Chapter 3

Materials and Methods

3.1 Study area

Mae soon sub-district, located on Fang district, Chiang Mai province was selected as the study site of this study. With regard to the study area, most of the agricultural areas are extensively Sai Nam Pueng mandarin orchards. Current, the area has been now facing the serious situation of declining mandarin productivity.

3.1.1 Boundary

The study area locates on the latitude of 19° 48’ 23’’ N to 19° 54’ 13’’ N and longitude of 99° 2’ 36’’ E to 90° 11’ 45’’ E. Total area is approximately 52,962.3 rais. Northern border connects to Sansai and Monpin sub-districts, eastern border connects to Mae Kha sub-district, western border connects to Mae Ngon sub-district, southern border connects to Mae Ngon and Mae Ka sub-districts. The whole areas are administrative under Fang district, Chiang Mai province (figure 3.1).

3.1.2 Topographic conditions

The study area; separated into 2 main parts: mountainous and lowland areas. The mountainous part including forest area is located on the western part of the study area. The geomorphological area is undulating and gradually leveling towards Fang river, which divides Ma Soon and Mae Ka sub-districts. In this area, a soil is rather

unfertile. Crops and fruit trees were applied with agrochemical particularly fertilizers and pesticides at the high rates. With regard to the eastern Mae Soon sub-district, the area is mostly lowland and partly foothill along the Fang liver in the area, eastern study as lowland and foothill, soil is suitable for cultivation. Regarding the water reservation the area, Fang river and Mae Soon stream are mainly the two water sources in Mae Soon sub-district. Mae Soon stream is originated from the two sub-stream lines; Mae Soon Luong and Mae Soon Noi sub-streams (Fang district, Agricultural office, 2008). Geographically, the topographic condition of Mae Soon sub-district was shown in figure 3.2.

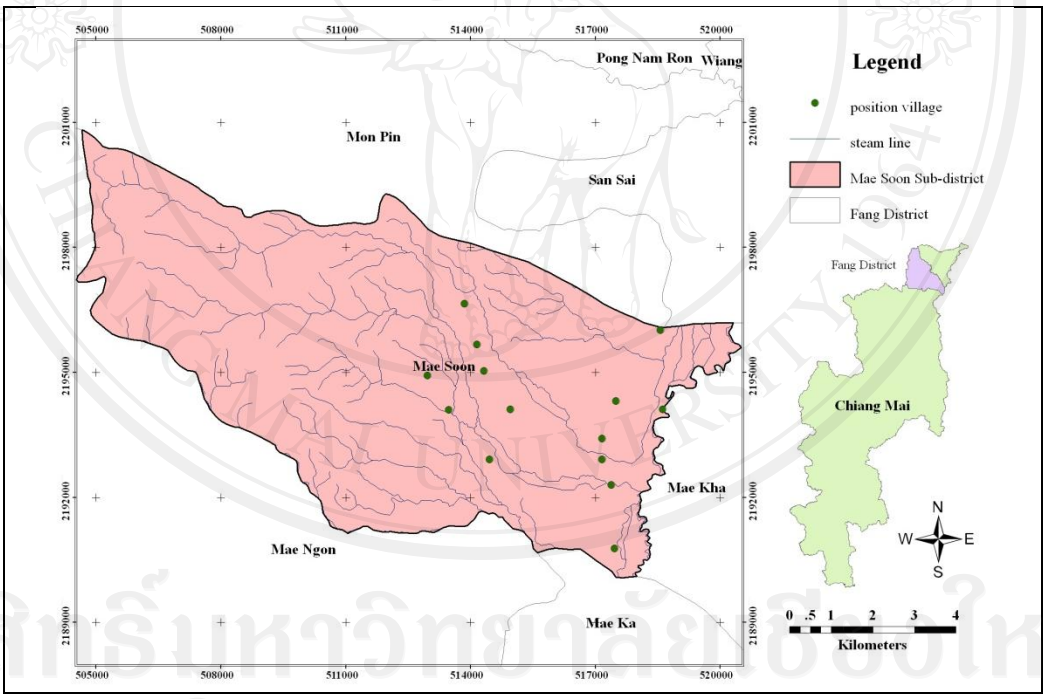

Figure 3.1 Boundary and neighboring administrative areas of the study site: Mae Soon sub-district

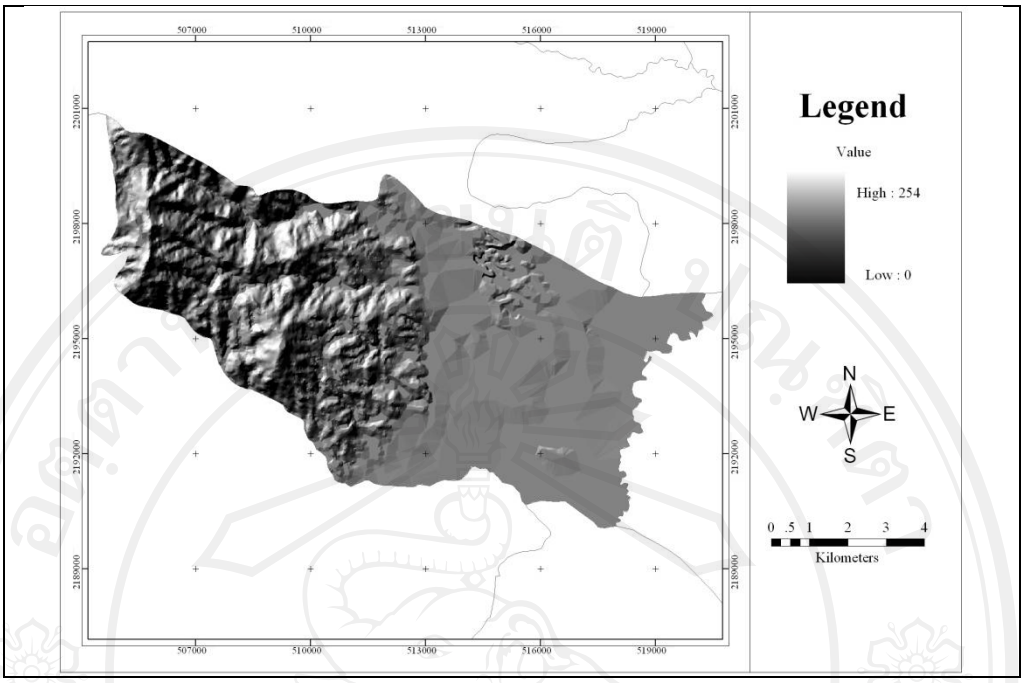

Figure 3.2 Topographic hill shade of Mae Soon sub-district

3.1.3 Climatic condition

Regarding to Mae Soon sub-district, the climate in the study area is under the influences of the north eastern and west eastern moonsoons. In general, this area has high intensity of rainfall and moist cool climatic condition all year round. However, in 2009, rainfall distribution was rather abnormal compared to previous years. The average monthly rainfall in 2009 started in April (figure 3.3). It rained heavily (336 mm) in May and then gradually reduced to 78.5 mm in June. During July to September it rained heavily with uniform distribution. In October, the amount of rainfall dropped about 50% compared to the previous period. Low average monthly rainfall was in November, December, January, February and March. The average monthly rainfall in May 2009 (336 mm) was higher than in 2008 (102 mm) and 2010 (166 mm), repectively. Total amount of rainfall in 2009 was lower than in 2008 and

with were 1,053 mm (2008), 992 mm (2009), and 1,255 mm (2010), respectively. Onprapai and Santasup (2010) used the rainfall data in 2009 as a factor to calculate water requirement of the mandarin trees in Mae Maow watershed where the watershed could be closed to Mae Soon sub-district. Thus the reported The representive area for the water requirement of mandarin citrus in Mae Soon sub-district.

With regard to the temperature in the study area, average in the cool dry season (figure 3.4) (December 2009-January 2010), average monthly maximum temperature in winter was between of 20-28°C and average monthly minimum temperature was about 10°C. In summer, during March-April, maximum temperature in day time was approximately of 34-35°C. After that, the temperature has decreased slightly to over 30°C until October. During in May to September, maximum temperature at night time was about 24°C. In October, the temperature at night time has dropped gradually to below 20°C and 15°C in October and November, respectively. The difference of temperature between day and night times at the study area is approximately 10°C during October and April. The temperature has affected on the peels of mandarin fruits was the changed from green to yellow-orange color.

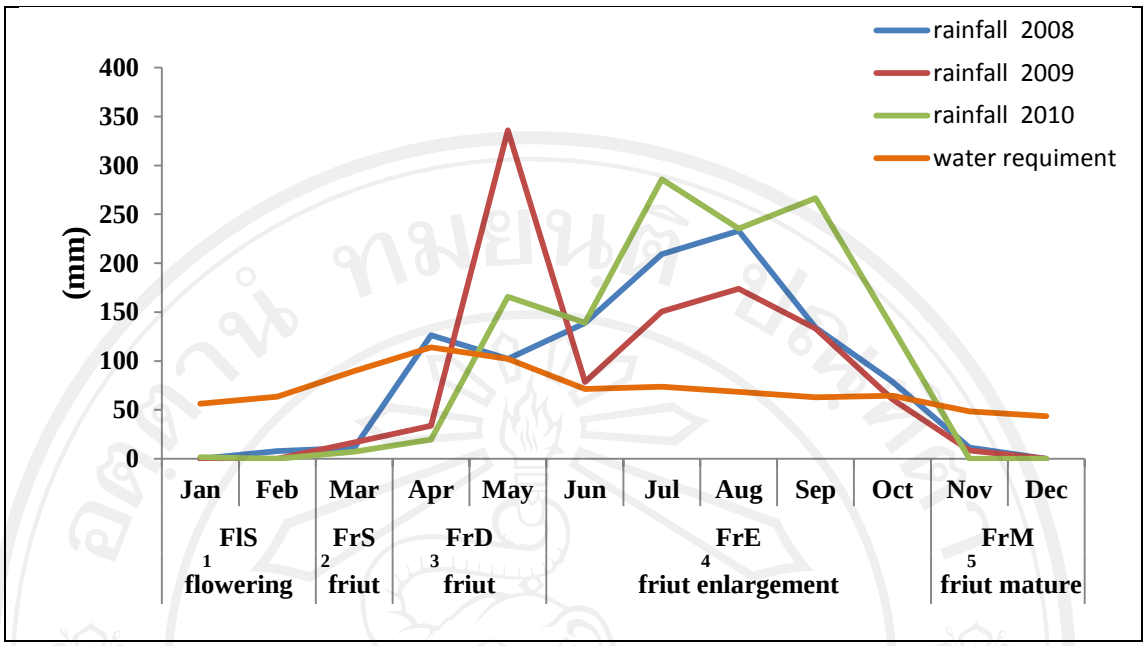

Figure 3.3 Average monthly rainfall in 2008-2010

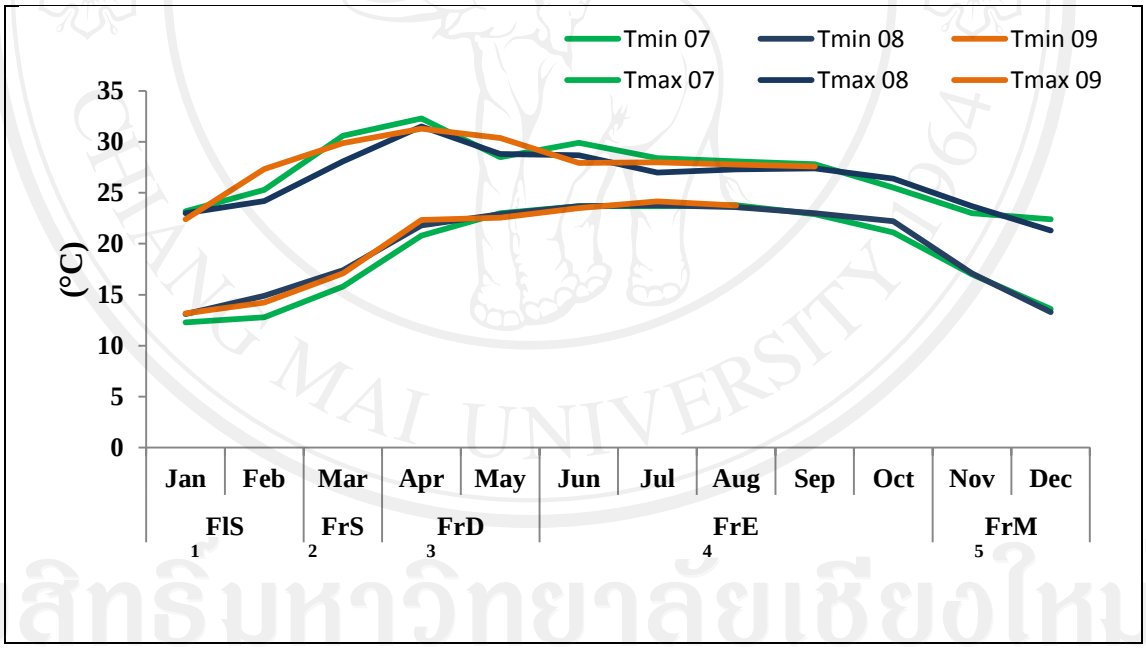

Figure 3.4 Maximum-minimum temperature in 2007-2009
[1]FlS: flowering stage, [2]FrS: fruit setting stage, [3]FrD: fruit development up to 2.5 cm diameter, [4]FrE: fruit enlargement, [5]FrM: fruit maturing

3.1.4 Socio – economic status

Regarding to social-economic contexts in the study area, Mae Soon sub-district consists of 17 villages. Population is totally 11,592 in which male are 5,741 while females are 5,851. Most of the population are Buddhists. Major occupation of the population are agriculture (62.8%). The remaining are commercial and labors. With regard to agriculture career, cultivated commercial crops are mainly fruit crops such as mandarin and litchi. Rice and garlic are also the major farming in the lowland. Other types of annual crops are also grown as the second crop in dry and sometime rainy season such as chili pepper and vegetables. In addition, Sai Nam Pueng mandarin and litchi major cash crops for Mae Soon sub-district.

3.2 Conceptual frame work

The conceptual frame work of this research is shown in the following diagram (figure 3.5):

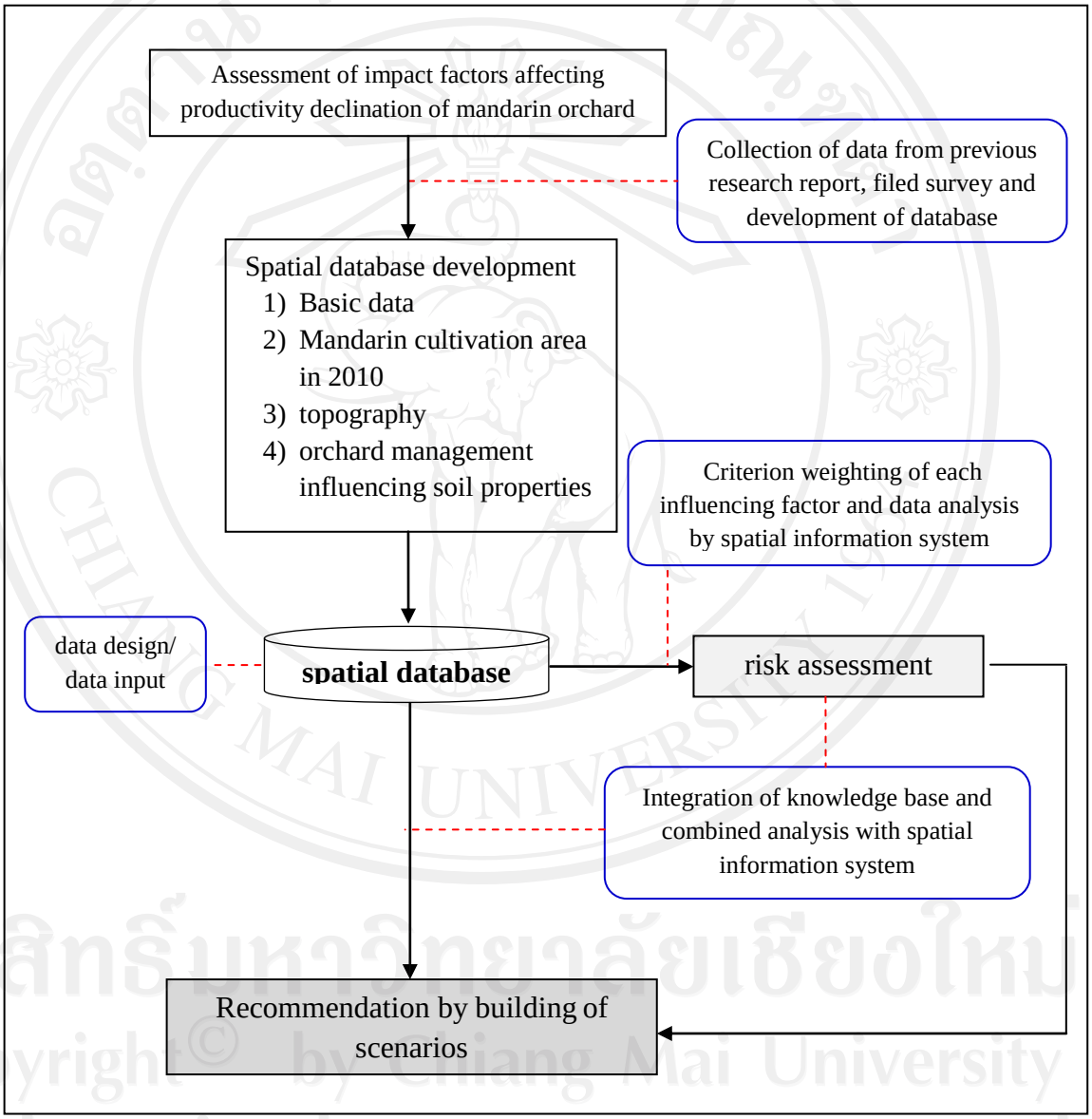

Figure 3.5 Conceptual framework

3.3 Research procedure

3.3.1 Data preparation and pre-processing

To identify mandarin cultivated areas in Mae Soon sub-district, the resolution of THEOS satellite multispectral with 15 meter-resolution and panchromatic were image in black and white with 2 meter-resolution were combined the ortho-photo with 0.75 meter-resolution. Ortho-photo for identifying mandarin cultivated areas in Mae Soon sub-district. THEOS multispectral image was taken on January 2010 (figure 3.6a) meanwhile, THEOS panchromatic image was taken on February 2010 (figure 3.6b). In addition, ortho-photos was taken in 2002, provided by Land Development Department (LDD). The ortho-photos were used as the reference for geometric correction of the obtained satellite images. Geometric correction of the orthophoto was previously done by Onpapai and Santasup (2009). Regarding to the geometric correction of THEOS satellite images, a minimum of Ground Control Points (GCPs) at least 50 points were placed systematically in distribution throughout entire study area. Polynomial equation was used for transforming of the distorted image coordinates to map the correct coordinates.

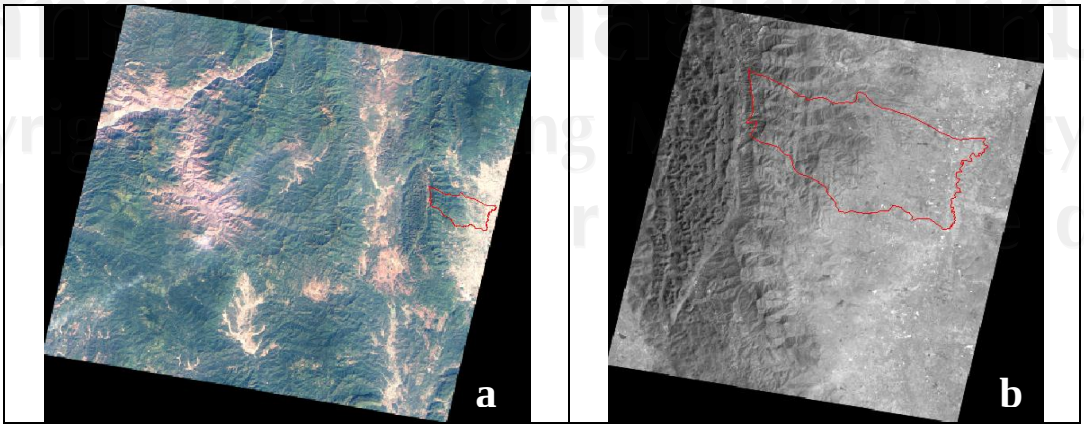

Figure 3.6. Multispectral (a) and Panchromatic (b) image of THEOS satellite

With regard to the panchromatic image, with the high resolution of 2 maters, the image could be combined with the multispectral image to obtain multispectral image additionally with the 2 mater-resolution. Generally, the new image is called “pan-sharpend image” using the technique of image confusion (Erdas,2007). As a result, the new image could result in a good quality in both high spatial and multispectral resolution. figure 3.7 showed THEOS satellite images before and after the processing of image confusion.

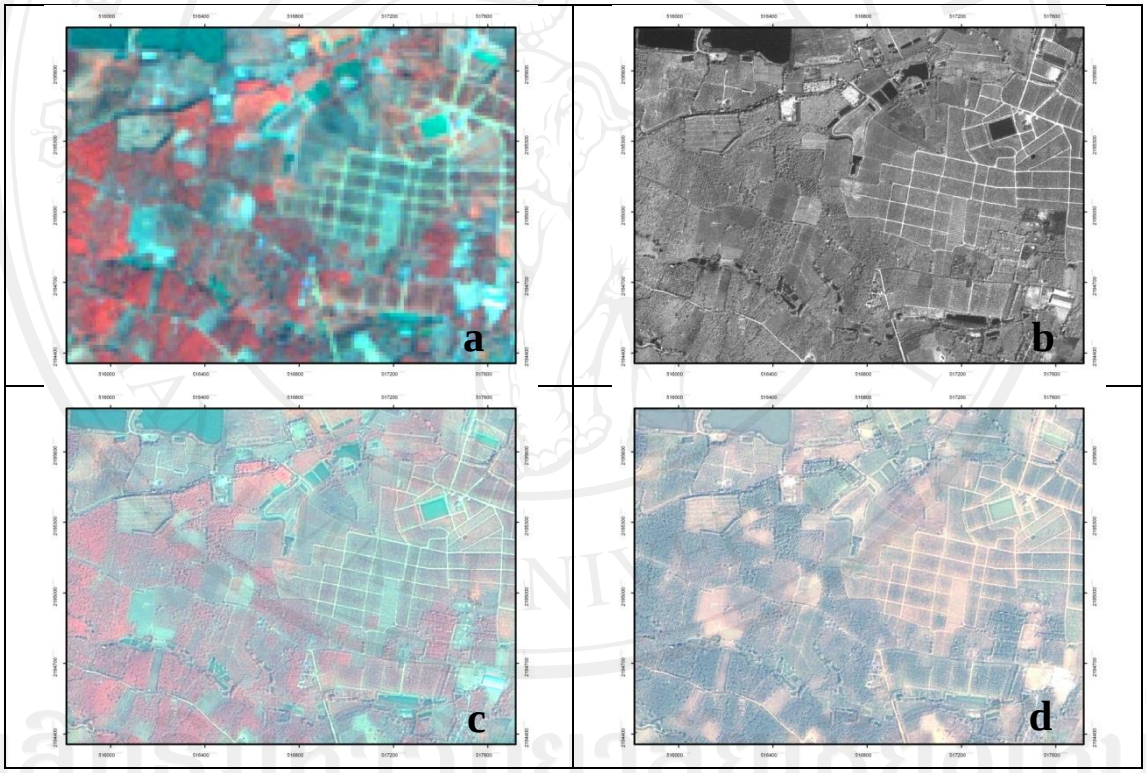

Figure 3.7 THOES satellite image with 15 meter resolution (a), panchromatic image with 2 meter resolution (b), false pan-sharped multispectral image (c) and true pan-sharped multispectral image (d)

3.3.2 Classification of mandarin orchards

In order to identify land use and mandarin orchard areas using satellite with Digital Image Processing. Visual interpretation to the satellite image was used in order to identify mandarin cultivated area. Generally, the technology of image classification had been conducted mainly Supervised and Unsupervised classification techniques. In case of mandarin orchards, land use classifications with supervised and unsupervised technique were conducted already with an unsatisfied result. According to Sasiprapa *et al*. (2007), the classification techniques (supervise and unsupervised classification) were not completely successful for the mandarin areas, due to some confusing spectral responses between mandarin orchards and forest areas.

Accordingly, as an optimal approach to classify areas, visual interpretation is another technique to conduct the land use classification. Base on the THEOS multispectral satellite image with 15 meter-resolution, basically, spatial visualizable objects, such as color, tone, size, shape, shadow, texture, site and environment were used in combination with the field positioning data of mandarin orchards using the GPS receiver. The technique was employed effectively for identifying big mandarin orchards, roads within the plots and reservoirs. In the case of small mandarin orchards where were connected by other fruit trees such as litchi and longan, the identification using shape, road and pond in the orchards were not possible. Thus, identification of the small mandarin orchards could be done using the pan-sharpened multi-spectral image combine between a panchromatic image with 2 meter-resolution and the multispectral image with 15 meter-resolution. Regarding the technique, litchi and

longan orchard with the clear spacing and non-definite shape could be separated from the small mandarin orchards as shown in figure 3.8.

For more details, obviously, spectral response of mandarin some areas were similar to the response of forest area except deciduous diptero carps forest areas. As a result, mandarin orchards could not be indentified dry correctly using supervised and unsupervised classification techniques. Furthermore, generally, spectral reflectance of the younger mandarin trees was usually mixed with soil reflectance because of less canopies of the trees.

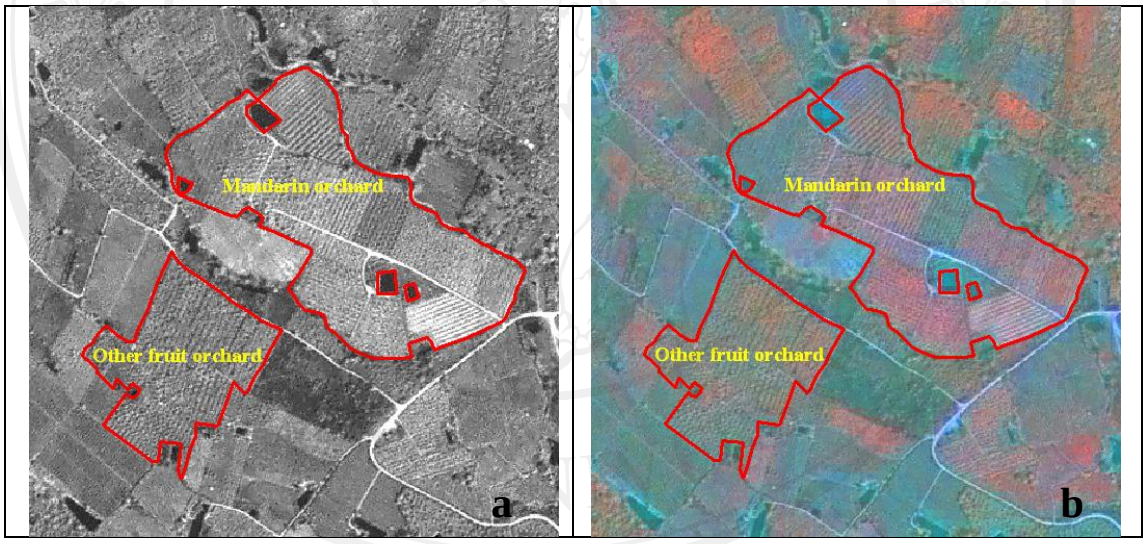

Figure 3.8 Comparison of panchromatic image (a) and pan-shaped (b) image of mandarin orchards and other fruit tree orchards

The total numbers of 904 mandarin farmers who obtained Good Agricultural Products (GAP) certificates from Department of Agriculture (DOA) in 2009 were selected for the suitable sampling farmers in this study. To select the target farmers, 200 questionnaires were distributed to the mandarin cultivated farmers by the head of each village in 16 villages of Mae Soon sub-district. The questionnaires could provide

farmer' interview about their orchards as follows; location, ages of mandarin including their orchards as follows; location ages of mandarin trees, orchard history, topographic condition, planting materials, available water in their orchards, schedule of irrigation, water sources, irrigation method, soil texture, fertilizer types, orchard management particularly fertilizer application in soil and foliar spraying rate, occurrences of plant nutrient deficiency and diseases, orchard productivity, expected factors influencing orchard productivity declination, fruit yields in 2008-2010, benefit and their opinion on proper soil for mandarin cultivation, soil improvement, water quality, pesticide application and the most important disease in their orchards. The detail of questionnaires was given in the appendix A. Based on the information given by the mandarin cultivated farmers in the questionnaires, 92 mandarin orchards which had the cultivated area less than 50 rais and were more than four years old were selected. The selective orchards were distributed throughout entirely Mae Soon sub-district. Expectedly, all owners of selective orchards were still taking care o ontain the productivity yearly.

Field survey was conducted to collect coordinate data of the 92 selected orchards using Global Positioning System (GPS) and visualized observe on the real condition of the orchards. The orchard coordinates data collected by GPS was recommended to locate recorded was in at the center of each orchard (Onpraphai *et al.*,2010).

After field survey, the 50 productive orchards were finally selected to collect soil property data, plant nutrient status and fruit yield and size. These selected fifty orchards located throughout entirely the area.

In April 2009, soil samples were collected in the selective mandarin orchards after the fruit harvest. With regard to a sampling in each orchard, three undisturbed soil samples were taken using soil core for analysis of physical properties such as bulk density (BD) and porosity. Within an orchard, a soil composite sample from ten random samplings was collected from the top soil (0-20 cm.) for analysis of soil chemical properties such as pH, organic matter (OM), cation exchange capacity (CEC), electrical conductivity (EC), available P (avai.P), exchangeable (exch.)K, Ca and Mg and extractable (ext.)Cu Mn, Zn and Fe. The methods of soil chemical analysis are indicated in table 3.1.

Table 3.1 Methods of soil chemical analysis

Parameter	Methods
pH	Soil : water ratio: 1:1, pH meter
OM	Walkley & Black
EC	Soil : water ratio: 1:5, EC meter
avai.P	Bray no.II extracting solution, color development by ammonium molybdate antimony potassium tartrate ascorbic acid , spectrophotometer
exch.K	NH_4OAe 1 M pH 7, flame photometer
exch.Ca,Mg	NH_4OAe 1 M pH 7, atomic absorption spectrophotometer
ext.Fe,Zn,Mn,Cu	DTPA extracting solution, atomic absorption spectrophotometer
CEC	Soil leaching with NH_4OAe 1 M pH 7

Three composite samples of the top soil (0-20cm) taken from 10 random sampling areas were analyzed for microbial biomass using chloroform fumigation extraction (Nunan *et al*.,1997).

Evaluating criteria reported by Supakumnerd *et al.* (2005) were used for soil chemical properties, meanwhile soil total porosity was evaluated as suggested by Panomtaranichagul (2008) and Bulk Density was evaluated according to Land Development Department (LDD, 1999).

Mandarin leaf samples from each orchard were collected twice in April and July, 2009 when the mandarin fruits got the age of 3 and 6 month, respectively. A hundred mandarin leaves were taken from ten trees per orchard. Collected leaf samples were the third leaves from the top of non fruit bearing twigs. Four twigs from each tree located in four different directions were of the representative for collecting leaf samples. The collected leaves from each orchard were combined together into one sample and then washed firstly using tip water followed by deionized water before drying in a hot air oven at 70 ˚C. The dried leaf samples were ground by grinding machine before analyzing to find out of N, P, K, Ca, Mg, Cu, Fe, Mn, Zn and B.

According to Walinga et al. (1989), in order to analyze N, the leaf samples were digested in digestion block according to the method of Walinga *et al*.(1989) while dry ashing was used for the other plant nutrients. After the digestion, N concentration of the digested samples were determined by indophenol blue method (Novozamuskey *et al.*1974). Ammonium vanado phosphor molybdate method

(Suwanawong, 2001) was used for P determination of the samples after dry ashing, while B was determined colorimetric ally by Azomethine-H method (Numan *et al.*,1997). Determination of K was done by flame photometer (Helmke and Sparke, 1996) and atomic absorption spectrophotometer was used for determination of Cu Mg Cu Zn and Fe (Walinga *et al*.,1989). The details of plant analysis are given in the appendix. The status of N, P, K, Cu, Mg, Fe, Mn, Cu, Zn and B were evaluated according to the criteria proposed by Smith, 1966, Koo *et al.* 1984; Malevolta 1989 which were cited in World Fertilizer Use Manual ; citrus (1992).

3.3.3 Collecting data of orchard management

In order to collect the data of orchard management, the 50 selected farmers were interviewed using questionnaires during collecting soil samples. The collecting data is as follows;

1) farmer knowledge of soil and fertilizer applications of flairs, ideal soil for mandarin cultivation, usefulness of compost and manure liming effect of pH of water on effectiveness of pesticide and foliar spraying, criteria for spraying of insecticides and the most important diseases,
2) topographic and environmental conditions of the orchards including land preparation for the planting,
3) planting materials,
4) water sources, availabilities of required water for mandarin including irrigated schedule and method,

5) soil management such as checking of soil quality, kinds and rates of fertilizer applications for soil and foliar spraying, application of manure or compost, mulching, criteria of fertilizer application and liming,
6) occurrence of plant nutrient deficiency,
7) evaluation of the mandarin productivity,
8) expected causes of the mandarin orchard collapse,
9) mandarin fruit yields in 2008-2010,
10) occurrence of the greening disease symptom of mandarin fruits,
11) occurrence of declination of mandarin trees and distribution of the declined trees in the orchard,
12) future plan in case of orchard collapse

Each parameter of farmers' management was evaluated by calculating the frequency (% of the total numbers).

3.3.4 Collecting data of fruit yield and sizes

Data of fruit yield was collected two times, firstly at the seasonal fruit yields in 2009 and during November 2010 and January 2011 which was obtained by farmers' interviews. The data was collected by counting the numbers of mandarin fruits on the trees using five sampling trees per orchard. Five fruits tree with the major average fruit were randomly selected for measuring fruit diameter using Venire Caliper. The Natural Standard of Agricultural products and Food (Thai Agriculture commodity and food standard; TACFS-50) is shown in table 3.2. The data of harvested fruit yields was combined with the calculated yields to get the total in-season fruit yield for 2010/2011.

Table 3.2 National standard of mandarin fruit

Fruit no.	Fruit diameter (mm)	No. of fruits/Kg
3	52-57	16
4	57-60	12
5	60-65	10
6	65-70	8

Source: Office of National Standard of Agricultural Products and Food (2009).

3.3.5 On farm trial

One farmer's orchard located in Pong Num Ron sub-district, Fang district was selected as the experimental site for on-farm trial in order to find out whether it was possible to reduce fertilizer application rates for mandarin fruit production. The orchard is slightly sloping area with eastern topographic aspect and a good water drainage. Obviously, total mandarin trees in this orchard can definitely get the sun light from early morning.

'Sai Num Pueng' mandarin trees in this orchard got the age of 4-5 years. They were grown on troyer root stocks, approximately of 54 trees per rai (338 trees /ha). Before the trial, the soil had pH of 5.0, and contained high level of soil organic matter (2.5-3.0%), very high level of available P (>100 mg P/kg) and high level of exchangeable K (100-300 mg K/kg).

On farm fertilizer trial was conducted during June 2008- January 2009. The experiment design was randomized complete block with 5 replications and 4 treatments. In the first treatment, soil application of N, P and K fertilizers (table 3.3) and spraying of foliar fertilizers (table 3.4) according to farmer's practices (NPK+ FL) were used. In the other three treatments, soil application of P and K fertilizers

were omitted because the soil in the experimental plots were rich in available P and exchangeable K. Urea was applied into the soil for the second and third treatments at the same rate of N as that in treatment 1. The same foliar spraying of fertilizer and hormone as used in treatment 1 was applied in the second treatment (-PK+N+FL) while foliar spraying of trace elements was used according to nutritional status of the leaves by leaf analysis (-PK+N+fl) in the third treatment. In the forth treatment, the rate of N removal by the expected mandarin fruit yield (70 kg/tree) (Supakumnerd *et al.*, 2005) plus additional N to compensate N lost by leaching about 40% of N removal by fruit yield. The same foliar spraying of trace elements as used in Treatment 3 was applied in the forth treatment (-PK+n+fl). In the first and second treatments, foliar spraying of fertilizers and hormone was done every 7 days throughout the experimental period. According to leaf analysis data before the application of foliar spraying, the mandarin trees from treatment 4 were deficient in Zn. Thus, 'Fol-Max' foliar fertilizer containing Zn. (70%Zn) was used in treatment-3 and 4. Spraying of Fol-max four times from the beginning of the trial to 15 October. After that no foliar spraying of Zn was used because the leaf analysis data indicated that the tree in treatment 3 and 4 had sufficient level of Zn. The rate of N, P_2O_5 and K_2O applied to soil in each treatment was shown in table 3.5 For each treatment in each replication, there was one row of 11-13 mandarin trees. The first and the last trees in each row were considered as the borders. Throughout the experimental period, sprinkle irrigation and pest control by farmer practices were used. The collected data were in season fruit yields harvested in December 2008 and January 2009, fruit sizes and the content of total soluble solid or sweetness. The treatment effects were

analyzed by F-test and the differences among the means were compared by least significant difference (LSD) at $P<0.05$.

Table 3.3 Fertilizer application by farmer

Date/Mo/Yr.	Fertilizer grade	Rate of application (kg/tree)
27 June 2008	13-13-21:15-15-15 (2:1)	1.0
9 August 2008	13-13-21:15-15-15:0-0-22 (1:1:1)	1.0
30 August 2008	dolomite	2.5
27 September 2008	13-13-21:0-0-22 (1:1)	1.0
20 October 2008	13-13-21:0-0-22 (1:1)	1.0
20 November 2008	22-0-0	1.0
13 December 2008	Hi-mag	1.0
20 December 2008	13-13-21:0-0-22 (2:1)	1.0

Table 3.4 Foliar spraying of fertilizers and algal extract by farmer practice

Product	Rate of application /ha
CaB	1.50-3.0 L
Mg	0.75 L
Algal extract	1.88-3.00 L
Alzaiger[1/]	0.38-0.75 L
Amino acid	3.00 L
Super K	4.50 kg
Fetilon[2/]	0.19-0.38 kg

[1/] Alzaiger contains Zn Mg and Mn

[2/] Fetilon contains MgO, S, Fe, Mn, Cu, Zn, B and Mo

Table 3.5 Rate of N, P_2O_5 and K_2O applied in to the soil for each treatment

Treatments	Rate of application (kg)					
	N		P_2O_5		K_20	
	per tree	per ha	per tree	per ha	per tree	per ha
1) NPK+FL	0.67	226.13	0.45	151.88	1.03	347.63
2) -PK+N+FL	0.67	226.13	0	0	0	0
3) -PK+N+fl	0.67	226.13	0	0	0	0
4) -PK+n+fl	0.08	28.12	0	0	0	0

3.3.6 Spatial database development

Input data (figure3.9) were obtained from official documents, research report in the study area, field survey, farmers' interviews, THEOS satellite, orthophoto and soil analysis of selected fifty farmers. The details of map layers and types of both spatial and attribute data including the scale of constructed map and sources of information were shown in table 3.6. The steps of development of spatial database of basic data of the study area were shown in figure 3.10.

Table 3.6 Detail input of data

Feature class	Type of data		Map scale	Sources
	Spatial data	Attribute data		
1.basic data of study area				
1.1. administrative boundary of sub-district and village position				-office of agricultural economic (2002)
-sub-district boundary	-polygon	-area of sub-district	1:50,000	- Royal Thai Survey Department (RTSD)
-village position	-point	-village position	1:50,000	-LDD (1988)
1.2. steam line	-line	-steam name	1:50,000	-LDD (1988)
1.3. soil series	polygon	-drainage -runoff -permeability	1:25,000 1:25,000 1:25,000	LDD (1988)
1.4. topography -elevation -slope	polygon	-elevation -slope	1:25,000 1:25,000	the project of " soil and water resources management appropriately with mandarin production (2553)
2. land cover	polygon	mandarin cultivated area in 2010	1:25,000	satellite image and field survey
3. information fifty sampling mandarin orchards				
3.1. boundary sampling orchards	polygon	boundary sampling orchards	1:25,000	satellite image and field survey
3.2. soil quality		-pH, CEC,OM, Avai.P, Exch.K -bulk density, porosity		soil analysis data
3.3.orchard management		-general information -fertilizer use -basic knowledge of management -water use		farmer interview and field survey
3.4. leaf nutrient Status		%N ,%P, %K, %Ca, %Mg, %Fe, %Zn, %Mn, %Cu, %B		plant analysis
3.5.fruit yield and fruit quality		-fruit yield (kg/tree) -fruit size (cm) -%fruit from greening disease infected tree		farmer interview and field survey

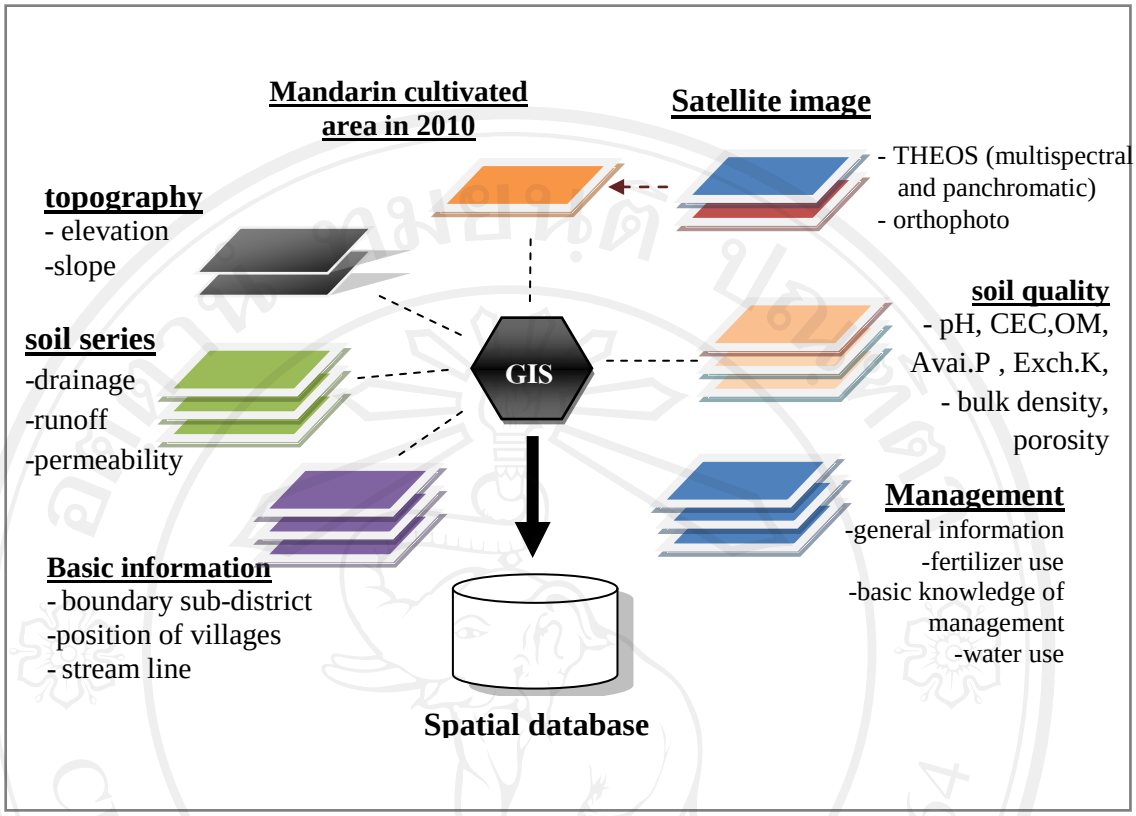

Figure 3.9 Method development

1) Basic data of study area

1.1) administrative boundary of sub-district and village position

Administrative boundary of Mae Soon sub-district was received from Office of Agricultural Economics, Ministry of Agriculture and Cooperatives and the village positions were received from Land Development Department and Office of Agricultural Economics with the map scale of 1:50,000 in Universal Transverse Mercator (UTM) Zone 47 N on 1975 Indian System. The Indian System was converted to WGS84 (World Geodetic System 1984) by using ArcGIS 9.2 (ESRI, 2007) before clipping of Mae Soon sub-district from the entire area. The positions of villages in Mae Soon sub-district boundary were rechecked by using the map of Mae Soon sub-district from Mae Soon sub-district Administration Organization and filed

survey before correcting the data (name and location) based on the existing data in the study area.

1.2) stream line

Stream line was developed from information of Land Development Department, Royal Thai Survey Department and some of Mae Soon sub-district Administration Organization with converting Indian system to WGS84, after that input and update steam line, clipping of Mae Soon sub-district from the entire area of Steam line.

1.3) soil series

Spatial soil database of the study area had received from Land Development Department (1999). Firstly, converting the datum from Indian 1975 system to WGS84 using ArcGIS 9.2 (ESRI, 2007) and then the soil series existing in Mae Soon sub-district boundary spatial database. The obtained data was compared with the document of Land Development Department (1999) for data connection and reliable information.

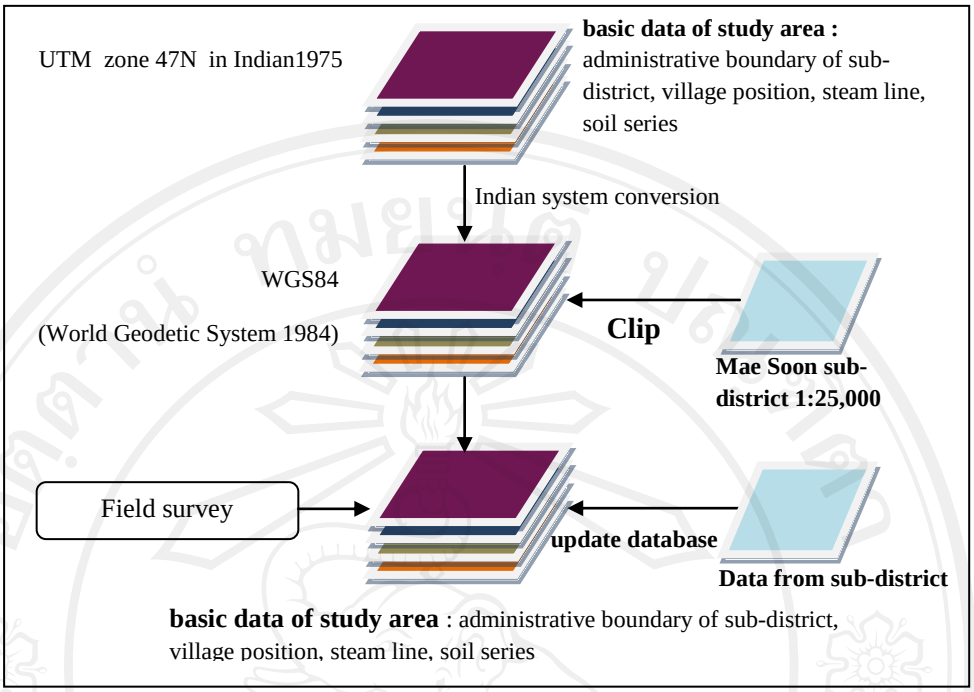

Figure 3.10 Step for development of spatial database of basic data of study area

1.4) Topography : slope and elevation

Digital Elevation Model: DEM was used for development of spatial database of elevation and slope. The resolution of DEM was adjusted to 10 meters using ERDAS imagine 8.4 program in order to fit the other spatial database with the scale of 1:25,000. Analyzed and developed contour lines of the Land Development Department. According to the topographical map scale of 1:50,000 of Royal Thai Survey Department, Mae Soon sub-district boundary spatial database was overlaid to clip out Mae Soon sub-district topographic spatial database using 3D Analysis module of ArcGIS 9.2 program (ESRI, 2007).

The spatial databases of slope was developed from DEM using 3D Analysis module of ArcGIS 9.2 program (ESRI, 2007) and then classify the slope and elevation by using spatial analysis module. Reclassification of the spatial database of slope and elevation was done in order to get the new set of data expressing slope unit as percentage and elevation unit as meters of mean sea level for risk assessment in the further step.

The correction and accuracy of the data were checked by using topography map of Royal Thai Survey Department.

2) Spatial database of mandarin cultivated area

In item 3.3.2 the details of identification of mandarin cultivated area of Mae Soon sub-district were described.

3) Information of fifty sampling mandarin orchards

The coordinate of each selected mandarin orchards from Global Positioning System (GPS) obtained from field survey was used to develop spatial database of boundary of the sampling orchards. Then polygons of boundary of the fifty selected orchards were constructed by using ArcGIS 9.2 (ESRI, 2007).

Since the fifty selected mandarin orchards were subset of Mae Soon sub-district, thus spatial database of slope elevation including other soil properties such as runoff, drainage, and permeability of these orchards could be developed by clipping out from those of Mae Soon sub-district.

In this study, drainage and permeability of the soil were considered as soil management influencing physical soil properties. Some of the soil chemical properties such as pH, soil organic matter, available P and exchangeable K which were also soil

management influencing properties were used as the input data for development of spatial database of fifty selected orchards. The other data such as methods of orchard management by the farmers, plant nutrient status in the index leaves, fruit yield, fruit size, exchangeable Ca and Mg and extractable Mn, Cu, Fe and Zn and microbial biomass were the attribute data.

3.3.7 Risk assessment of the factors affecting productivity declination of mandarin of mandarin orchards

AHP or Analytical Hierarchy Process (Saaty, 1980) which is the multi-criterion decision analytical process was used for this working step. The AHP process (figure 3.11) consisted of the analytical steps as follows;

1) criterion setting by considering of the cause of productivity declination of mandarin orchards in the study area based on the data from field survey and farmers interview,

2) criterion standardization by selecting of the factors contributing to each productivity declining cause, dividing the selected factors into classes according to the suitability and limitation for mandarin cultivation and categorizing each of them into risky classes according to its contribution to each productivity declining cause,

3) criterion on weighting of each factor related with each productivity declining cause based on the importance of the factor and comparing the significance of evaluated factors by using the program developed by Ekasingh *et al*.(2006) in only to help making the best decision.

Calculation of the degradation index of each studied orchard from the standardized factors for each productivity declining cause by using the analytical

method proposed by Malczewski (1999) and categorizing the calculated degradation indices for each cause into 5 risky classes with the same divided interval from the highest to the lowest. The interval for categorizing the risky class of each productivity declining cause of mandarin orchards was calculated by using the following formula:

$$\text{risky class interval} = \frac{\text{maximum value} - \text{minimum value}}{\text{no of risky class}}$$

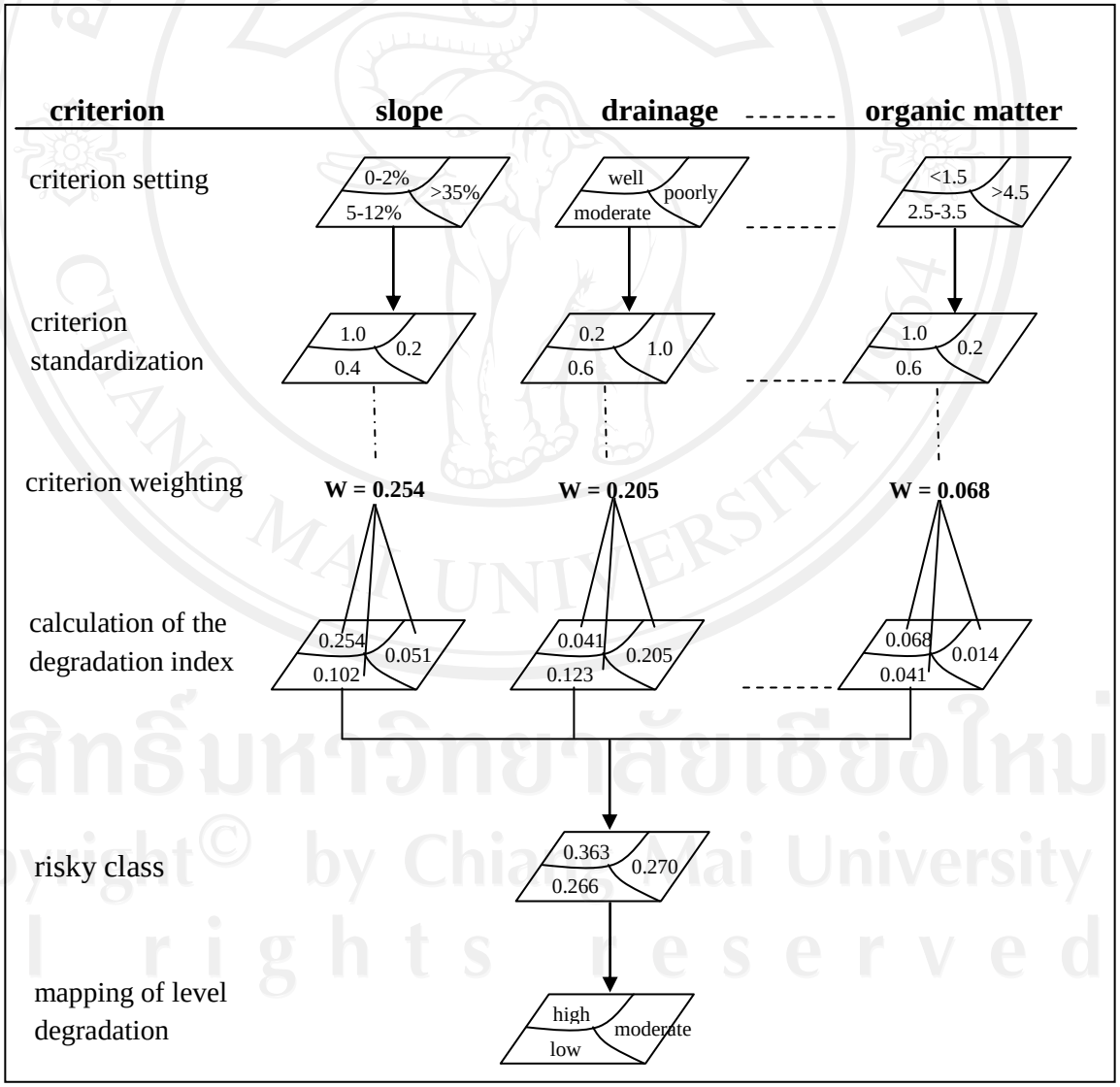

Figure 3.11 The multi-criteria analysis with GIS

3.3.8 Recommendation of the proper management of mandarin orchard according to the topographical condition and soil quality of the cultivated area

The knowledge from farmers' experiences, expert, information from research reports were integrated by GIS system in which the data of risky levels of productivity declination of mandarin orchards at the present stage were compared with the future scenario in order to propose. The proper management of mandarin orchards according to the existing topographical condition and soil quality. The effectiveness of the proposed orchard management was considered from the reduction of percentage of risky area compared to the whole mandarin cultivated area.