CHAPTER 2

RESEARCH METHODOLOGY

2.1 Framework of the Study

The major effort in this study is to evaluate the proper rice management strategies that accomplished by incorporating biophysical data into the crop model to simulate rice yields for different scenarios (based mainly on the weather condition). Such rice yield per land unit can be used directly in the stochastic dominance analysis when farmer's objectives of rice self sufficiency is considered. The varying rice prices and inputs' price were then incorporated to derived gross income from rice per land unit and used in the stochastic dominance analysis when farmers' objective of maximizing rice farm income is considered. Figure 2.1 shows the theoretical concept of the main component of this study.

According to the theoretical framework, two major theoretical concepts covered in this study, i.e. the crop growth model and stochastic dominance analysis. Details of these two concepts are described the following sections.

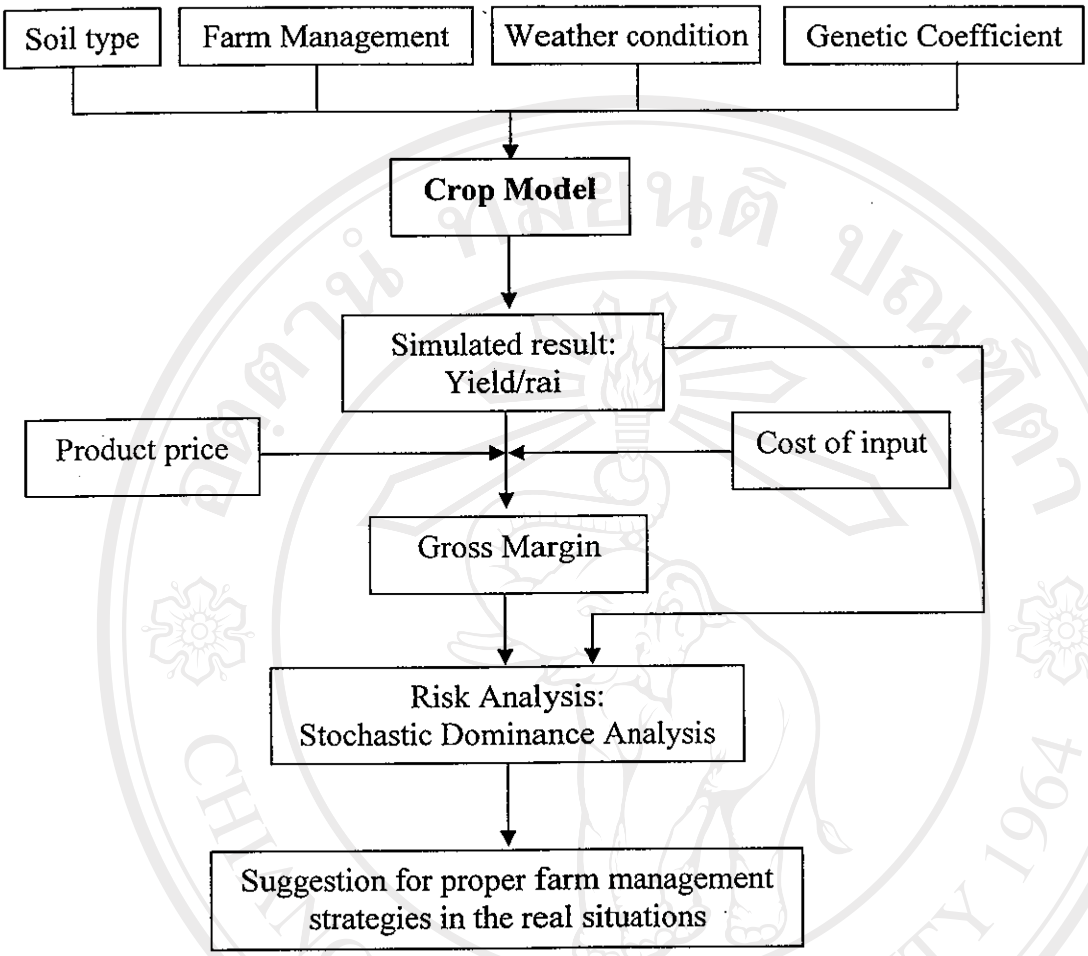

Figure 2.1 The framework for the evaluation of proper farm management strategies.

2.1.1 Crop Model

Empirically, rice yield can be generated using available computer softwares. DSSAT v3.5 (Decision Support System for Agrotechnology Transfer) which particularly included CERES-Rice model for rice yield simulation is the most popular among the other. IBSNAT assembled and distributed this mentioned software. This software package enables its users to match the biological requirements of crops to the physical characteristics of land so that objectives specified by the user may be obtained. The decision support software consists of 1) a Data Base Management

System (DBMS) to enter, store, and retrieve the "minimum data set" needed to validate, list and use in the crop models for solving problems; 2) a set of validated crop models for simulating processes and outcomes of genotype by environment interactions; 3) an applications program for analyzing and displaying outcomes of long-term simulated agronomic experiments.

The DSSAT was designed to allow users to (1) input, organize, and store data on crops, soils, and weather, (2) retrieve, analyze and display data, (3) calibrate and evaluate crop growth models, and (4) evaluate different management practices at a site (Tsuji *et al.*, 1998).

The functional capabilities of DSSAT v3.5 can be summarized in figure 2.2. Crop simulation models are at the center of the system. Databases describe weather, soil, experiments, and genotype information for applying the models to different situations. Software in the system helps users prepare these databases for their own fields or farms so that DSSAT can simulate performance of real or proposed experiments at their sites (experiment performance data are contained in FILEP, FILED, FILEA, FILET). Outcomes from the application software allow users to compare simulated results with their own measured results to give them confidence that the models work adequately, or to determine if modifications are needed to improve their capabilities or accuracy. Outputs can be printed or graphically displayed for conducting sensitivity analyses. In addition, programs are contained in DSSAT to allow users to simulate options for crop management over a number of years to assess the risks associated with each option (Tsuji *et al.*, 1998). Users can choose options in the DSSAT to create different management strategies by modifying in experiment details file, and the simulated performance indicators that can be analyzed.

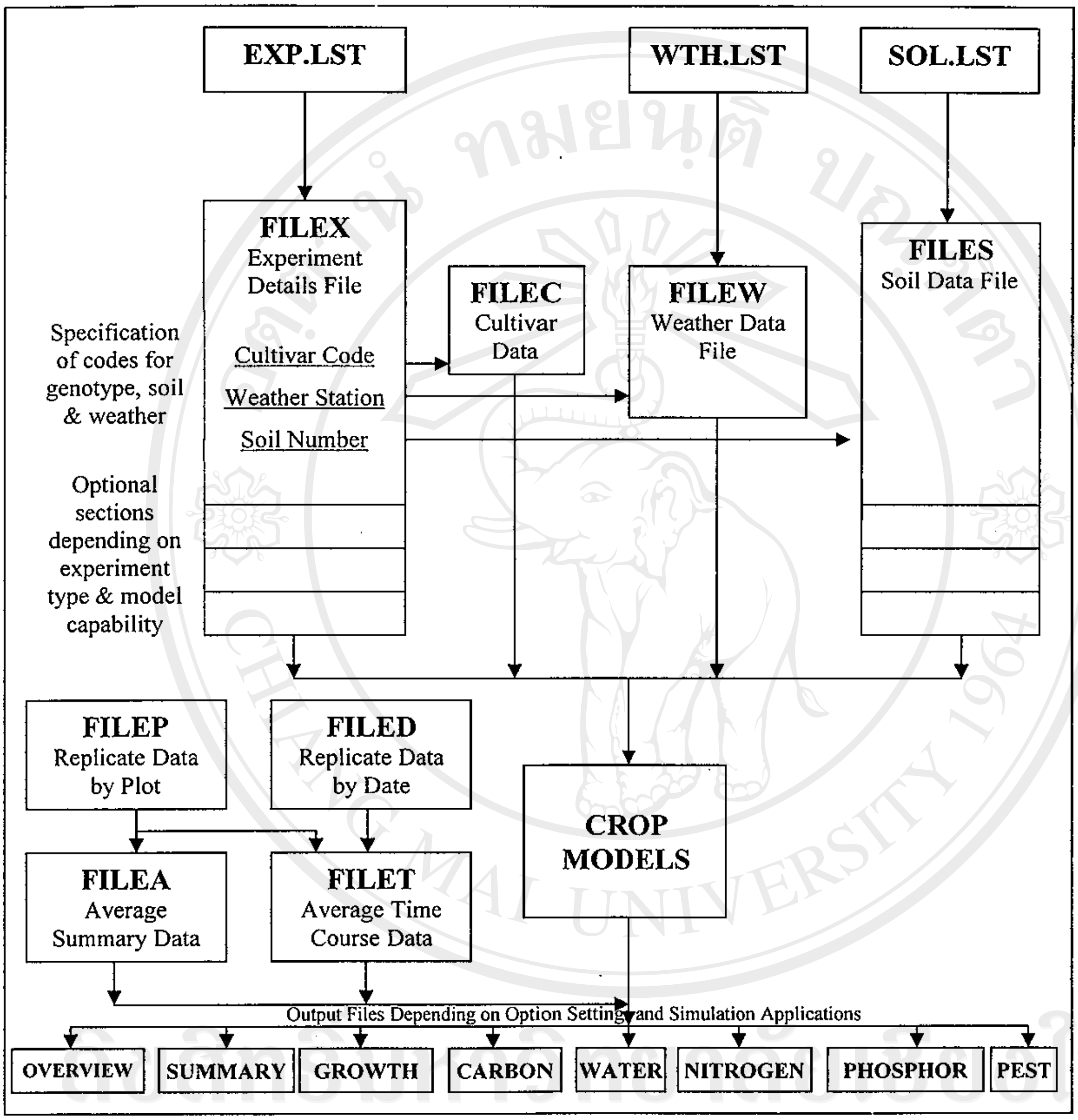

Figure 2.2 Schematic of the main component of DSSAT v3.5

Originally individual CERES crop models were combined into a single module to simulate wheat, maize, barley, sorghum, and millet as part of DSSAT. Only the CERES-Rice model was kept separate because of its major differences in soil, water and nitrogen balance routines and the need to simulate transplanting effects. The CERES-Rice model was developed by Ritchie and modified for transplanted rice by research at the International Fertilizer Development Center (IFDC) (Jongkaewwattana and Jintrawet, 1993). The CERES-Rice model simulates growth on a daily time step and requires daily weather data (maximum and minimum temperature, solar radiation, and precipitation). They compute crop phase and morphological development using temperature, day length, and cultivar characteristics. Daily dry matter growth is based on light intercepted by the leaf area index multiplied by a conversion factor. Biomass partitioning into various plant components is based on potential growth of organs and daily amount of growth produced. Soil water and nitrogen balance sub models provide daily values of supply to demand ratios of water and nitrogen, respectively that are used to influence growth and development rates. Table 2.1 demonstrates the general process for CERES-Rice Model.

The CERES-Rice model as part of DSSAT v3.5 was used in this study. Rice yield was generated based on the crop growth model of CERES-Rice. In Thailand, the model had been calibrated and validated for the major Thai rice cultivars by Decision Support System for Crop Production Project (Ekasingh *et al.*, 2000). This study used 30 years of historical weather data in San Sai district, Chiang Mai province to put in the CERES-Rice model. The study used seasonal strategies (different varieties, planting dates, or fertilizer application schedules, for instance) to simulate yield for evaluating the rice farm management practices.

Table 2.1 General process diagram for IBSNAT / CERES Model

INPUT	PROCESS	OUTPUT
Controllable Inputs		
Variety seed	Plant growth	Grain yield
Plant spacing	Phase development	Yield components
Date of sowing	Morphological development	Aboveground biomass
Date & amount of irrigation	Soil water balance	Dates of phase
Date & amount of N fertilization	Soil nitrogen balance	Developmental changes
Type of fertilizer N		Optimal output at user selected frequency
Genetic coefficient		Soil water balance components
Type of residue		Soil N balance components
		Root densities
Non-controllable Inputs		
Daily weather data		Indices of nitrogen & nitrogen &water stress
Day length		
Soil properties & initial conditions		

Source: Jongkaewwattana S., 1993.

2.1.2 Concept of Stochastic Dominance Analysis

Stochastic dominance has been developed to identify an alternative that would be preferable to another. The basic approach of stochastic dominance is to resolve risky choices while making the weakest possible assumptions. These important assumptions in traditional stochastic dominance (McCarl, 1996) are:

1. Individuals are expected utility maximizers.

2. Two alternatives are to be compared and these are mutually exclusive, i.e. one or the other must be chosen but not a convex combination of both.

3. The stochastic dominance analysis is developed based on population probability distributions.

The Expected Utility Basis of Stochastic Dominance

Stochastic dominance in this study assumed expected utility of yield and gross margin maximization ($u(x)$). Let's assume that x is the level of yield or net margin whiled f(x) and g(x) gives the probability of each level of outcomes for alternatives f and g. If f is preferred to g then the sign of equation (1) or equation (2) is positive. The decision criteria could be written as the difference in the expected utility between the prospects as follows (McCarl, 1996).

$$\int_{-\infty}^{\infty} u(x)f(x)dx - \int_{-\infty}^{\infty} u(x)g(x)dx \geq 0 \qquad \text{----------- (1)}$$

And equation (1) can be rewritten as equation (2):

$$\int_{-\infty}^{\infty} u(x)[f(x) - g(x)]dx \geq 0 \qquad \text{----------- (2)}$$

First Degree Stochastic Dominance

It can apply the integration by parts formula to the last version of the expected utility equation. By defining a and b terms which fit the integration by parts structure and choose a to be $u(x)$ and b as the difference between the cumulative density functions as follows (McCarl, 1996):

The basic integration by parts formula is:

$$\int_{-\infty}^{\infty} a\, db = ab\Big|_{-\infty}^{\infty} - \int_{\infty}^{\infty} b\, da$$

Where[1]

$$a = u(x)$$

$$b = (F(x) - G(x))$$

$$F(x) = \int_{-\infty}^{x} f(x)\,dx$$

$$G(x) = \int_{-\infty}^{x} g(x)\,dx$$

In turn the differential terms are:

$$da = u'(x)dx$$

$$db = (f(x) - g(x))dx$$

Notice that under this substitution that a*d*b encompasses the terms in the expected utility equation that f dominates g by first degree stochastic dominance. Given this substitution the integration of (3) or (4)

$$\int_{-\infty}^{\infty} u(x)(f(x) - g(x))dx \geq 0 \qquad \text{----------- (3)}$$

And equation (3) can be rewritten as equation (4):

$$\left[u(x)(F(x) - G(x))\right]_{-\infty}^{\infty} - \left[\int_{-\infty}^{\infty} u'(x)(F(x) - G(x))dx\right] \geq 0 \qquad \text{----------- (4)}$$

It was observed a couple of things about this result. In the left braces of equation (4), when the F(x) and G(x) terms are evaluated at x levels of minus infinity they are both zero because it is at the far left hand tail of the probability distribution

[1] Note that F(x) and G(x) are cumulative probability of the outcomes x for alternative f and g respectively

where the cumulative probabilities equal zero. Thus, the evaluation at minus infinity is zero. Similarly, when x equals plus infinity since these are cumulative probability distributions both equal one so it has the utility of plus infinity times a term which equals one minus one which is zero. Thus, it is written as equation (5):

$$-\left[\int_{-\infty}^{\infty} u'(x)(F(x)-G(x))dx\right] \geq 0 \qquad \text{----------- (5)}$$

Suppose that the overall sign is positive then f dominate g. first, suppose that it is assumed non-satiation i.e., that more is preferred to less or $u'(x) > 0$ for all x. Thus, the $u'(x)$ term does not have anything to do with the overall sign of this term as it will always be a positive multiplier. This means that the value of this term takes its sign from the $F(x) - G(x)$ term. One can then make a second assumption that the difference between $F(x)$ and $G(x)$ is negative or zero for all x. This means that the cumulative probability of distribution of f must always lie on or to the right of the cumulative probability distribution of g (Figure 2.3).

Base on the first degree stochastic dominance rule, that given two probability distributions f and g, distribution f dominates distribution g for two conditions (McCarl, 1996). First, the decision maker has positive marginal utility of wealth for all x ($u'(x) > 0$). Second, for all x the cumulative probability under the f distribution is less than or equal to the cumulative probability under the g distribution with strictly inequality for some x.

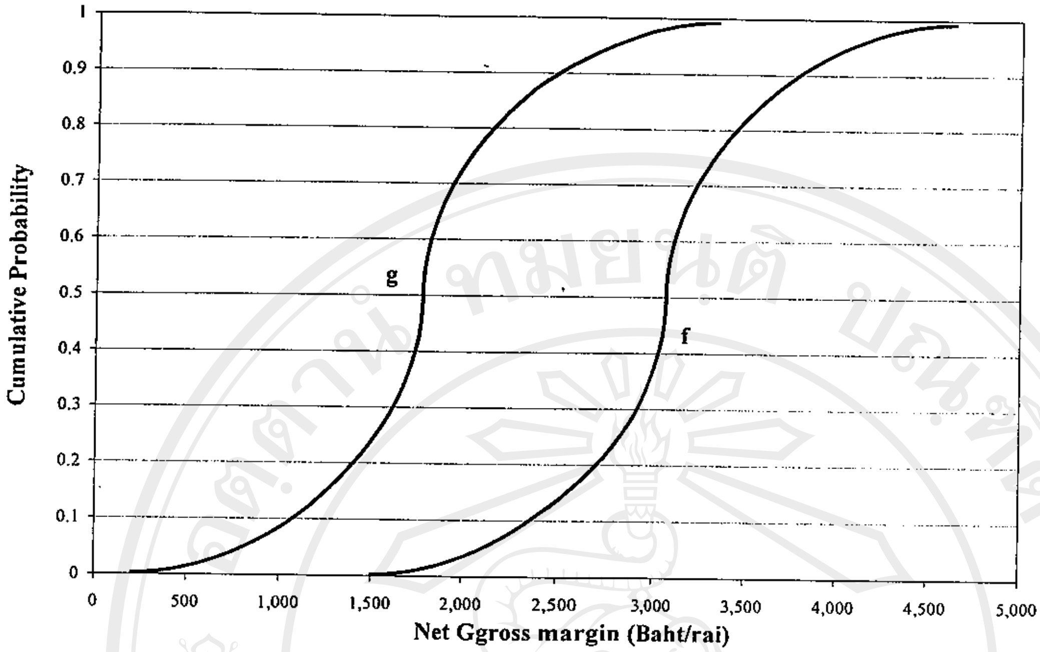

Figure 2.3 The first degree of stochastic dominance analysis

Second Degree Stochastic Dominance

Second-degree stochastic dominance provides a basis for eliminating distribution from the first degree stochastic dominance set (Anderson *et al.*, 1977). The additional behavioral assumption that the decision maker is averse to risk by applying integration by parts and setting the following (McCarl, 1996):

$$a = u'(x)$$

$$db = (F(x) - G(x))\, dx$$

So that:

$$da = u''(x)\, dx$$

$$b = (F_2(x) - G_2(x))$$

Where the terms F_2 and G_2 are the second integral of f and g with respect to x, i.e

$$F_2(x) = \int_{-\infty}^{x}\int_{-\infty}^{x} f(x)dx$$

$$= \int_{-\infty}^{x} F(x)dx$$

Under these circumstances, if one plugs in its integration by parts formula, the equation that f dominates g by second degree stochastic dominance is rewritten as follow:

$$-\left[u'(x)(F_2(x)-G_2(x))\right]_{-\infty}^{\infty} + \left[\int_{-\infty}^{\infty} u''(x)(F_2(x)-G_2(x))dx\right] \geq 0 \quad \text{----------} \ (6)$$

In the equation (6), at the right braces, this contains the second derivative of the utility function multiplied times the difference in the integrals of the cumulative probability distributions with a positive sign in front of it. In order to guarantee that f dominates g the sign of equation (6) must be positive. Second degree stochastic dominance makes two assumptions that render this term positive. First, it is assumed that derivative of the utility function with respect to x is negative everywhere ($u''(x) < 0$). Second, it assumed that $F_2(x)$ is less than or equal to $G_2(x)$ for all x with strictly inequality for some x. Under these circumstances, it has a negative time a negative leading to a positive.

In the left braces, first, add the assumption on non-satiation $u'(x) > 0$. This term is then multiplied by $F_2(x) - G_2(x)$, which is a negative at plus infinity since it has already assumed that $F_2(x)$ smaller than $G_2(x)$ while it is zero at x equals minus infinity since there is no area at that stage. This coupled with the leading minus sign yields the positive value of equation (6).

The second degree stochastic dominance rule can be stated. Under the assumption that an individual has the following behavior (McCarl, 1996):

1. Positive marginal utility: $u'(x) > 0$.
2. Diminishing marginal utility of income: $u''(x) < 0$.
3. That for all x, $F_2(x)$ is less than or equal to $G_2(x)$ with strict inequality for some x

Then it show that f dominates g by a second degree stochastic dominance. Figure 2.4 shows the second degree of stochastic dominance analysis.

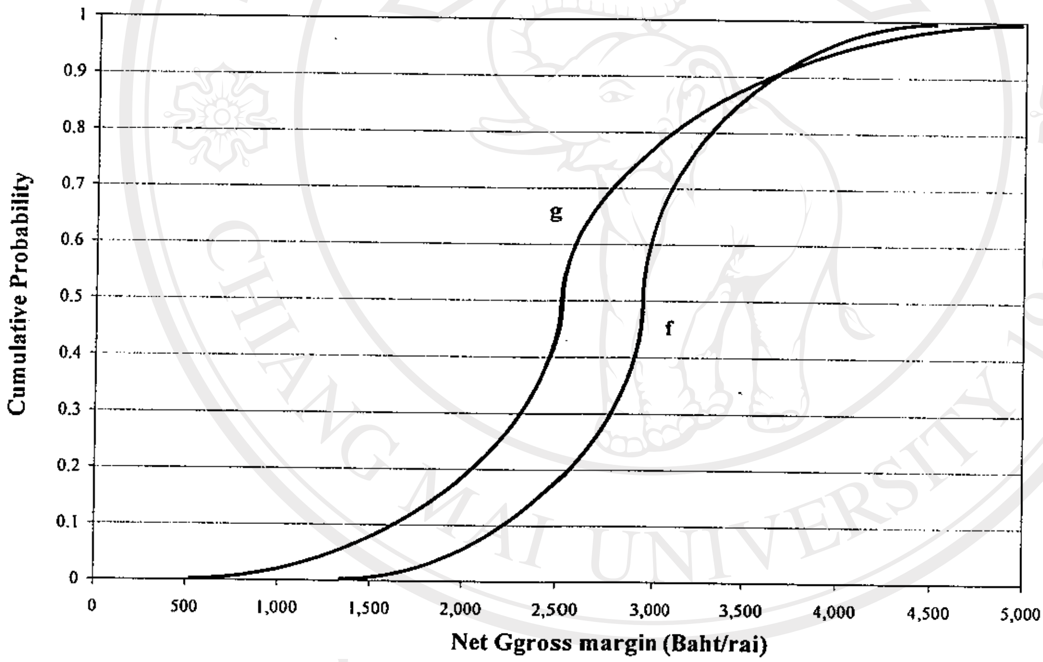

Figure 2.4 The second degree of stochastic dominance analysis

2.2 Data Collection

2.2.1 Primary data

Formal farmers' survey was used in this study in order to collect data on biological, economic and social conditions of rice farmers in San Sai district, Chiang Mai province. The economic data collected included the source and cost of each farm management practices. In this study, the cost of farm practices included land, labor, equipment, material and other management categories. This study interviewed 126 rice farmers representing 36 treatments in San Sai district, Chiang Mai province (Figure 2.5). The samples surveyed were selected using purposive technique in order to satisfy conditions that covered 2 seasons (rainy and dry season), 4 rice varieties (KDML105, NSPT, RD6 and SPT1), 3 soil series (Hang Dong, San Sai and San Pa Thong soil series) and 3 fertilizer management levels (low, high and intensive).

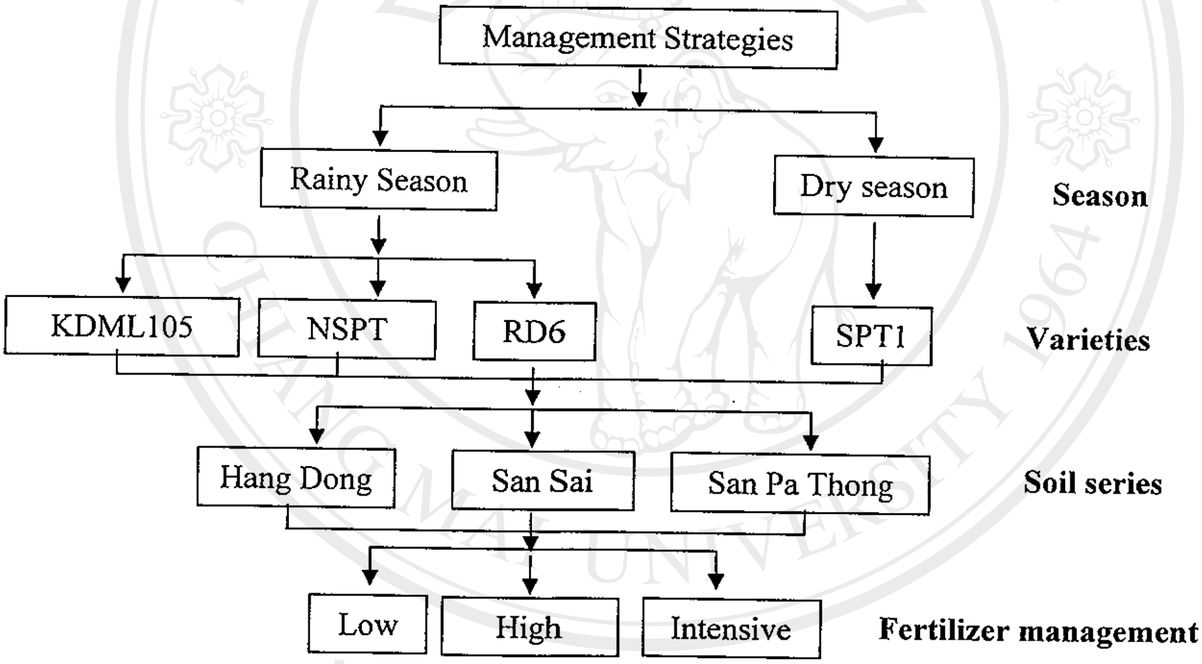

Figure 2.5 The treatment of farm management for simulation in rice production

2.2.2 Secondary Data

This study collected additional needed data from documents and reports of government agencies. Rainfall, temperature, soil series, rice variety data, price of rice, price of inputs and some data needed for running crop model were gathered from the government agencies such as rice experimental station, Chiang Mai provincial office of agricultural extension and Chiang Mai University's library.

2.3 Data Analysis

2.3.1 Descriptive Analysis

This analysis was used to investigate conditions and descriptive of irrigated rice farmer in Chiang Mai province. The investigating issues comprise of farmers' perceptions and rice production management system. The analysis covered farmers' attitudes and adaptations to risks based on their own farming experiences, the scales of farming, individual skills, availability of capital, traditions and other socio-cultural factors.

2.3.2 Quantitative Analysis

This analysis was designed to derive the proper rice management strategy. It comprises of the following steps:

1. Rice Yield Simulation

CERES-Rice model in the DSSAT package was used to simulate yield by using biophysical data of the study area. These biophysical data used in the model were soil series, management practices, weather condition and genetic coefficient. The inputs were fed into the model to simulate the results as grain yield. The simulation was replicated for 30 years of different weather condition. Rice production and gross margin per unit of land (rai) were computed for each management option as defined by equations (7) and (8), respectively. The computed yield and margin arrays were served as the basic data for the stochastic dominance analysis in the next steps.

$$Y_i = S_i / 6.25 \qquad \text{----- (7)}$$

$$\pi_m = (P_j \times Y_i) - TC_k \qquad \text{----- (8)}$$

Where as

Y_i = Grain yield (Kg./rai)

S_i = Simulated yield (Kg./Ha)

π_m = Net margin (Baht/rai)

P_x = Price of rice (Baht / Kg.)

TC_x = Total cost (Baht/rai)

2. Empirical Stochastic Dominance Analysis

The stochastic dominance analysis was used to evaluate decision to crop management practices. The first step in this analysis was the construction of cumulative distribution function (CDFs) for those computed yield and gross margin of each management scenarios. Next, the first-order stochastic dominance (FSD) or second- order stochastic dominance (SSD) was used to evaluate the rice farm management practice. The empirical model for the actual computation procedure for FSD and SSD are as follows:

Step 1 Take the outcomes of yield or gross margin for all the probability distributions and array them by descending order.

Step 2 Write the relative frequencies of observations against each of the outcome levels for each probability distribution.

Step 3 Divide the frequencies through by the number of observations under each of the items.

Step 4 Form the cumulative probability distribution starting at the first outcome value by taking zero plus the probability of that outcomes for each farm management practice. For the second and following values, the computation takes the cumulative probability of the prior outcome values plus the probability at that outcome. At the end, the cumulative probability distribution is one. The algebraic formulas for the computation are:

$$F_0 = G_0 = 0 \qquad \text{----- (9)}$$

$$F_i = F_{i-1} + f_i \qquad i > 1 \qquad \text{----- (10)}$$

$$G_i = G_{i-1} + g_i \qquad i > 1 \qquad \text{----- (11)}$$

Where the F_i and G_i are the cumulative probability at outcome of farm management practice f and g level i^{th} respectively.

Step 5 Form the second integral of the probability using the same formulas as that of the cumulative frequency, i.e.:

$$F_{2,1} = 0 \qquad \text{----- (12)}$$

$$G_{2,1} = 0 \qquad \text{----- (13)}$$

$$F_{2,i} = F_{2,i-1} + F_i \qquad i > 1 \qquad \text{----- (14)}$$

$$G_{2,i} = G_{2,i-1} + G_i \qquad i > 1 \qquad \text{----- (15)}$$

Where F_{2i} and G_{2i} are cumulative of the cumulative probability at outcome x of the farm management practice f and g level i^{th} respectively.

Step 6 Perform the stochastic dominance analysis by examining F_i vs. G_i and $F_{2,i}$ vs $G_{2,i}$. if every single observation in cumulative probability distribution function (CDF) for farm management practice f (i.e. F_i)is less than or equal to that for farm management practice g (i.e. G_i) with some strictly equalities then farm management practice f dominates farm management practice g by first degree stochastic dominance. The second degree stochastic dominance holds when first degree fails. If the integrated cumulative $F_{2,i}$ is always less than or equal that for $G_{2,i}$ with several strictly inequalities then the farm management practice f dominates the farm management practice g by the second degree dominance. Finally, if the second degree dominance does not hold, both practices are efficiently determined by the stochastic dominance analysis.