground Control Points

Rectifying photo image requires and relies on GCPs, the known real world coordinates on an aerial photograph. GCPs were obtained from the field survey and a topographic map. Selected GCPs were chosen based on the following criteria i.e., their location must well distributed around the area on each aerial photograph, and there must be at least four GCPs for each aerial photograph.

The GCPs' coordinates were determined by two methods. The first was to read from 1:50,000 topographic map. This method was applied in case that GCPs were located in the areas that were very difficult to reach by field survey. However, most of the GCPs read from topographic map were the features that could be easily identified or obviously shown on the map such as mountain peak, merge point of streams, road intersection and other man made features.

The second method utilized the Global Positioning System (GPS) which was developed to identify the real world coordinate at any selected location by receiving the signal from NAVSTAR satellites. It is a satellite-based, radio navigation system operated by the U.S. Department of Defense (DOD). The GPS consists of 24 satellites in 12-hour orbits and the ground support necessary to maintain the system. GPS provides all-weather, worldwide 24-hour navigation capability (Trimble Navigation, 1992). The differential GPS was employed at the point that the survey could be made and there was no object that obstructed the satellites' signal. Thus in the location of dense forest with thick canopy, GCP might not be obtained by this method.

Differential correction is a technique using GPS satellites and a software to increase the accuracy of recording positions. It is based upon the fact that most signal errors that occur are common to all users (GPS receiver) within about 500 km. If a correction factor is applied to these errors, accuracy is greatly improved This technique requires that at least two receivers be used. The first receiver, the base station, is placed on a known reference position and records measurement data from all satellites in view. One or more other receivers, called rovers or remotes, collect position data at unknown locations using a subset of the satellites being tracked by the base. The compute GPS positions of the base receiver are compared to the known base station position, and the offset differences are used to increase the accuracy of the rover positions (Figure 3.4).

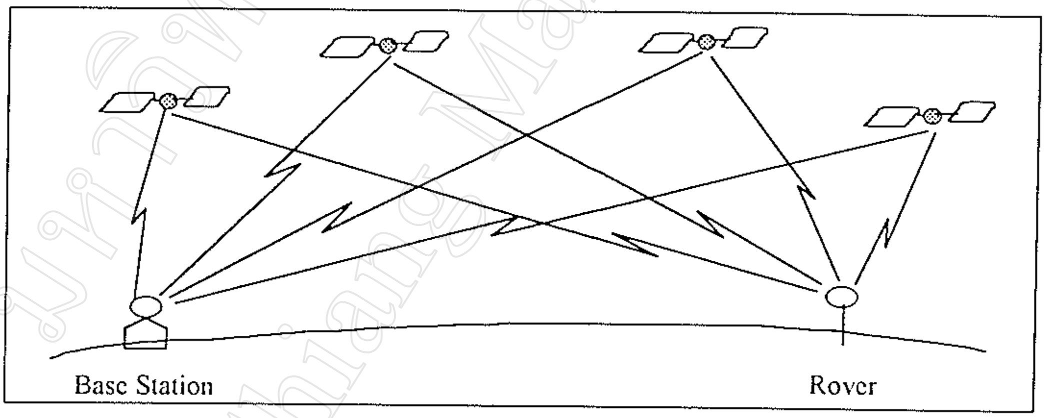

Figure 3.4 GPS differential correction.

(*Source: Trimble Navigation, 1992*)

This study employed two GPS receivers and a software for differential correction. The base station was CMT MC-V, 80C88 microprocessor based, with three 128 Kbyte RAM (Corvallis Microtechnology, Inc., 1991), connected to an attenna which was placed on a building at the Multiple Cropping Center, Faculty of Agriculture, Chiang Mai University which has known reference coordinate. The rover was GPS Pathfinder Basic Plus, a high performance 3- and 6-channels handheld receiver with the storage capacity of 256 Kbytes which can hold up to 10,000 positions. This model can provide accuracy of 2 to 5 meters after differential correction (Trimble Navigation, 1992).

These two GPSs were operated simultaneously while conducting GPS survey in the study site. The position data recorded by the rover then were transferred to a PC and processed the differential correction through PFINDER Software (Trimble Navigation, 1991) which is capable to handle file transfer, data manipulation, review, edit, display data, and process data differential correction.

3.3.2.2 *Creating an Empty Tic Coverage*

An empty coverage was created with the map unit based on the aerial photo coordinate system (mm). The coordinate values can be normally obtained from photo fiducial mark's value reported in the camera calibration report. This report should be available from Royal Thai Survey Department, the organization that took the photograph. Unfortunately, the available camera calibration report in the study area was not complete, thus the alternative method to create an empty coverage was applied instead. The detailed procedure is described in Appendix A.

The TIC coordinates in the empty coverage then was used to register the photo image to the same coordinate system so that the image could be combined with ARC/INFO coverage in the subsequent operation.

3.3.2.3 *Registeration and Resection the Aerial Photo Image*

Registration was achieved by using the collected GCPs which had the known coordinates on an aerial photograph image. Once these points had been defined, resection operation was carried out to determine the spatial location and the altitude of a camera at the moment an aerial photograph was taken.

In this process, the focal length of the camera taking the aerial photograph must be presented and the tolerance value needed to be specified. The tolerance value refers to the distance that GCP coordinates are allowed to be off from the calculated coordinate value. Resection will be successful if the error value falls within the tolerance value range. Thus, this value reveals the accuracy of geocoding photo image. This accuracy depends on ;

- the flying height and scale of the aerial photograph;
- the accuracy which the fiducial mark were taken;
- the accuracy of defining GCPs;

The result of resection process was a camera parameter file which was applied in the final step of geocoding the photo image.

3.3.2.4 Orthophoto an Aerial Photo Image

Orthophoto process required Triangulate Irregular Network (TIN) which represented the continuous elevation of the study area. The data had been already created by Ekasingh et al. (1995). The source of data used to generate TIN was the topographic map of the study area at the scale of 1:50,000 with 20 m contour interval.

The orthophoto process corrected for the relief and tilt displacement appeared on an aerial photo image. The output was the errors correction image or orthophoto image that was ready for further interpretation and digitizing to create a land use map.

3.3.3 Digital Orthophoto Mosaic

The orthophoto mosaic was produced by the geometric merging of many individual orthophoto created in the previous steps. The purpose of mosaicking was to produce a full orthophoto image that covered the entire study area. Since each individual orthophoto image had the same coordinate system, hence each piece of photo image could be stitched together. This process was implemented by using the GRID module in ARC/INFO.

3.3.4 Orthophoto Interpretation and Land Use Classification

Once tilt and relief displacement had been eliminated, and digital orthophoto mosaic had been done, the orthophoto image was used as the source for interpretation and digitizing to produce the land use map. The image was retrieved and displayed as background under ARCEDIT module in ARC/INFO. Zooming and panning options were mostly used to enlarge and scroll to the area of interest that needed to be interpreted and digitized.

Different land use types were interpreted and classified into five categories,

1. paddy
2. upland field
3. bush fallow
4. forest
5. village and others

Interpretation process was also enhanced by employing the stereoscope together with the on-screen interpretation. This helped differentiate the relative altitude of the features on the aerial photos, the pattern of different land use patches, and particular characteristics of different land use types.

The interpreted photo images of each year were digitized using Arc/Info to create land use coverages. These coverages will be further analyzed in the next section.

3.4 Land Use Change Detection

Two land use coverages representing land use types in 1954 and 1983 were obtained from interpretation and digitizing process. They were spatially cross-tabulated and summarized as a table showing land use classes during the above periods. Furthermore, the land use map of the study area classified by using Landsat TM data captured in 1994 (Ekasingh et al., 1995) was also analyzed and compared to determine the land use change during 1983 to 1994.

3.5 Assessment of Rice Sufficiency Level

The following relationship modified from Brush (1975) was employed to quantify aggregate rice supporting capacity of the study area which include both upland rice and paddy rice.

3.5.1 Upland Rice Supporting Capacity

The critical population size (person) supported by upland rice was defined as:

$$Pu = DA / [C(A+B)] \qquad \text{..........................(3)}$$

where A and B are cultivation period (year) and fallow period (year) respectively, obtained by formal survey using questionnaire. C is acreage needed per capita to provide average subsistence (ha/person). D is total amount of available arable land (upland rice area in ha) that was derived from previous aerial photo interpretation and GIS analysis.

3.5.2 Paddy Rice Supporting Capacity

The critical population size (person) supported by paddy rice (*Pp)* was defined as:

$$Pp = A / C \qquad \text{..........................(4)}$$

where A is total paddy area (ha) and C is acreage needed per capita to provide average subsistence (ha/person).

The overall rice supporting capacity of the study area is $Pu + Pp$.

3.5.3 Average Amount of Subsistence Rice Need

Part of the questionnaire in the next section was designed to investigate the total amount of rice that farmers need for consumption purpose. Rice sufficiency level then was assessed by comparing rice supporting capacity against number of population at present study period.

3.6 Crop Cutting

Average rice yield was obtained by using crop cutting technique for both paddy and upland rice. The sample plots were randomly selected from every valley and some upland patches owned by farmers in the study area. Seventy samples of 1 m^2 paddy rice and 51 samples of upland rice plots were collected at harvesting period. Yield and yield component were measured and calculated to determine average paddy rice yield and upland rice yields. The yield data were used to calculate rice supporting capacity in the formula above to obtain the number of people in the community that can be supported by rice produced in the study area.

3.7 Informal and Formal Survey

This study employed two interviewing methods. At the beginning, informal interviewing was conducted to gather general information and the background of community settlement, traditional agricultural practice, adaptation to the introduced technologies that occurred, and socio-economic status of the farmer in the study area.

Subsequently, information obtained from the informal survey was used to develop the questionnaires for later formal interviewing. Ninety five households, or about 36 % of the total households in the study area were randomly sampled for the formal survey (Table 3.2). The questionnaires were designed to test the hypothesized alternatives of the farmers to overcome rice sufficiency problem. The following adaptive strategies were investigated:

Table 3.2 Number of total households and sample size in study villages.

Villages	Total household	Sampled household	% of total household
Watchan	81	27	33
Den	72	26	36
Nong Jed Nuai	76	27	36
Huai Bong	34	15	44
Total	263	95	36

- limit population size by prohibiting the immigration;
- improve rice production system such as expand the cultivated area, adapt to new technology change (fertilizer, pesticide, herbicide, and adopt to new variety), shorten fallow period in upland rice system;
- turn to alternative cash crops and/or livestock that could provide the income to exchange for rice;
- involve in off-farm work to gain cash income;
- use other food sources e.g. pumpkin, maize, taro, wild yam etc.;
- strengthen local organization for food storage e.g. rice bank; and
- borrow or ask for rice from relatives or/and neighbors.

Thereafter, questionnaires were developed and pretested twice, then used for formal survey after the revision.

The data gathered from this formal survey were statistically analyzed and summarized in the form of comparative table and descriptive detail. Average rice consumption obtained from the formal interviewing was used in the rice supporting capacity formula discussed in the previous section to complete rice sufficiency assessment of the community.

Results of orthophotographs interpretation of the study area in 1954, 1983 and Landsat TM 1994 classification were also used as evidences to clarify the responses of farmers towards the expanded rice areas.