Chapter 3

THEORETICAL FRAMEWORK

3.1 Introduction

The arrangement of the subsequent sections entails the following ideas. Theories of subjective equilibrium and subsistence affluence incorporate the discussion on choice to expand cash income beyond the existing subsistence needs. Therefore both theories will be reviewed. As will be outlined, these theories imply the incorporation of other factors beyond the farm that, to a certain extent, can contribute to the expansion of farmers' cash incomes. Consequently, a decision theoretic approach and a systems approach are used; by regarding the farm as a system and a decision unit. Thereby analysis can be restricted to farm level without totally neglecting factors beyond the farm. Their influence on the generation of cash incomes, by assumption, is incorporated in the decision maker's preferences and beliefs.

3.2 The Subjective Equilibrium Theory

3.2.1 Its history

Early theories of agricultural development for Less Developed Countries (LDCs) seem to be influenced by Rostow's theory of stages of economic development. Some of these models - Perkins-Witt's model, Johnston-Mellor's model, and Hill-Mosher's model - were summarized by Wharton Jr. (1968). It is most commonly stated that structural transformation must occur as an effect and, compatibly, as a sign of development, where the importance of agriculture in terms of its share in gross national product and employed workforce declines relative to other economic sectors. At the outset, the agricultural sector has an important role in this transformation, by providing surplus food and other produce - some of which can be exchanged with capital goods - and man power. In relation to this, transformation models for surplus labour were later developed by Jorgenson (1961), Nichols (1963 and 1969), and Fei and Ranis (1964).

One of the main points of debate concerning these models is manifested in the question whether transferring labour from agriculture will reduce total agricultural output. Fei and Ranis assume the marginal productivity of labour in traditional agriculture to be zero or close to zero. Thus, some of the labour force can be transferred without reducing total agricultural output. Jorgenson, on the other hand, assumes that transfer of labour from agriculture will result in the reduction of total agricultural output. The transfer should therefore be accompanied by technological change to improve the productivity of the remaining labour force in order to maintain or increase total agricultural output. Mellor (1967) mentioned that there is empirical evidence collected by Schultz as well as Kao et al., which supports Jorgenson's assumption. Kao et al. conclude that marginal productivity of traditional agricultural labour is positive.

Mellor (1963) imposes the concept of limited aspirations or a socially or culturally determined demand ceiling on the conventional production function analysis; this may resemble the inseparability of production and consumption decisions by traditional farmers. This demand ceiling lies beyond the minimum subsistence needs. Farms with different resource endowments - quantity and quality of land, labour and other resources - will have different production functions. The average product curve per member worker, which Mellor calls average of living curve, will also vary between farms accordingly. The marginal productivity of farm labour is usually represented by those points where the demand ceiling cuts the average of living curves. Mellor hereby shows that marginal productivity of labour will not necessarily be zero or positive, but will vary with farm's resource endowments, and, depends also on the culturally determined demand ceiling.

Nakajima (1969) seems to support Mellor's model. He shows that, with a demand ceiling, and without a labour market, the marginal productivity of labour tends to vary from family farm to family farm. In most, the main causes will be the differences in: (a) quantities in non-labour resources farms have, (b) number of workers in farms, and (c) number of dependants in farms. Accordingly, an agricultural development plan based on an assumption of a uniform marginal productivity of farm labour seems to be unjustifiable.

The incorporation of the demand ceiling in conventional production economic analysis, however, marks the advent of subjective equilibrium theory. Subjective equilibrium models for peasant farms with respect to labour usage were developed by Mellor (1963), Sen (1966), and Nakajima (1969).

3.2.2 The concept

The term subjective equilibrium refers to a condition where the marginal preferences and motives for acquiring agricultural factors as sources of income is equal to the marginal productivity of these resources.

The model, basically static, assumes a production and a consumption schedule. The concept of limited aspirations is manifested in farmers' objectives in production and consumption decisions, and is measured in terms of utility. Mellor, Sen and Nakayima based their utility evaluation on the disutility of family labour use - or disutility of sacrificing leisure - and utility of goods and services gained. It implies a trade-off between leisure and goods and services enjoyed by the farm family members and, compatibly, a choice problem for them.

Mellor, however, seems to implicitly assume a lexicographic ordering of these utility components until the minimum subsistence needs are reached. In Mellor's case the region of choice lies above the line showing minimum biological needs. Leisure in Mellor's sense refers to the potential labour time within a certain time period, after allowing labour time used for generating minimum biological needs and biologically required minimum rest time. Consistently, goods and services in the region of choice refers to those generated in excess of the minimum subsistence needs.

Sen and Nakajima, on the other hand, apply the choice problem from zero labour supply or its complement, one hundred per cent leisure. The utility component labour supply or its complement leisure seems to be the physiologically possible maximum labour hours within a certain time period. It further seems to imply that goods and services, either subsistence or cash, are equally preferred.

Mellor (1963) uses an iso-utility curve - showing declining marginal utility of leisure and goods and services if both increase - and a production possibility curve showing declining marginal productivity of labour: given a fixed technology and other resources. He further shows that in order to maximize utility with respect to labour use the farmer will operate at a point of tangency between the iso-utility curve and production possibility curve. This is the point where the marginal rate of indifferent utility substitution between leisure and goods and services gained equalizes marginal productivity of labour used.

Sen (1966), examines the equilibrium condition, more specifically, for different ex-post uses of produce: all consumed, all sold, and partly consumed, partly sold. Apparently, for maximization of utility, the same rule holds; that is: the marginal product of labour equalizes the real cost of labour. However, for the third condition, where a three dimensional utility schedule is involved, an additional rule is given which states that the product should be divided in such a manner between direct consumption and exchange in the market that the relevant marginal substitution between the two commodities equals their price ratio.

3.2.3 Its relevance to the problem

The subjective equilibrium concept becomes an important theoretical issue in the context of small-farm development in LDCs, since Schultz (1964) reveals that small-farmers in low income societies are trapped in a technical and economic equilibrium. The critical conditions underlying this type of equilibrium, as summarized by Stevens (1977) from Schultz's theory, is given as follows:

(1) The states of arts - all technology and the nature of resources used in agriculture as well as traditional knowledge of planting times, crop and livestock management practices, processing and sales activities - remain constant.

(2) The states of preference and motives for holding and acquiring resources of income remain constant; this refers to the proposition that slow cultural change has occurred in most low income societies, in their religious beliefs, traditional cultural activities, and local institutional management. As a result the preferences and incentive for economic activity have changed little. Thus the pattern of demand for all items remained unchanged from generation to generation.

(3) Both of these states remain constant long enough for marginal preferences and motives for acquiring agricultural factors as sources of income to arrive at an equilibrium with the marginal productivity of these resources, viewed as an investment in

permanent income streams, and with net savings approaching zero.

The theory of subjective equilibrium implies that small farmers are good decision makers, given their preferences and beliefs - which involves their knowledge - and resources. However, this equilibrium is maintained at a low productivity level; which means that economic returns to investment in existing farm conditions are low. These small farmers' characteristics are therefore termed as 'efficient but poor'.

Mellor (1963) has shown that in order to break this development stagnation, a simultaneous two fold action is needed to shift the equilibrium point upwards; that is shifting the production function, and shifting the decision makers' aspirations towards higher indifference utility curves. Associated remedies which have been suggested are: technological change (Fisk 1962, 1964 and 1971; Mellor 1963; Schultz 1964; Mosher 1966; Dillon and Anderson 1971; Hayami and Ruttan 1971; and Stevens 1977), and market development (Fisk 1964 and 1971; Yudelman 1964; Shand 1965; Mosher 1966 and Penny 1966).

In conjunction with those two, various associated changes have been suggested. Hayami and Ruttan (1971), in their induced development model, stress the need for a responsive government and private institutions to be engaged in research, extension and marketing activities, or in other words, in producing and distributing technology and associated information through a smooth, two way communications between farms and those institutions. Their theory, however, has a crucial weakness in that they assume market price will reflect the needed technology perfectly and all parties are responsive to the market price signal. Due to market failure, price may not reflect the scarcity of resources perfectly (Bator 1958), and adoption of new technology may result from factors other than price as well (Epstein 1971; Tsuchiya 1972).

The term subjective in this theory assumes the crucial role of the decision maker's personal attitude and knowledge in decision making. Two kinds of attitudinal aspects have been mentioned in this respect. First, attitude towards risk has been suggested as a major determinant of the adoption of new technology (e.g., Wharton Jr., 1969; Dillon and Anderson 1971; Moscardi and de Janvry 1978). Second, change from subsistence to commercial mindedness is essential to support market development (Penny 1964; Yudelman 1964). These two aspects will be discussed further in Section 3.6.

3.2.4 Summary remarks

The subjective equilibrium theory highlights two main tools which can be used to explain the result of a farm operation: the decision maker's utility function and the existing farm's production function.

The discussion up to this stage leaves two main problems to be solved. The first refers to the decision process which might have an effect on utility elicitation, and secondly, the subjective aspect with respect to the demand ceiling.

Subjective equilibrium theory reveals the decision problem and the decision criterion of the small farmers, which is consistent with the aim of expanding the cash economy. However, speaking in the context of generating cash income, Mellor's model, with an implicit assumption of lexicographic utility ordering, implies a different decision process compared to Sen's and Nakayima's model. In Mellor's model, the decision to generate cash income is allowed only after minimum subsistence requirements have been met. If we can assume that after this point has been reached the farmers are fully satiated with their own produced goods and will gain additional food only by buying it from the market, then the utility function to be derived may include only cash income as the utility component. Certainly, in the specification of the model, the assumptions that farmers put priority on subsistence food consumption should be incorporated. On the other hand, if Sen's and Nakayima's model is adopted, then the utility function to be elicited is a multidimensional one, with cash consumption and subsistence consumption as the utility components. It is obvious that utility elicitation for the latter model is much more complicated than in the Mellor's one. Perhaps, the more important basic problem to be asked is not that of the ease of eliciting utility functions, but that of the representativeness of the model; i.e. which one of those models truly resembles the decision making process of the traditional farmers? Hopefully, forthcoming discussions will highlight some information in this respect.

The second problem, that of limited aspirations, is an ambiguous one. As unsaturated demand in modern economic theory refers to a variety of goods and services rather than to a particular good and/or service, then the respective problem is whether limitations imposed on cash demand refers to less variety of goods and services demanded or to the risk aversion attitude imposed on cash generating activities.

3.3 The subsistence Affluence Theory

3.3.1 Introduction

The theory of subsistence affluence is a very close relative to the subjective equilibrium theory of Mellor (1963), Sen (1966), and Nakayima (1969). This concept refers to a pure or semi subsistence economy where supply of labour and other input factors are in excess of that required to meet the demand ceiling for food and other subsistence household's needs. It can therefore be regarded as a branch of subjective equilibrium theory applied to a relatively resource rich situation.

The theory was first developed by Fisk (1962, 1964 and 1971), with respect to the Papua New Guinean village economy. Shand (1965) extended Fisk's model by including indifference analysis. Stent and Webb (1975) discussed the behaviour of the model under different conditions: single untraded product, two untraded products, two products one of which is traded, two products each of which is traded, and the introduction of tax. Two empirical tests of this theory were reported by de Boer and Chandra (1978), and Philp (1979).

3.3.2 The concept

Fisk, like Mellor (1963), explains his model in a very simplistic way using a total production curve with respect to labour use, a labour supply curve, and a demand ceiling. The potential supply of labour is assumed to be a function of food supply - or its corresponding level of nutrition - and social and customary factors such as the amount of leisure regarded as desirable for ceremonial and recreational activities. Fisk further shows that if the economic equilibrium point, that is where the potential supply of labour curve cut the total production curve, lies above the demand ceiling, then there are potential unused labour resources which can be used at a very low opportunity cost. This means they can be made available without involving any serious hardship in the sacrifice of socially or culturally acceptable leisure.

Better clarification of the subsistence affluence concept is given by Stent and Webb (1975) using production possibility curves and indifference utility curves. They show that if the maximum utility or bliss-point lies on, or within, the production possibility region, then subsistence affluence prevails. If the bliss-point lies beyond or outside the production possibility region, then a constrained maximum prevails.

3.3.3 Subsistence affluence and development

According to Fisk (1962 and 1964), in a subsistence economy such as that in New Guinea villages, the actual level of production will be limited by the demand ceiling rather than by the potential supply of labour or labour ceiling. He said (Fisk 1964, p.156):

> 'Unless population pressure on land resources had developed to a degree that is unusual in a primitive economy, the level of production in a subsistence unit would be limited by the internal demand for subsistence products, rather than by the supply of factors of production; there is therefore a development potential concealed within the subsistence sector in the form of surplus of potential labour and unused productive capacity of the tribal lands, which could be diverted to production if the necessary incentives were provided'.

Fisk's theory, assumptions of which can be found in Fisk (1962 and 1964), can be elaborated as follows:

$$Y = f(D^s, D^c) \qquad \ldots\ldots (3.1)$$

where,

Y = total production,

D^s = internal demand for subsistence products, and

D^c = demand for cash reserves.

Further,

$$D^s = f (N^h , P^h , S^c) \qquad ..... (3.2)$$

where,

D^s = internal demand for subsistence products,
N^h = population or number of household members,
P^h = physical activity, and
S^c = social and customary factors;

and,

$$D^c = f (F_r , F_i) \qquad ..... (3.3)$$

where,

D^c = demand for cash reserves,
F_r = response factors, and
F_i = incentive factors.

Incentive factors are the strength of the incentives, transmitted by the market forces. These include the utility of money and return to labour. The return to labour to a certain extent, depends on exogenous economies of scale in the spheres of processing, transport and other marketing factors, including crop prices. Response factors are the strength of the resistence or inertia of the subsistence group or the particular farmer to the changes required for supplementary cash production. To the response factors belong psychological, physical, social, economical, and perhaps, political characteristics of the subsistence group.

Epstein (1970), extends function 3.3 by relating it to the rate of cash crop expansion. She shows that exogenous economies of scale depend also on the size of the business at farm level; or internal economies of scale, which is further a function of the incentive factors. Hereby, she shows that, in a dynamic sense, cash crop expansion and market development effect each other recursively.

3.3.4 Summary remarks

The utility function and the production function are the main tools of analysis used in explaining subsistence affluence theory. In this case, cash demand appears to be the crucial limiting factor.

Philp (1979), concluded from his findings that subsistence and cash work for Papua New Guinean village craftsmen and probably for others too, are two separate activities which have not yet reached a stage of trade-off in terms of labour time used. Under this condition, where subsistence needs have been reached, low cash earning potential will still affect potential labour response, as long as this is not in conflict with labour time for subsistence activities. De Boer and Chandra (1978) have shown that the subsistence affluence condition does not exist anymore among the native Fijian farmers. Instead constrained maximization in the light of subjective equilibrium occurs. Native Fijian farmers seem to have reached a stage of trade-off between cash and subsistence activities. They have used their surplus potential labour up to a point where further expansion of cash generating activities will result in reduction of labour time for subsistence production and other social and cultural activities, which is unacceptable for the farmers who put priority on those activities.

Philp's, as well as de Boer and Chandra's findings support Mellor's lexicographic utility ordering. Therefore it is reasonable to answer the question raised in sub-section 3.2.4 by accepting that Mellor's utility ordering is suitable for Melanesian farmer decision making in Irian Jaya.

3.4 Systems Research and Operations Research

3.4.1 System as a concept

The term system has been given different definitions. However, the difference seems to be only on the accentuation of the abstract boundary of a system. Some, for example Gilpin (1973) and Weinberg (1975), define it as merely a framework for study of structural and behavioural complexes. Others define it as structural and behavioural complexes, or inter-relationships between factors (Dent and Anderson 1971; Wright 1971; Cavallo 1979).

The entities or elements exhibiting cause and effect relationships may form self contained organizations, ranging from small and simple ones to large and complex ones; sometimes so widespread and pervasive, that it is difficult, if not impossible, to perform an integrated study of them. Hence, a conceptual boundary may be put around the complex to limit its organizational autonomy (Wright 1971; Gilpin 1973).

The conceptual idea of a system contains several components. Some, which have been mentioned before, are the elements or what Cavallo (1979) called basic attributes, linkages or inter-relationships between those elements, and a conceptual limit. Others are: the environments in which the system has to survive; fixed inputs in to the system from the environment (termed parameters or supporting attributes) (Gilpin 1973; Cavallo 1979); an identifiable state or condition of the systems; and the behaviour of the system in response to flows and events within it and environmental influences.

3.4.2 Systems research

Systems research is used to encompass all activities involving the study of a complex system. The objective of systems research may be to predict the behaviour of a system or, more commonly, to improve control over some existing system, or to design a new system. Systems research may consist of systems analysis and synthesis. Systems analysis refers to the attempt to analyse and explain the process of transformation within the system; that is the strength and direction of the cause and effect relationships of all elements of the system. Its objective is to gain a better understanding of how the system is and how it works. System synthesis is usually concerned with system control or management; that is to modify the original system by modifying the relationships of the elements of the system, and system design; that is the design of an entirely new system (Wright 1971).

An integrated approach is increasingly used in planning present day organizations. Systems analysis, which is used in studying those organizations, comprises two basic methods: the systems approach and systems flow (Kircher and Mason 1975). The systems approach provides an overview of the organization, and the systems flow method is used to analyse its activities.

There are five basic concepts of the systems approach in studying organizations. They are:

(i) Purposes or goals set by man and to be achieved by the organization.

(ii) The environment of the organization.

(iii) Resources within the organization.

(iv) The organization itself; that is the functional and hierarchical structure of the elements of the organization.

(v) Management decisions.

Three other concepts constituting the systems flow are:

(vi) Inputs: that is all items that enter the organization from the environment or as feedback, that, with the endowed resources, become resources required for the operation of the organization.

(vii) Process: that is the transformation of inputs in to goods and services desired by the environment or by the next stage in the organization.

(viii) Output: that is goods and services produced and then used internally, sold, bartered, or given away free. Some of the output can be returned to become input to the original system. When this occurs with information, it is called feedback.

To simplify the study of a system, generally, models are used to represent the system. Wright (1971) quoting Ackoff et al. (1962), and also Roccaferrera (1964) distinguish three basic types of models: the iconic model, analogue model, and symbolic model. The iconic model is a scaled down model of the real system, and represented in pictorial form such as photographs or geographic maps, or a physical model such as an experimental plot or a miniature housing complex. The analogue model is based on the use of one property to represent another. For example, rats and monkeys are used as analogue models for medical experimentation, as are graphs to represent trends in production. A symbolic model, which is also called a mathematical model, is a model where the components of an event and their relationships are expressed by mathematical symbols. Simulation models, which are familiar in systems research, are combined analogue and symbolic models (di Roccaferrera 1964).

3.4.3 Operations research

Management is the leadership, policy setting, and decision making part of an organization. Management makes the decisions which, (a) establish the purposes, (b) react to environmental opportunities and constraints, (c) acquire the resources, allocate the resources to elements of the organization, accept the obligations, and (d) plan, control and review the organization structure and operations.

Operations research refers to research using a systems approach to solve problems of organizations for management purposes. This is to provide managers of the organizations with a scientific basis for solving problems, involving interaction of the components of the organization in the best interests of the organization as a whole. A decision which is best for the organization as a whole is called an optimum decision; one which is best relative to the functions of one or more parts of the organization is called a sub-optimum decision (Churchman, Ackoff and Arnoff 1953; Gilpin 1973; Kircher and Mason 1975).

3.4.4 Farm as a system and a decision unit

Modern agriculture is characterized by increasing human intervention in the growth and production of plants and animals: by modifying nutrient content in the soil using fertilizer, modifying the soil water system by applying water through irrigation, protection from pest and diseases using insecticides and pesticides, reducing competition from unnecessary plants by applying herbicides or weeding, and modifying the soil structure by soil tilling. All goods and services used by man to influence the growth of plants and animals in order to maintain or increase production are called inputs.

Using the system's flow method, the general relationship, as taken from Mosher (1966), is presented in Figure 3.1, which shows that production inputs are transformed into outputs on farm. A farm is therefore called a production organization. The aim of this organization is economical: to make profits or, most commonly in LDCs, to satisfy food and other household subsistence needs. Therefore a farm may also be called an economic system. However, man's control over the whole process of production within a farm is only partial. The actual production process remains basically biological. A very simplified illustration of basic biological relationships as taken from Mosher (1966) is shown in Figure 3.2. Accordingly, a farm is also called a bio-economic system.

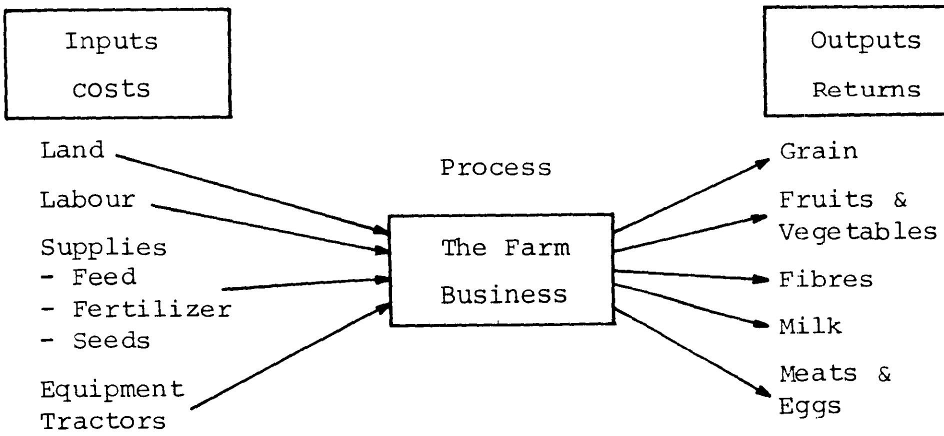

Figure 3.1 A simplified farm system's flow.

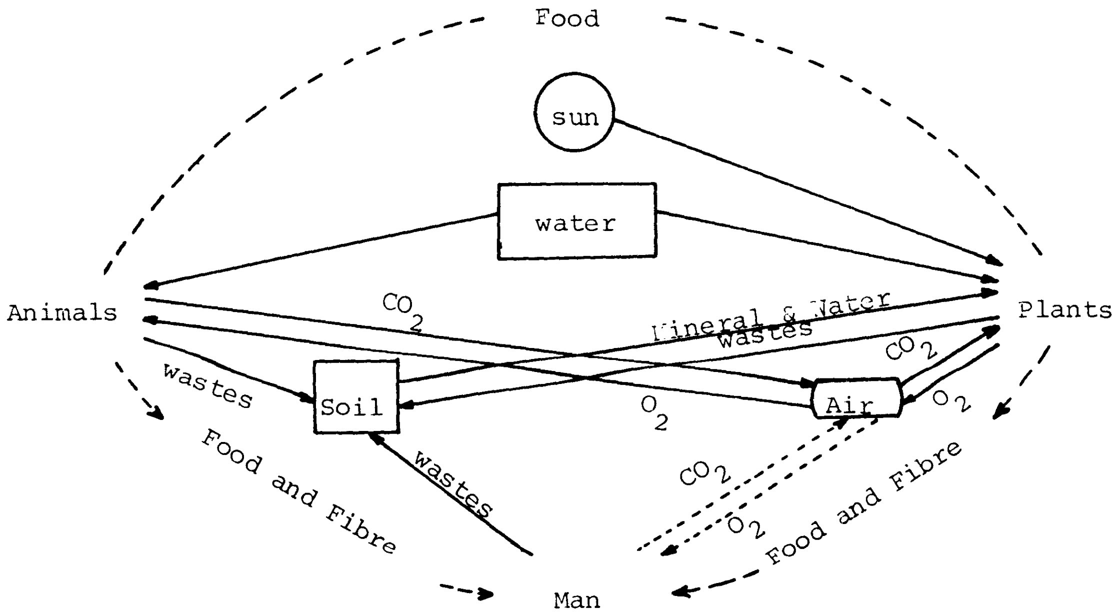

Figure 3.2 Basic biological relationships of farm production

Increasing man's knowledge of biological and economic relationships underlying the whole process is the basic requirement to increase man's ability to control plants and animal growth, and production. In studying a farm business in order to improve farmer's control of the production process, operations research models can be used. The general form of operations research models according to Churchman et al. (1953) is given as follows:

$$E = f\ (x_i , y_j), \qquad ..... (3.4)$$

where,

- E = the effectiveness of the system,
- x_i = the variables of the system, which are subject to control, and
- y_j = those variables which are not subject to control.

The degree of man's control over the entire production process is basically manifested in decisions. A farmer, who makes decisions concerning his farm organization and operation considers a whole range of factors which can be categorized into: (i) his goals and aspirations, (ii) factors which are under his control, and (iii) factors which are beyond his control. By incorporating farmers' goals, the general form of operations research model can be extended to be a generalized decision model. Its form, as adapted from Eisgruber and Lee (1971) can be given as follows:

Maximize the criterion function

$$U = \pi (Y), \qquad .....(3.5)$$

subject to the outcome function

$$Y = \phi (X , Z) \qquad .....(3.6)$$

and the decision function

$$X^* = D (U) \qquad .....(3.7)$$

where,

- U = the level of utility,
- Y = the outcome attributable to a specific course of action and a 'state of nature',
- X = the possible courses of actions or strategies (X^* is the optimal strategy),

Z = the possible states of nature (or expected behaviour of y_j in general operations model above),

ϕ = the transformation function relating a course of action and states of nature to an outcome,

π = the criterion function transforming an outcome in to a utility, and

D = the decision rule specifying how to evaluate the utilities to determine the optimal strategy.

The decision problem, within the context of the model, is to select a particular course of action or strategy from all admissible strategies or values of X so as to maximize U.

The two types of decisions to be made in connection with yearly farm organization are: (1) those which determine the kind and amount of products to be produced; and (2) those which determine the amount and form of each factor of production which will be used to secure the desired commodities.

In their decision making, farmers rarely consider solely a particular crop or a production factor. They generally consider a particular crop in terms of the whole farm's cropping system (Mosher 1969 and 1971). Accordingly, as long as the problem is not very complex and can be handled by the computer without decomposing it first, the whole farm approach seems to be the best method to be used in studying farmers' decision making. Furthermore, as is implied in subjective equilibrium and subsistence affluence theories, a farmer's decision which is made within the context of the whole farm includes the consumption aspects.

3.4.5 Summary remarks

The discussion in the previous sections entails the idea that the results of the farm operation, to a certain extent, can be explained by the outcomes of the farmer's decisions, which depend further on the outcomes preferred by the farmers, farmers' beliefs concerning the chances that uncertain events affecting the production process might occur and available production resources.

Traditional Melanesian farms are typified by multiple cropping with more than one main crop (Barrau 1957; de Boer and Chandra 1978). The whole farm approach in studying farmers' decision making appears to be consistent with this situation rather than a particular crop approach.

Two actions are further demanded: the design of the model implying farmers' decision making within the context of the whole farm, and the measurement of the components of the model. Subsequent discussion will be concentrated on these aspects.

3.5 Modelling Decisions on Annual Farm Plans

3.5.1 Introduction

As indicated above, decisions on farm plans involve risk. This means the actual outcomes remain uncertain at the time of decision. Uncertainty is due to factors which are beyond farmer control. Many researchers have discussed and tested the importance of risk in farmers' decisions concerning their farm operations (e.g. Officer 1967; Anderson and Dillon 1971; Low 1974; Wolgin 1975; Roumasset 1976; Moscardi and de Janvry 1977; Dillon and Scandizzo 1978). Even risk is not the sole factor determining decision-maker's behaviour (Roumasset (1977); however, it remains an important one. Therefore, further discussion on the models will be presented within the context of risk involvement.

The performance of a farm operation can be assessed using budgeting, functional analysis, or activity analysis techniques (Hutton 1970). With respect to managerial operations, budgeting is incomplete in terms of identifying the control measure to be employed.

Functional analysis comprises a class of techniques of which regression models are one. These techniques are almost always partial. All the parts, within a relatively narrow segment of the farm business, are covered with a high degree of completeness. **Since it is partial, it is not preferable to be used for the purpose of studying the whole farm business.**

Activity analysis or mathematical programming has approximately the same range of application as budgeting. The whole farm can be conveniently modelled. Despite its weaknesses, e.g. from its linearity assumptions, it has the advantage over the previous two approaches in that control measures can be employed and decision components can be easily introduced. This model therefore seems suitable for this purpose. But before discussing mathematical farm programming models, basic decision models will be reviewed first.

3.5.2 Risky decision models

A decision model is comprised of several components: a set of alternative courses of actions, a set of states of nature, consequences associated with actions and states of nature, and a choice criterion (Eisgruber and Nielson 1963). Additional components implying the existence of a learning process are prior probabilities, experiment, likelihood probabilities, posterior probabilities and strategies (Anderson *et al*. 1977). The choice problem is to select certain courses of action from alternative ones with corresponding alternative consequences in order to maximize decision criteria. The learning process implies that, by experiment or collection of further information on **probabilities** of the states of nature, the original subjective degree of beliefs (prior probabilities) can be revised according to Bayes theorem. Revised degrees of belief are called posterior probabilities. Given the preference function denoting decision criteria and subjective degrees of belief of the decision maker, then the decision analysis procedure to select the best strategy is executed by applying Bernoulli's principle. The procedure - including its underlying principles - is explained in Dillon (1975) and Anderson *et al*. (1977). Therefore it will not be repeated here. Those interested in greater detail should go to these or similar readings.

According to Roumasset (1977), three criteria can be used to distinguish decision making models:

(i) The use of probability: subjective or objective;

(ii) Decision making process: specified or not;

(iii) Learning plays a role in the model or not.

Further, one additional criterion is suggested (see Sharma 1979); that is

(iv) Decision criteria measured in value or utility.

Based on the first three criteria, Roumasset classifies and discusses briefly several decision making models: expected utility model, Bayesian, safety-first, cautious optimizing, Shackle and pure behavioural.

The first four models use subjective probabilities, two of which, the expected utility and the Bayesian ones, do not specify the decision process. Learning is assumed to play a role in Bayesian, cautious optimizing and pure behavioural models. In all these models, expected utility is used as decision criterion.

Various aspects can be named that have to be considered in determining the best decision model. However, probably the most important one is that the model should exactly or closely represent the actual behaviour of the decision makers. Hence, criteria for classification can also be questioned within this context. The main aim for considering these aspects is to select a suitable decision model, incorporating all or most criteria, that captures the situation around the small farmer's decision making. Consequently subsequent dicussion will emphasize the following points: value and utility as decision criteria, subjective and objective probability in decision making, the decision process, and the learning process.

Values and utility. All models, as classified by Roumasset, use expected utility as the decision criterion. It seems to indicate that there is a general consensus among the decision analysts to use expected utility rather than expected values as decision criterion. There are strong reasons, empirical as well as theoretical, supporting the use of utility to values.

Empirically it has been tested and confirmed both for commercial farmers in advanced countries (e.g. Officer and Halter 1968; Lin et al. 1974) and for traditional farmers in LDCs (e.g. O'Mara 1971; Wolgin 1975; and Herath 1979 as reviewed by Hardaker 1979) that the subjective expected utility model predicts farmers' behaviour better than does the expected profit maximization model.

Theoretical reasons have been discussed by Officer (1967) and Anderson _et al_. (1977) by referring to a security dimension as another explanatory factor of decision maker's behaviour. Another reason why utility is superior to value is that it can translate differently measured components in a multiple goals situation into a single utility measure.

Subjective and objective probabilities. These two types of probabilities have been discussed in almost every textbook on statistics and decision theory (e.g. Schlaifer 1959; Pratt _et al_. 1965; Mendenhall and Reinmuth 1974; Anderson _et al_. 1977). Objective probability is usually empirically determined, and is defined as a limit of a relative frequency; that is the number of favourable cases to the total number of cases, if the trial is repeated infinitely. Subjective degree of belief is defined as the belief that a person has in the truth of a proposition. This one is different from the former in that it allows revision in the beliefs by getting additional information either from own experience, own experiments or from other sources.

Sharma (1979) has shown that the decision to adopt new technology by Nepalese farmers can be explained by the variation of their subjective degree of beliefs in the result of using that technology. The use of objective probability exclusively appears to be unlikely in decision making. According to Anderson _et al_. (1977) a concept based on infinite trial seems irrelevent to 'finite' decision making. As well, states of nature - such as weather - in decision making are not always repeatable in exactly the same way. Nevertheless, objective probability might still be used, indirectly, as likelihood probabilities (Officer and Dillon 1968).

Decision process. This may refer to stages or sequences in decision making. Two cases have been mentioned where decision process might be specified. First, if there are sequentially dependent alternative acts. In case discrete probabilities are attached to the alternative states of nature, decision tree representation can be used to analyse this kind of decision (Anderson _et al_. 1977). Second, another way of specifying decision process is through a lexicographic ordering of preferences. In this case, the decision maker may put priority to certain preferences and allow to achieve them first in terms of resource use before deciding on other preferences (Roumasset 1977).

Actually the main problem in this study with respect to decision process does not lie between those two cases, but in the necessity to specify the decision process. If the specification of the decision process does explain the behaviour of the decision maker and hence, the result of the decision, then it seems necessary to specify it. In this light it seems reasonable to refer to several theories and empirical evidences concerning small farmers' decision making who employ lexicographic ordering of preferences (Mellor 1963 and 1967; Low 1974; Farrington 1976; Roumasset 1976 and 1977). Lin et al. (1974) conclude from the result of their test on data from commercial farmers in California that the lexicographic model predicts farmer behaviour better than the profit maximization model. They also found that the expected utility model is the best of these three.

The learning process. The learning process involving Bayes theorem refers to the revision of decision maker's beliefs by getting more information on the likelihood probabilities of the states of nature. This process is allowed by the supporters of subjective probability, but not by those supporting objective probability. The learning process of the small-farmers with respect to their decision making is implied in Schultz's theory as explained in point (3) sub-section 3.2.3 (p.33). The long period to reach the equilibrium point implies internal managerial improvement. As states of arts and states of preferences and motives remain constant, then this improvement should be attributed to improvement in understanding the states of nature. This is consistent with the learning process mentioned above.

Even though the learning process is important, however, the author can't find any programming model which specifies this process explicitly. Implicitly, it can be incorporated by steadily changing the subjective degree of beliefs in the occurences of the uncertain events. Furthermore, the process itself seems to be important in dynamic rather than in static analysis. As this study is based on static analysis, the learning process will not be considered in the selection of the model.

From previous discussions in this section, it can be suggested that the suitable decision model for this study is the subjectively expected utility model, in which the decision process specification is allowed.

But before making a final selection, mathematical programming models denoting annual farm plans will be reviewed.

3.5.3 Annual farm planning models

Mathematical programming models have been developed which can serve various farm planning purposes. The static models are generally used for annual farm planning. The conventional deterministic models ignore uncertainty. Recent farm planning models which are extensions of the previous ones allow the specification of risk factors. Various models of this sort have been reviewed by Anderson *et al.* (1977) and Wicks *et al.* (1978), who have classified existing models according to where risk is incorporated in the programming matrix.

Perhaps the crucial problem to be resolved in risk programming is locating where risk is considered,[1] how it should be specified or in other words, how risk should be taken in account in the model and how it should be measured. Most of the programming models can be distinguished based on these aspects. The location of the elements in the programming models which are considered to be subject to risk may be found in the objective function, in the resource constraints or in the input output matrix.

Wicks *et al.* (1978) divide the models where risk is considered to be found in the objective function in those with non-linear and those with linear objective functions. Non-linear models include the quadratic programming model (Markowitz 1959; Hazel 1971) and the separable programming model (Thomas *et al.* 1972).

In the quadratic programming model, it is assumed that farmers base their choice solely on expected income (E) and associated risk, which is measured in income variance (V). It is assumed further that farmers would prefer a strategy with high V only if E were also greater. This implies that farmers are risk averse and have a concave utility function. There are two methods of determining the optimal farm plan using quadratic

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[1] It should be noted that 'where risk is considered' is not synonymous with 'where risk is specified'; there are models - e.g. safety first models - where components to be maximized, for example income, is subject to risk, however, the related risk factor is specified as a constraint.

programming. First, directly use a quadratic utility function as the objective function to be maximized. The second method consists of a two-stage approach: determine firstly a set of all feasible farm plans which satisfy the efficient E-V criteria and resource constraints. A farm plan that satisfies E-V criteria in this case is the one which minimize V for a given E. After that, let the farmers select the one according to their preferences, or determine the optimum plan using farmers' iso-utility curves. The optimum plan is determined by the point of tangency between efficient E-V boundary and farmers' iso-utility curves.

In separable programming, the non-linear function is broken down in to its linear segments. Each linear segment is incorporated additively in the objective row as artificial activity (e.g. Rae 1971 a,b).

Models with a linear objective function can be classified in to three groups as follows:

(i) Where risk account is introduced as a constraint; this belongs to the safety-first approaches: e.g. focuss-loss constraint or maximum admissible loss approach (Boussard and Petit 1967; Boussard 1971; Andrews and Moore 1971), and flexibility constraints (Day 1963).

(ii) Where minimizing risk is taken as the objective; this method belongs to the game theory approaches: e.g. Wald maximim model which is used to identify a feasible farm plan with the largest of worst possible total gross margin that nature could inflict from any of the possible states of nature (McInerney 1968; Hazel 1970; Low 1974); and its relatives, the minimize regret model, maximum parametric model, and the regret parametric model (Hazel 1970); to this belongs also minimization of total absolute deviation (MOTAD) model (Hazel 1971).

(iii) Using more than one linear objective function; where risk may be specified in one of the objective functions; to this belongs Monte Carlo programming (Carlson _et al_. 1969; Wardhani 1976).

Obviously, risk may possibly be attached to input-output coefficients and resource constraints too. A tenant farmer with a yearly contractual arrangement may regard the land constraint as risky. A perennial crop farmer using seasonally casual labour for harvest may find the labour constraint risky. However, for a Melanesian farmer in Irian Jaya, where land is relatively plentiful, and family labour is the main source of labour, such a resource constraint risk will probably not exist.

Input-output coefficients in farm production plans depend on basic biological, physical and other factors, and thus are subject to risk. There are two main techniques to take account of risk in this case. First, one can repeat the formulation of activities containing risky input-output coefficients in the programming model using different input-output coefficients. The amount of repetition depends on the number of variable cases in which the input-output coefficients occur. As the number of cases are sometimes too numerous and the corresponding matrix may be too large to be handled by the computer, the number of repetitions are usually restricted by specifying only a few 'states of nature'. The respective input-output coefficients are determined by selecting the one representing central tendency of those in each state of nature. Most programming models use this kind of input-output coefficient in combination with a risky objective function. To these belong the Wald maximin model and its relatives as mentioned earlier, parametric quadratic programming (Chen 1973) and discrete stochastic programming (Cock 1968; Rae 1971 a,b). The second technique to take account of risky input-output coefficients, particularly in risky production of intermediate products, is the mean absolute deviation model with risky input-output coefficients (MOTAD with RINOCO) as developed by Wicks and Guise (1978). The method is an extension of the MOTAD formulation for risky gross margins. Mean absolute deviations are estimated from a sample set of input-output coefficients, and converted into standard deviations. These are incorporated into chance constraints of which the most restrictive may not be violated with more than a perspecified probability.

Even though numerous applications of mathematical programming for planning small farms are found, only a few of them incorporate risk analysis (e.g. Heyer L972; Low 1974; Schluter 1975; Farrington 1976; Sanders and Dias de Hollanda 1979). All these models used a linear objective function, where risk specification followed decision rules adopted in linear alternative models for mathematical risk programming such as in game theoretic models, safety-first models and the MOTAD model. Hardaker (1979) has reviewed the use of programming models in research for small-farm development, particularly the models incorporating risk measure. Even the linear alternative models of mathematical risk programming are useful in many cases, however, in view of decision theory, they lack sound axiomatic foundation. According to Hardaker (1979), in those models, "computational tractability is won by representing the farmer's actual preferences in a particular arbitrary way". Furthermore, farmer's subjective probability is usually neglected. The exclusion of subjective probability may lead to signifying an income or profit level which in fact has a low probability of occurence (Boussard 1979).

In line with Hardaker (1979), stochastic discrete programming appears to be the suitable model in that the decision rules which are consistent with the decision theory can be imposed. Risk, in this model, may be considered in the objective function and input-output coefficients. Further, it allows lexicographic specification (Rae 1971 a), which could be possible in the traditional farm situation, where farmers put priority on subsistence production and consumption. Despite the problem that sometimes the matrix becomes so large that it is difficult, if not impossible, to be handled by the computer, given that the utility function and subjective probability can be elicited, they can easily be incorporated in the model.

3.5.4 Summary remarks

The main purpose of the discussions up to this stage is to determine the suitable model combining the decision theoretic approach and mathematical programming within the context of annual farm planning by traditional farmers. Risk is considered important, thus it must be taken into account.

Various aspects for a suitable decision model have been mentioned in the concluding remarks of the discussion in sub-section 3.5.2. These aspects must surely fit into the proposed programming model: a multi-dimensional objective function and where subjective account on risk can be easily incorporated in the objective function as well as in the input-output matrix.

Stochastic discrete programming according to Cock (1968), Rae (1971 a,b), and Hardaker (1979) seems to fit this purpose. This model uses a utility maximizing objective function, using linearly segmented utility evaluation, allows a lexicographic decision rule, and permits incorporation of the farmer's degree of beliefs on the state of nature. This model will be discussed further in Section 4.3.

3.6 Small-Farmers' Utility Functions

3.6.1 Introduction

The reason to select expected utility maximization rather than expected value maximization have been discussed in Section 3.5.2. Utility maximization is said to be a better criterion in that it explains the decision maker's behaviour under risk more accurately than profit maximization (e.g. Officer 1967; Anderson *et al.* 1977; Lin *et al.* 1974; Hardaker 1979).

It is worthwhile to mention that there are also weaknesses reported concerning the use of the subjective expected utility model. Sharma (1979) refers to the difficulties found in eliciting the utility indifference curve of the small-farmers as reported by Roumasset (1976) and Dillon and Scandizzo (1978) among others. There are also inconsistencies in the result obtained as reported by Binswanger (1980). The theoretical weaknesses are reviewed by Officer (1967). He refers mainly to the basic axioms underlying Bernoulli's principle as restated by von Neumann and Morgenstern, where inconsistencies may exist in the transitivity and continuity axioms.

These shortcomings should obviously not be regarded as intractable. More suggestions for improvements are needed, which coincidentally means more use of the model. The suggestion to consider possible lexicographic preference ordering in the multidimensional utility case where the continuity axiom is violated (Officer 1967) is a good example of such a suggestion. Despite its shortcomings, however, given that it predicts small-farmers' behaviour better than any other alternative models, it is, at present, the best available operational model to study small-farmers decision making (Hardaker 1979).

By accepting the subjective expected utility model and hence the utility function, then these points remain to be discussed further: the components of the utility function, and methods of utility elicitation.

3.6.2 Components of small-farmers' utility functions

At the outset it seems necessary to define certain key words used in this sub-section. These are: components of a utility function, consequences of a decision, utility, and a utility function.

Components can be defined as those items a decision maker includes in his objective when making his decisions. Consequences are the sets of values in which the components may occur. For example, money income is a component but the amount of money income is a consequence. Component and consequence are thus two aspects of the same thing. Components determine the dimension of the utility function, whereas consequences are related to the degree of each dimension.

Utility is a cardinal measure of the degree of a decision maker's preferences among actions or among their corresponding consequences, given his knowledge or beliefs on the states of nature (Officer 1967; Anderson et al. 1977). A utility function is an expression of preferences among consequences, showing the relationships between utilities and corresponding consequences. A rational decision maker decides and acts consistent with his preferences and beliefs. This means he is maximizing utility, which is an expression of his preferences (Anderson et al. 1977).

Most commonly, predefinition of all possible acts for farm management problems may be impossible because the number of possible acts may be infinitely large, or acts may have been chosen from within the confines of a restrained set (Rae 1971). As such, the preferences extracted from the farmer's mind will be based on preferences among consequences or set of outcomes attributed to main components of the proposed utility function. Obviously, these components must be consistent with the farmers' ones.

There are two cases from previous discussions which might supply some information in this respect. First, the acceptance of expected utility rather than expected values implicitly assumed the proposition that farmers' satisfaction does not depend solely on money income; or in other words, utility is not a linear function of money income. This proposition allows the inclusion of other components beside money income into the utility function, thus assume its multi-dimensionality. Second, the inclusion of risk adds another dimension to satisfaction. It suggests that satisfaction does not accrue to the products alone, but also to how the products are brought about.

Traditional small-farmers are known to retain multiple goals with various priorities. Those goals may be regarded as components of the utility function that has to be derived. Many researchers have theorized about the components of the small-farmers' utility functions. Some of them have used those components in empirical analysis (e.g. Fisk 1962, 1964; Mellor 1963, 1967; Shand 1965; Sen 1966; Nakayima 1969; Hardaker 1975; Stent and Webb 1975; Dillon and Scandizzo 1978). Most of them seem to agree that the main components are food and other subsistence household needs, cash reserve needs, labour use or its complement, leisure, and risk.

Perhaps disagreement lies in the question whether these components are considered to be equally preferred or to follow a certain preference ordering. This question has been discussed in Sections 3.2 and 3.3. The temporary answer for the Melanesian farmers' case as concluded in sub-section 3.3.4 is that a lexicographic preference seems to exist, where farmers tend to put priority on food and other household subsistence needs. There is also another point mentioned in sub-section 3.3.4 related to Philp (1979) and de Boer and Chandra's (1978) empirical findings which seems important here given their information on the preference ordering of Melanesian farmers. That is the leisure-cash activity choice problem.

Fisk (1964) refers to incentive factors and response factors as variable to stimulate the use of surplus labour in subsistence affluence situation. De Boer and Chandra as well as Philp have shown that surplus labour has been used for cash activities, even though, according to Philp, the return per labour for cash activities was low. De Boer and Chandra show that for native Fijian farmers, this surplus labour has been fully used. Hence, several inferences can be drawn from these findings. First, as long as the return per labour for cash activities remains low, priorities will be put on food and other subsistence household needs. Second, given available surplus labour time after allowing time for subsistence activity and for rest and recreation, this surplus labour time will be fully devoted to extra cash activities. Then the choice problem between cash activities and leisure can be assumed to become non existent. Third, as a result of accepting the previous two inferences, the remaining choice problem, which will be the components of the utility function, is between cash income needs and the risk factor in generating it.

3.6.3 Methods of utility elicitation

As was mentioned earlier, utilities are cardinal numbers assigned to possible outcomes or consequences of a decision, and expressing the decision maker's preferences among those consequences. These preferences among consequences should be extracted and summarized from the decision maker's mind. Methods for this purpose have been discussed by Officer (1967) and Anderson *et al*. (1977), among others. Officer reviewed the work of pioneers in utility elicitation. Anderson *et al*. reviewed the available methods, and explained particular cases for unidimension and multidimension utility elicitation. In general, two methods are used to assign utility to its corresponding consequence, based on decision maker's expression. Those are direct method and moment method.

Direct method. Each single outcome is transformed directly into a utility, and weighted by the probability of its occurence. The process of elicitation of utility is easy using this method. However, a complex computational problem usually follows because the utility function obtained is usually large. Furthermore, direct questioning of the decision makers to express their degree of happiness or satisfaction with a certain consequence can not easily be justified (Officer 1967).

Moment method. This method uses iso-utility (indifference) curves showing the point of indifference between various consequences of each utility component. Two methods of utility elicitation of this kind are reviewed by Anderson *et al*. (1977). First, the equally likely risky prospect and finding its certainty equivalent (ELCE) method. Second, equally likely but risky outcomes (ELRO) method. Before discussing those methods in turn, several basic axioms underlying the elicitation methods will be reviewed first.

In order to summarize the decision maker's expression of preferences concisely, they must conform to a few perfectly reasonable rules of behaviour. These rules or axioms, derived from Bernoulli's postulates and reintroduced by von Neumann and Morgenstern, are (i) ordering, (ii) transitivity, (iii) continuity, and (iv) independence (Officer 1967; Anderson *et al*. 1977).

(i) Ordering. This implies that the decision maker can order the consequences according to his preferences. For example, for outcomes x_1 and x_2, the following order may be held:

$x_1 < x_2$ which means x_1 is less preferred to x_2;

$x_1 = x_2$ which means x_1 is equally preferred to x_2;

$x_1 > x_2$ which means x_1 is more preferred to x_2.

It will follow respectively that

$U(x_1) < U(x_2)$: utility from x_1 is less than utility from x_2;

$U(x_1) = U(x_2)$: utility from x_1 is equal to utility from x_2; and

$U(x_1) > U(x_2)$: utility from x_1 is greater than utility from x_2.

(ii) Transitivity. This is a logical extension of ordering, if more than two consequences occur. For example, for consequences x_1, x_2 and x_3. If $x_1 > x_2$ and $x_2 > x_3$, the logical deduction is that $x_1 > x_3$.

(iii) Continuity. If for a decision maker $x_1 > x_2 > x_3$ or $U(x_1) > U(x_2) > U(x_3)$, then a subjective probability $1 > P(x_1) > 0$ may be found such that $P\,U(x_1) + (1-P)\,U(x_3) = U(x_2)$.

(iv) Independence. In the case where for a decision maker $x_1 > x_2$, and $P(x_1) = P(x_2)$, then if choice has to be made between x_1, x_3 set of consequences and x_2, x_3 set, the decision maker will prefer x_1, x_3 set, provided that x_1, x_2 is independent of x_3.

For multidimensional consequences, theoretical inconsistencies that might exist especially for transitivity and continuity axioms, has been discussed by Officer (1967). He refers to lexicographic ordering that violates continuity axiom, and intransitivity that may exist. Therefore, for multi-dimensional consequences, a slight but reasonable extension of the axioms is necessary (Anderson et al. 1977, quoting Fishburn 1970). However, for unidimensional consequences, these axioms provide sufficient basis for utility elicitation. Hence, ELCE and ELRO methods of utility elicitation will be reviewed subsequently.

ELCE method. This method is modified from von Neumann - Morgenstern or standard reference contract method (Officer 1967; Dillon 1975). As the method is outlined very clearly in Anderson et al. (1977), it will be reviewed only very briefly here.

In this case a bargain between certainty equivalent (CE) and equally likely risky outcomes - or two outcomes with point five probability of occurence - is offered to the decision maker. First pair of the risky outcomes are the best and the worst possible outcomes. By steadly increasing or decreasing the amount of CE if risky outcomes or its alternative CE is chosen respectively, a CE can be found, for which the decision maker is indifferent between those two alternatives. This CE is further paired with the highest and, in the next turn, with the lowest of the possible risky outcomes and the bargains repeated to find respective CEs. These CEs are again paired with the highest and in turn with the lowest possible outcomes used in the same bargain, and the process continued with new bargains until enough points are found to draw the respective utility curve.

For utility measure, arbitrary utility numbers are assigned to the lowest and the highest possible outcomes. For example, if the highest possible outcome is x_1 with it arbitrary utility number say, eight, and the lowest x_2 with its arbitrary utility number say, zero, then from the result of the first bargaining process, the utility can be calculated as follows:

$$.5\ U(x_1) + .5\ U(x_2) = U(CE_1)$$

$$.5\ (8) + .5\ (0) = 4.$$

If in the second bargaining, the possible risky outcomes are x_1 and CE_1, then the respective utility calculation is,

$$.5\ U(x_1) + .5\ U(CE_1) = U(CE_2)$$

$$.5\ (8) + .5\ (4) = 6.$$

By repeating the process several times, a utility function can be fitted, showing the relationship between utility and corresponding CEs. It can easily be interpreted from the curve drawn whether the decision maker is a risk averter or a risk taker, that is when the curve is convex or concave respectively. This method is the easiest to be carried out. Furthermore, by using an equally likely or point five probability, the expression of preference is assumed to be independent of decision maker's beliefs, and bias due to probability preference can be avoided.

ELRO method. This method, which is also called the Ramsey method (e.g. Officer 1967; Dillon 1975; Roumasset 1976), differs from the previous one in that two sets of equally likely risky outcomes are used as alternatives instead of one set of risky outcomes and CE. The reason here is to overcome bias due to gambling preference (Officer 1967).

The procedures of this method are clearly explained in Anderson et al. (1977) and Officer (1967). If the utility has to be determined between two risky outcomes then the procedure begin with choosing the reference interval of two values in the middle of the range such that the range is about one tenth of the original range. For example, if the original range of values is between zero and hundred, then the reference interval can be taken say, between 45 and 55. They are further regarded as the highest possible outcomes between the two equally likely risky outcomes. The one with the higher value between those two is paired with the lowest one in the original range, i.e. 55 is paired with zero in the sample. The choice problem is presented in sequence 1 of Table 3.1. Further, using the procedure of questioning as for the ELCE method, a certain number as a pair for 45 can be found at which the decision maker is indifferent between a_1 and a_2 say, x as in Table 3.1.

The procedure of assigning utilities is as follows: Assume U (55) - U (45) = 1, and U (0) =) or any other number. Then U (x) can be determined by calculating

$$.5\ U(45) + .5\ U(x) = .5\ U(55) + .5\ U(0).$$

Rearrange it to find

$$U(x) - U(0) = U(55) - Y(45)$$

$$U(x) - 0 = 1.$$

By replacing zero with x as shown in sequence 2 of Table 3.1, the procedure

Table 3.1

Sequences of Alternatives Offered Using ELRO Method

Sequence 1				Sequence 2			
θ	P	a_1	a_2	θ	P	a_1	a_2
θ_1	.5	45	55	θ_1	.5	45	55
θ_2	.5	x ?	0	θ_2	.5	y ?	x
Sequence 3				**Sequence 4**			
θ	P	a_1	a_2	θ	P	a_1	a_2
θ_1	.5	55	x	θ_1	.5	x	y
θ_2	.5	v ?	y	θ_2	.5	z ?	v

of questioning is continued to find a new number as a pair of 45 say, y such, that the decision maker is indifferent between a_1 and a_2. After that U (y) can be determined using the same procedure as for U (x). Following the procedure as shown in sequences 3 and 4 of Table 3.1, the choice problem is further rearranged and continued to determine utility points of the number preferred, until the highest value of the original range - e.g. hundred in this case - is reached.

ELCE and ELRO methods can also be used in eliciting utility for multi-dimensional utility analysis to supplement special approaches: benchmark approach, quasi-separable utility function approach, and also in conditions where lexicographic orderings exist (Anderson et al. 1977).

3.6.4 Presentation of the utility function

After eliciting utility based on the decision maker's preferences, utility function can be fitted by relating utility numbers to respected consequences or certainty equivalents. Different aspects for its algebraic representation have been discussed by Officer (1967) and Anderson et al. (1977). They cover the alternative types of functions to be specified - including their theoretical and empirical advantages and weaknesses.

It can be summed up here that, which ever function will be selected in this case, the main requirement is that it must fit the data accurately. Judging by plotting the fitted function and assessing visually how well it matches the elicited utility values seems to be the best test of goodness of fit (Anderson et al. 1977). Of course, this should be used in addition to statistical tests.

3.6.5 Summary remarks

In this section, different aspects of assessing utility functions have been discussed. In sub-section 3.6.2, two aspects are discussed in particular: the components of small-farmers' utility functions and their preference orderings. It tends to suggest that for Melanesian farmers at their present stage of development, cash activities and subsistence activities are not substitutable in terms of labour use, nor are cash activities and leisure. The choice lies between the alternative cash activities, that is between wage earning activities (with sure cash earnings) and cash cropping (with risky cash earning). Consequently, the suitable method of utility elicitation is the ELCE method.

3.7 Subjective Probability

3.7.1 Introduction

Probability theory is part of mathematics and statistics, and found its applications in widespread branches of applied sciences. Three types of probability have ever been mentioned: objective probability, logical probability, and subjective probability (Kyburg and Smokler 1964). The development of objective and subjective probability as a theory is discussed by Raiffa (1970). A particular historical perpective of subjective probability theory is discussed by Officer (1967). Keynes has been regarded as the pioneer of logical probabibility (Kyburg and Smokler 1964).

Objective probability and subjective probability have been defined earlier in sub-section 3.5.2. Logical probability is defined as the logical relationship between a proposition and a body of evidence (Officer 1967; Anderson et al. 1977). It demands a thorough understanding of all the rules and laws and characteristics underlining the proposition and related body of evidence.

Subsequent discussion will be concentrated on subjective probability, which is of major interest in this study. It seems that the best way to explain is by contrasting it to the other two probability concepts.

3.7.2 The concept of subjective probability

The description of and comparison between subjective and objective probabilities have been discussed in sub-section 3.5.2. It can briefly be said that subjective probability differs from the objective one in that the process of learning is allowed in the former, which resulted in the revision of prior subjective probability to form posterior subjective one. In the process of revision, information on likelihood probability is needed and, that likelihood probability may be an objective one. Furthermore, in statistical inductive approach where infinite repetition is impossible, a subjective interpretation is usually executed, which makes objective probability not a pure one, but containing subjective aspects (Officer 1967).

Dillon (1975) tends to reject the logical probability for decision making because of its impossible demand in terms of time and cost, among others, to understand all the rules, laws and characteristics underlining the proposition and the related body of evidence. Perhaps, this attitude should be interpreted in terms of the complexity of the decision problem. In simple decision problem, logical and subjective probabilities may coincide. Officer (1967) describes the relationship between these two probabilities as follows:

> 'Probabilities have to be formed which are a reflection of a degree of belief about an external event; it does not matter at which stage we start in the formulation of the probability, whether at the early stage (i.e. the logical relation between two arguments), or at a latter stage (i.e. the degree of belief about the external event, which result from the logical relationship between the proposition and evidence)'.

To sum up, subjective probability is the personal belief in the truth of a proposition, regardless of how that belief was formed within the decision maker's mind.

3.7.3 Methods of elicitation

There are three aspects that have to be considered in selecting a method to elicit subjective probability. First, whether the term 'nature' in the problem under study involves a simple factor (one random variable) or a compound factor (more than one random variable). Second, whether each random variable has a continuous or discrete distribution. Each degree - qualitative or quantitative - in which the variable is measured, represents each possible state or event which are mutually exclusive and form an exhaustive set. Third, when the term 'nature' refers to a compound factor, whether the random variables involved are independent or not from each other.

If more than one independent random variable is involved, the following alternative approaches may be used: (i) directly elicit the joint distribution, or (ii) elicit the probability distribution for each single random variable and using probability calculus transform them to joint probabilities. To elicit subjective probabilities using the first approach, however, is technically difficult; especially when many random variables are involved (Anderson et al. 1977). This difficulty must be greater if the probability has to be extracted from the mind of traditional, illiterate farmers. In some theoretical discussions (e.g. Rae 1970, a; Hadley 1967) the second approach tends to be suggested.

Following the second approach, there are two methods to assign probabilities to the states of a single variable with a continuous distribution: (i) direct, as a cumulative distribution function (CDF), or as a probability density function (PDF) or, (iii) indirect, using past or future hypothetical sample. PDF, compared to CDF, is much more difficult to be elicited. Therefore CDF is usually advocated (Anderson et al. 1977; Sharma 1979). CDF may be defined as either P $(x \leq X^*)$ or P $(x \geq X^*)$, where X^* is some particular magnitude of random variable x. Two methods of elicitation in this case are, (i) visual impact method, and (ii) judgemental fractile method.

(i) Visual impact method. First, determine the range of the variable, and then divide this range into a number of mutually exclusive and exhaustive intervals. Counters, say one hundred, are allocated to the cases. More counters are allocated to the case considered most likely to occur, less to the less likely to occur, and none to those considered not likely to occur. Probability is observed as the ratio of observed counters in each cell to total counters.

(ii) Judgemental fractile method. This method is suggested by Raiffa (1970). It is based on finding equally likely probability intervals. Assume a CDF with a cumulative probability from zero to one, and divided into fractiles 0.5, 0.25, 0.75, and so on. These fractiles are assigned by relating them to certain magnitudes of the random variable, extracted from the farmer's mind. In this case the farmer is asked to name the certain magnitude of the random variable for which the probability is greater than, or less than the respective probability fractile.

3.7.4 Summary remarks

In sub-section 3.7.2 the concept of subjective probability is described. Subjective probability is said to be a personal degree of belief. This does not mean that all probabilities extracted from the decision maker's mind are completely reliable. They are subject to bias too. Some potential biases have been reviewed by Sharma (1979) from Tversky and Kahneman(1974) and Stael von Holstein (1975). Those are, representativeness, availability, adjustment and anchoring, convervatism, and probability preference. These potential biases can be reduced if the method of elicitation is reliable and when the interviewer can capture farmers' true decision making processes and the true random variables.

Chapter 4

METHODOLOGY

4.1 Procedure of the Study

The approach to solve the problem in this study is distinguished into three stages: (1) development or synthesis of the programming model that adequately represents the decision making model of the indigenous farmers in the study region within the context of their annual farm plans (model synthesis, verification and validation); (2) identification of the most limiting factor by running the model to achieve optimum solution (hypothesis testing); and (3) experimenting with the model by parametizing the constraining factors or increasing the related prices or input-output coefficients.

4.2 Selection of the Study Region and Sampling Method

In Irian Jaya, there are about twelve regions which are proposed to be developed as main agricultural centres (Sebayang 1972). From these Nimboran is selected as the case study region. A map of Nimboran sub-regency is shown in Figure 4.1. Between the proposed regions, Nimboran is the closest to Jayapura, the capital city of the province Irian Jaya. As such, almost all agricultural development policies for Irian Jaya have been tested in Nimboran and, as reviewed in sub-section 2.3.1, some ended with failure. Other aspects of the region, such as socio-economic conditions, have been outlined in Section 2.3.

In 1979, there were 1056 families in Nimboran sub-regency. From this number, 166 were transmigrant families, and 160 families of government officials, teachers and traders. Indigenous farmers consisted of about 730 families. If we accept the concept of traditional farm as an organization of nature, labour, capital and management as well as a decision unit in which production and consumption decisions are not separated, then a nuclear family unit can not be taken as representing a farm unit. By observing a village life in Irian Jaya and particularly in Nimboran, a household unit is those who live in one house, who share cooking, and share their labour in farm activities. This, most often, is an extended family

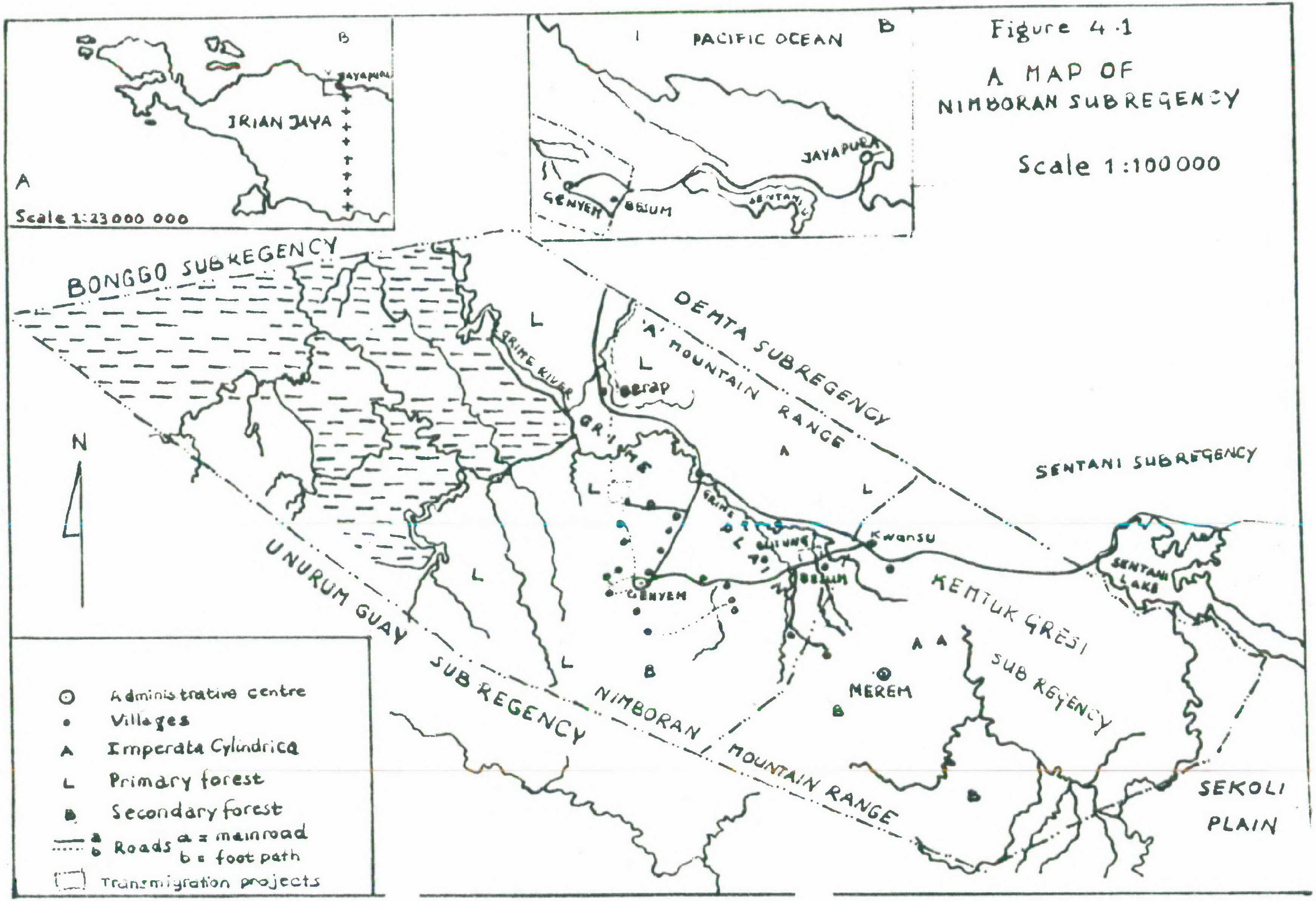

Figure 4.1
A MAP OF NIMBORAN SUBREGENCY
Scale 1:100 000

with more than one nuclear family. Accordingly, in this study, a household is taken to represent a farm unit. Thus, based on the number of houses, there are about 357 indigenous farm units in Nimboran sub-regency. From this figure, 195 units have adopted new farm activities such as cocoa production and cattle raising, whereas 162 still cultivate traditional crops only. Thirty farms consisting of 15 cocoa growers and 15 non cocoa growers were randomly selected from 357 indigenous units. Eight of the sample farms are located in the villages close to the local administrative centre, i.e. Genyem, another eight farm units are located along a busy road between Genyem and Jayapura, i.e. in the village Besum, and 14 of the farm units are located along the less busy road, i.e. in the village Berap.

Because a decision analysis approach is used in this study, it is considered necessary to explain who are the farm level decision makers and how, where, when they make decisions. The following short story emphasizes the attempt to answer these questions simultaneously.

> ... late in the afternoon, each member of the farm family return home from their day's work. After taking a bath in the creek or fountain, the female members start preparing the evening meal. Teenagers light the lamps. Male members sitting cross legged around the hearth, and chatting about everything and changing each other's experiences during the day. Females, while preparing the meal, fall now and then in the conversation. Occasionally, suggestions are passed where every one can comment on. If daddy (or grand pa) outlines his experience, or comment on certain suggestions, other members sit quietly, absorbing each word reaching their ears, like paying a solemn tribute to an honoured man. No one dares to argue. If there happens to be disagreement, it is expressed jokingly so as not to irritate the speaker. ... When the female members interrupt that the dinner is ready, the conversation ceased. No one of them ever realized that during the previous conversation, decisions were made ...

As implies in the story, it can briefly be said that even farm family heads are not the sole decision makers - all grown up members contribute in the decision making - however, they are the most influencial in the families. They seem to determine to a great extent the result of the families decisions. Therefore, during field work, the interview is conducted with household members as a group, where the presence of the family head - usually the oldest male member or the grown-up oldest son - is strictly required. The presence of other members is not strictly required.

4.3 Specification of the Model

4.3.1 The basic programming model

In this study discrete stochastic programming model as derived from Hardaker (1979), and is also consistent with Rae (1971 a, b) and Cock (1968) is used. This model is selected based on several reasons. First, the objective function is to maximize utility, which is assumed to be consistent with the traditional farm situation. Second, risk in this model is considered in the objective function, constraints, as well as in input-output coefficients, and is assumed to be reflected in the possible state of nature. Thus, farmers' preferences, which are measured in terms of utility, and beliefs, which are measured in terms of their subjective probability distribution of the possible states of nature, can be incorporated. Third, the model allows a lexicographic utility evaluation in case farmers put priority on subsistence food production, as is assumed to be the case in Nimboran.

The actual stochastic dicrete programming model developed for this study has 201 columns and 320 rows. It is therefore impossible to be shown in detail here. However, a simplified symbolic form of the model, and a pictorial form of the whole matrix block are shown in Figures 4.2 and 4.3.

The first figure shows the main component of the model. The symbols, description of which will be given subsequently, represent a set of factors rather than one single factor. The dotted lines and the striped lines enclose respectively the columns and rows that should be repeated for each state of nature. The matrix is further divided in to sub matrices A, B, C_1, and D_1, and vectors mu_1, RHS_1 and RHS_2. In the original matrix, only sub matrices C and D, and vectors mu and RHS_2 are repeated for each state of nature. The layout of the whole matrix is shown in Figure 4.3. Except for P_i, Q, Y, D_a and D_p, the magnitude of the constraints and other coefficients in the repeated parts of the matrix remain the same.

The symbols and subscripts in the model, as shown in Figure 4.2, can be described as follows:

Starting from the first row,

			θ_i (i=1 .....9)	
	Max E(u) =		$\sum_{k=1}^{k} P_i Ux_{10k}$	
	subject to =			
	x_2			$\leq L$
	$- x_1 + Nx_2 + Ix_{3p} + x_{4w}$			$\leq Nf$
	x_1			$\leq Ne$
	x_{4w}			$\leq Wm$
	$- x_2 + x_{3a}$			≤ 0
θ_1 (i=1...9)	$- Qx_{3a}$		$+ Ix_{5a} + Ix_{6a} \pm Ix_{8a}$	≤ 0
	$- Yx_{3p}$		$+ Ix_{5p} + Ix_{6p} + Ix_{8p}$	≤ 0
			$T_{1a}x_{5a} + T_{1p}x_{5p}$	$\geq E$
			Ix_{5a}	$\geq Ca$
			Ix_{5p}	$\geq Cp$
			$Ix_{5p} + Ix_{6p}$	$\leq Ym$
	$- QD_a x_{3a}$		$+ Ix_{6a}$	≤ 0
	$- YD_p x_{3p}$		$+ Ix_{6p}$	≤ 0
	Pwx_{4w}		$+ Pax_{6a} + Ppx_{6p} - x_7 \pm x_9$	≥ 0
			x_7	$= Cc$
			x_{8a}	≥ 0
			x_{8p}	≥ 0
			x_9	≤ 0
	$- Pwx_{4w}$		$- Pax_{6a} - Ppx_{6p} \pm x_9 + Jx_{10}$	≤ 0
			Ix_{10}	$\leq M$

and $x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8, x_9, x_{10}, \geq 0$

Figure 4.2: A Simplified Discrete Stochastic Programming Model for the Nimboran Farmers' Decision Making.

		θ_1	θ_2	θ_3	θ_4	θ_5	θ_6	θ_7	θ_8	θ_9	
	Max. E(u)=	Mu_1	Mu_2	Mu_3	Mu_4	Mu_5	Mu_6	Mu_7	Mu_8	Mu_9	
	A	B									RHS_1
θ_1	D_1	C_1									RHS_2
θ_2	D_2		C_2								RHS_2
θ_3	D_3			C_3							RHS_2
θ_4	D_4				C_4						RHS_2
θ_5	D_5					C_5					RHS_2
θ_6	D_6						C_6				RHS_2
θ_7	D_7							C_7			RHS_2
θ_8	D_8								C_8		RHS_2
θ_9	D_9									C_9	RHS_2

$$Mu = \sum_{1}^{k} P_i \; x > k$$

Figure 4.3: The Matrix Block in Pictorial Form of the Discrete Stochastic Programming Model for the Nimboran Farmers' Yearly Decision Making.

$E(u)$ refers to expected utility.

K Refers to the number of the linear segments of the utility function for each state of nature.

P_i Is the joint subjective probability of a state of nature or of a stochastic event. As will be explained in Section 4.4, nine joint stochastic events are specified in this study.

u Refers to marginal utility of linearly segmented utility evaluation. In this case there will be k values of u for each state of nature. Total, there will be 9k values of u.

x_{10} Is a set of artificial activities denoting a composite column vector measuring conversion of cash consumption to utility for each state of nature.

x_2 Denotes shifting cultivation activity.

L Denotes land area available for shifting cultivation.

x_1 is a composite column vector denoting labour exchange activities.

N Is a vector denoting the amount of labour used per hectare for shifting cultivation.

I Is an identity matrix.

x_{3p} Is a composite column vector denoting production activities of perennial crops.

x_{4w} Is a composite column vector denoting activities of the farm family labour outside the farm, which they get salaries.

N_f Is a column vector denoting male and female family labour time available per year.

N_e Is a column vector denoting male and female non family time available per year.

W_m Denotes the maximum labour time available for wage earning activities.

x_{3a} Is a composite column vector denoting production activities of annual crops.

Q Is a matrix denoting the yield of annual crops per hectare for each state of nature.

x_{5a} Is a composite column vector denoting the consumption activities of annual crops produced on the farm.

x_{6a} Is a composite column vector denoting the sales activities of the annual crops produced on the farm.

Y Is a matrix denoting the yield of perennial crops per man-hour for each state of nature.

x_{5p} Is a composite column vector denoting the consumption activities of perennial crops produced on the farm.

x_{6p} Is a composite column vector denoting the sales activities of perennial crops produced on the farm.

T_{1a} Is a matrix denoting the amount of energy (calories) available in one unit of annual crop product, which is consumed by the farm family.

T_{1p} Is a matrix denoting the amount of energy available in one unit of perennial crop products which are consumed by the farm family.

E Is a vector denoting total minimum amount of energy (calories) required by the farm family for the whole year.

C_a Is a column vector denoting total maximum and minimum amount of annual crop products which are consumed by the farm family for the whole year.

C_p Is a column vector denoting minimum amount of perennial crop products which are consumed by the farmily for the whole year.

Y_m Is a column vector denoting the maximum amount of product of each perennial crop; they are calculated based on existing land productivity and total land area of each crop.

D_a Is a matrix denoting the fractions of the annual crop products which are sold; these fractions take different values for each state of nature.

D_p Is a matrix denoting the fractions of the perennial crop products, which are sold; these fractions take different values for each state of nature.

P_w Is a matrix denoting the wage per man-hour received by the farm family labours for their job outside the farm.

P_a Is a matrix denoting the net prices of annual crop products which are sold.

P_p Is a matrix denoting the net prices of perennial crop products which are sold.

x_7 Is a column vector denoting the purchase activity.

C_c Denotes the minimum amount of cash needed, estimated as the minimum cash consumption which are realised by the farm families.

x_{8a} Is a diagonal matrix denoting the borrowing and/or lending activities of annual crop products from and/or to fellow villagers.

x_{8p}, Is a diagonal matrix denoting the borrowing and lending activities of perennial crop products from and/or to fellow villagers.

x_9 Is a vector denoting the activity to borrow or lend money from or to fellow villagers.

J Is a block diagonal matrix of ones trying use of cash for each state of nature to the utility evaluations.

M Is a column vector constraining, for each state of nature, the linearly segmented utility evaluations.

In subsequent sections, various components constituting the model will be elaborated. The components to be discussed are the activity set, the constraints, and the objective function.

4.3.2 The activity set

The representative farm is assumed to be engaged in exchange labour activities, production activities, subsistence consumption activities, sales activities, purchase activities, and borrowing and/or lending activities. Besides these, off-farm wage earning activities are also included in the decision model.

The crops considered in production, subsistence consumption, and sales activities are distinguished into those, particularly annual crops, for which land and labour can be varied, and those, particularly perennial ones, for which land area is fixed in annual farm plans, and only labour can be varied. To the first type belong Xanthosoma, Colocasia, Yams, Banana, Corn, Amaranthus (Spinach), and Saccharum edule. To the second type belong Cocoa, Coconut, Sago, and Betelnut. Those are the crops which are found in most of the sample farms. Except Cocoa, which is cultivated entirely to be sold, other crops are cultivated to be consumed, and partly sold.

Labour exchange activities (x_1). The main source of labour is the family. However, for tree felling, and sometimes for planting, respectively, male and female labour from other families in the same village or close relatives from other villages is employed in terms of exchanging each other's labour. In Nimboran, this activity is executed between May and September each year.

Production activities (x_{3a} and x_{3p}). These activities refer to transforming production inputs, in this case land and labour, into outputs. Annual crops, most of which are planted for subsistence consumption, are always grown on shifting cultivated gardens. In this case, it is difficult to segregate labour input per crop. Therefore, in the model, labour input coefficient is specified for shifting cultivation activity (x_2), and then the annual crops activities are segregated subsequently on the basis of the land area used. The level of production activities of annual crops are measured in land units, i.e. hectare, and that of perennial crops are measured in labour units, i.e. man-hours. Production per unit of land for annual crops (symbol a) vary for each state of nature. Production per unit of labour for perennial crops (symbol p) also vary for each state of nature. To production activities hold land and labour constraints. As land for perennial crops is considered fixed in annual farm plan, the related constraint is the maximum possible amount of product that can be produced from the existing area per year, provided that appriate labour are allocated to the job.

Subsistence consumption activities (x_{5a} and x_{5p}). This refers to the consumption of farm produced goods by the farm household, in which the goods are transformed in to corresponding energy through coefficients T_{1a} and T_{1p}. The symbols T_{1a} and T_{1p} refer to the amount of energy (calories) available in one unit of produce a and p respectively. The main protein source in the local diet is fish, which is normally bought in the market place.

Because in the model the purchase activity is not segregated into the items bought, then protein is not specified exclusively. Although it is inclusively considered in the amount of minimum cash consumption (C[illegible]) as the budget to buy fish in one year. This budget is equal to price of fish times the quantity of it, normally consumed in one year. The level of consumption activities are measured in physical units of the consumption goods. To subsistence consumption activities hold biological consumption constraint and composition constraints. Biological consumption constraint is measured in terms of energy (E) required by the farm household members in one year. This depends further on the number and age structure of the family, and on the intensity of work of the farm family labours. Composition constraints refer to the maximum and the minimum amount of each type of food the farm household members usually have in their diet.

In the model, all minimum amount of own produced food item consumed are specified (C_a and C_p). This is a lexicographic specification: to say, that farmers put priority on subsistence consumption.

Sales activities (x_{6a} and x_{6p}). This refers to the sales of farm produced goods. The level of sales activities are measured in physical units of the goods. The quantity of produce a and p sold is determined as a residual of production and borrowing (if exists) after allowing planned consumption and lending or returning debt (if exists). In the decision model, perception constraints are introduced to sales activities (see Section 3.4.4). It refers to the maximum proportion of each farm output (D_a and D_p) that are able to be sold according to farmers perception from experience. D_a and D_p vary for each state of nature.

Wage earning activities (x_{4w}). This refers to the activities of the male farm family labours outside the farm, for which they get salaries. The level of these activities are measured in labour units (man-hours). To wage earning activities hold maximum labour time constraint (W_m).

Purchase activity (x_7). This activity, measured in Rupiahs, entails the purchases of additional food and non-food goods and services. The reduction of purchase activities into one activity is done solely to match the computer capacity. The main aim to incorporate this activity is to capture the implicit assumption, that farmers consider their immediate cash consumption needs in their annual farm plans. The author believes that this aspect is captured nicely, regardless of whether those needs are expressed in quantities of each item or in the corresponding total minimum amount of money needed. Additional food items considered as components of this activity are salt, rice, fish, canned fish, flour, and beverages: coffee or tea, sugar, and wine or beer. To non-food goods and services belong: kerosene, clothes and foot wear, health care, education and transport. Farm tools and cooking utensils are bought only once in three to five years. Some farmers even showed axes and hatchet, which have been used for two generations.

Lending and borrowing activities. The farmers may borrow food items (x_{8a} and x_{8p}) and money (x_9) from fellow villagers in case there is not enough to support family living. For the people in Nimboran, only money debt should be repayed. According to local custom, it is morally wrong to claim food items given to support fellow villagers in need. In the model, borrowing activities are specified when state of nature is considered to be bad, and lending or debt repayment activities are specified when state of nature is considered to be good. It is assumed, that under normal conditions, farmers have enough to support their own families.

4.3.3 The constraints

The constraints on the representative farm operation are land constraint, labour constraints, biological consumption constraints, consumption composition constraints, minimum cash constraints, and sales perception constraints. The biological consumption, consumption composition, and sales perception constraints have been discussed under consumption and sales activities respectively. They will not be repeated here. Other constraints will be discussed subsequently.

Land constraint. Total farm land, measured in hectares, is distinguished in to land for perennial crops - which is fixed in annual farm plans - and land for annual crops (L) which can be varied in annual farm plans. As annual crop activities are expressed in land units (Ha), then their land input coefficients are ones. Perennial crop production is constrained by the maximum amount that can be produced under fixed land area (see production activities, in sub-section 4.3.2).

Labour constraints. After allowing biologically minimum rest time, i.e. five hours a day, time for household activities, i.e. six hours for female and four hours for male labour a day, culturally and socially determined rest days such as Sunday, Christmas day, independence day, and other days for local festivities, i.e. about three to seven days in a year, then the residual is total labour time available for farm and other economic activities. Labour availability figures is distinguished between male and female family labours, and male and female non-family labours. In Nimboran, non-family labours are the source of exchange labours, which are available in May until September each year. Family labour is the main source of farm labour. Exchange labour is regarded as supplying additional labour to the existing family ones. Labour input coefficients (N) refer to the amount of male and female family labour required per hectare for shifting cultivation activity per year. Perennial crop activities and wage earning activities are expressed in labour units. Thus, their labour input coefficients are one.

Minimum cash constraints. Cash income, the level of which is measured in Rupiahs, is generated by sales of farm produce, and from wage earning activities of farm family labours, or borrowed. It is further used to purchase additional food and other non-food goods and services. It is specified, that expected net cash income should be higher than, or at least equal to minimum expected cash consumption.

4.3.4 The objective function

It is assumed that the decision problem of the farmers is to select a strategy, which implies the whole yearly farm plan, in order to maximize the expected utility from the expected outcomes. Based on the discussion in Section 3.6.2 of theoretical background, and on the reasons which will be explained in sub-section 4.4.3, farmers utility functions - in this study - are estimated based on the single component: expected net cash income. Expected net cash income in this case is the expected gross cash income of the farm family in one year minus cash costs of generating it. It is the total amount earned before allowing any household spending.

In the model, cash activities are allowed only after the minimum subsistence food consumption and definite leisure time are fully met. This lexicographic rule is specified in terms of biological consumption and consumption composition constraints, as well as in labour constraints.

Risk involved in generating net cash income is considered beside its absolute amount. The estimated utility functions have non linear forms (see sub-section 4.4.3). The selected utility function is incorporated in to the programming model through artificial activities (x_{10}), which consist of the linearly segmented utility evaluations. In this case, using the method as explained in Rae (1971 b), the non linear utility function is divided in to linear segments. Each segment is assumed to have a constant marginal utility.

Associated with artificial activities, two kinds of constraints were also introduced. The first one is the equation relating the utility evaluations to the net cash income generated. The second is a set of constraints, consist of equations relating each x_{10} to its segment constraint, i.e. the total amount of money represented by that segment. Those equations can be given as follows:

$$P_w x_{4w} + P_a x_{6a} + P_p x_{6p} - Jx_{10} \geq 0 \qquad ..... (4.1)$$

$$Ix_{10} \leq M \qquad ..... (4.2)$$

The objective function, consistent with Bayesian formulation, is given as follows:

$$\text{Max. } E(u) = \sum_{i=1}^{9} \left(\sum_{k=1}^{k} P_i u x_{10k} \right) \qquad ..... (4.3)$$

The script k refers to the number of linear segments of the utility function for each state of nature, i refers to the number of states of nature, P_i refers to the subjective probability of occurences of each state of nature, and u refers to the constant marginal utility of each segment of utility evaluation for each state of nature.

4.4 The Data

4.4.1 Introduction

Consistent with the problem and objectives, and based on the theoretical considerations, a basic programming model is selected as has just been described. Based on the basic model, the information needed is considered and these are reiterated in the interview guide. Field work in Irian Jaya was conducted to test the interview guide and used the revised version of it to interview the sample farmers in order to get the information needed. The revised version of the interview guide is attached in the Appendix.

Further discussion will concentrate on technical aspects and results with respect to farm data collection, utility and subjective probability elicitation. Techniques of farm data collection will be discussed first.

4.4.2 Farm data collection : methods and results

Two techniques are used in farm data collection, i.e. interview and direct observation. Direct observation is an essential supplement to interview because there are many data which can not be obtained by interview alone. Those are crop area, conversion numbers from local physical measures to International Standard Unit (I.S.U.) measures, and the edible portion of each farm product. To get such data, farmers gardens and the market place were visited.

Production is reported only in local measures. Therefore, conversion numbers are needed to transform them to I.S.U. measures. Local measures and their corresponding I.S.U. ones are shown in Appendix Table A2.12. It was found that women were the better source to get information on the amount of production, consumption and sales, because they do most of the harvesting, sales and cooking activities.

Except for cocoa, farmers in the study region seem to have no record nor any knowledge about their crop acreage areas. For perennial and some annual crops, they tend to remember only the population of plants. Also, it was difficult to directly measure the area of each annual crop as they are planted in many small clusters, and unordered, in shifting cultivated gardens. The technique used during the survey is to visit the gardens and count the population of plants and the average distance. From these figures, the area per crop was estimated. The method of estimation is explained subsequently, using an example to calculate the area of banana.

Say, the population is 82 stools and the average distance three metres. Take the square root of 82; that is 9.05. Then the area of banana can be estimated as

$$(9.05 - 1) \times 3 \times (9.05 - 1) \times 3.$$

This is equal to 583.2 sq. metres or 0.0583 hectares. The logic of subtracting one from 9.05 can be explained as follows: if we array n poles at certain distance from each other, only n - 1 segments of distances can be created.

This method was firstly used in Karafir (1971, 1974). It has been shown that the accuracy of the estimation depends on the average distance taken. If properly taken, the estimated crop area is not significantly different from the true crop area. Of course, this method is inefficient if used to estimate the area of crops on large scale farms. For small shifting cultivated gardens, it can be easily applied. The results of preliminary analysis of the farm data collected - showing the distribution and central tendencies - are presented in appendices Tables A2.1 to A2.11.

4.4.3 Elicitation of the utility function : method and results

Various theoretical aspects of the small-farmers' utility functions have been discussed in Section 3.6. Subsequently, only methodological aspects during fieldwork and the results of utility elicitation will be discussed.

In this study, the utility function estimated is the utility function of net cash income from cash earning activities, after subsistence consumption requirements and locally acceptable leisure time have been met. This is assumed to be consistent with the indigenous farm community situation in Nimboran. The assumption is made based on the fact that there is an almost definite time schedule and job distribution between male and female for each of those activities, and most of the respondents, i.e. 24 out of 30, reported that they never experience a clash in time for cash and subsistence activities, and leisure. Six of the respondents who have regular casual jobs at certain projects in the region, such as agricultural collection and demonstration gardens, road building, and irrigation projects, occasionally use their time for these jobs for subsistence farm activities, in case there is not enough food supply at home. Therefore, it is assumed that if there is a clash, the farmers will put priority on subsistence food production. By asking the farmers how they would react if there was a possibility of clash, 28 out of 30 confirmed that it is their tradition to assure enough minimum food supply for their family first before using their labour for other activities. Based on this attitude it seems understandable, why all farmers in the region have pieces of land planted with traditional crops which support most of their food consumption.

There is a definite time for rest each day, and for special days the farmers regard as rest or feast days. For example, there are Sunday and other religious and national days. It is rarely found that farmers here work on Sunday or on any other religious day. This can be used to confirm farmers statement that there is no clash in the use of labour time for cash activities and leisure.

Utility of net cash income is estimated by considering risk involved in generating it. In this case, a variant of the ELCE method of elicitation - as explained in sub-section 3.6.3 - is used. As alternative for risky outcomes and certainty equivalents (CE), incomes from cocoa production and wage earning activities are taken, respectively. Surplus labour time available for cash activities used is 175.5 man-hours per month for a total period of about three months in one year. This means that, in total, there are 526.5 man-hours available activities in one year. This surplus is determined by subtracting labour time for rest and subsistence farming activities from total available labour time in one year.

The interview was conducted with the family head and all or most of the other members of the farm household were present. Thus, the answer represents a group consensus rather than an individual opinion. The group was asked to state, whether they would use surplus labour time available for eage earning activities with a salary of 30 Rupiahs per man-hour - which is equal to 15 795 Rupiahs per year - or for cocoa production for which the income is not certain, but can be 20 Rupiahs per man-hour, which is equal to 10 350 Rupiahs per year, or 1 600 Rupiahs per man-hour, which is equal to 842 400 Rupiahs per year with a fifty-fifty chance for each. By repeatedly increasing or decreasing the CE by 20 Rupiahs per man-hour - or 10 530 Rupiahs per year - if cocoa production or wage earning is chosen respectively, a CE is found, say, CE_1, in which the group is indi-ferent between wage earning and cocoa production. To determine the second indifferent point, CE_1 is used to replace the initial 10 530 Rupiahs as a pair for 842 400 Rupiahs per year for cocoa production. For sure income from wage earning activities, an amount equal to CE_1 plus 10 530 Rupiahs per year is taken. The question is then repeated in the same way to find the second CE, say CE_2. To determine the third indifference point, CE_2 is used to replace CE_1 as a pair for 842 400 Rupiahs, and as its alternative sure income, an amount equal to CE_2 plus 10 530 Rupiahs is taken. The whole process is repeated by the same way to find a series of CEs end drawing a utility function for the respective farm household.

To each pair of the initial risky income from cocoa production, 10 530 Rupiahs and 842 400 Rupiahs, arbitrary utility numbers zero and hundred are assigned, respectively. The utility for CE_1, CE_2 and so on are calculated using the method explained in sub-section 3.6.3.

Utility analysis was scheduled as the last job to be done during field work. The reason for that is to get a clear picture of the local farmers' cash income level first, which was gained from the interview by using the interview guide. Unfortunately, when all other data have been collected, only one week remained for utility elicitation. From twelve farm families interviewed, seven, who were interviewed earlier, completely reject wage earning activities, even for eage level greater than 842 400 Rupiahs per year. It seems, as later on was revealed, that the main reason for their rejection stemmed from the suspicion that the interview was connected with the selection of the farmers to be offered credit for cocoa expansion and cattle raising. There is a belief that those credits will be offered to those truly engaged in farming and have no other off-farm jobs. By including this point in the explanation of the interview objective as introductory to subsequent interviews, the respondents reactions changed significantly. As the result, utility functions for five farm households were successfully elicited.

All the elicited utility functions are concave, implying risk aversion attitude of the respective farm households. Based on visual assessment of their prominent features, the elicited curves can be classified into two groups. The utility curves of the first group - consisting of three farm families - show sharp increase in utility for each unit increase of money income above zero up to certain points. Beyond those points, the curves turn to be almost flat, exhibiting extremely small increase in utility for each unit increase in money income. The utility curves of the second group - consists of two farm families - show less steep increase in utility and do not have flat parts as shown by that of the first group.

Further, two kinds of decisions have to be made. First, to select the functional form that best fits the elicited data. Secondly, to determine utility function of which group can be taken to represent that of the Nimboran farmers.

Different functional forms are estimated to fit the elicited CEs and their corresponding utility values for each farm family: the quadratic function, cubic function, and exponential function as suggested by Buccola and French (1978). However, none of the estimated functions fit the elicited data properly. Therefore, it was decided to use the original curve in further analysis.

Having selected a suitable form of the utility function to be used for further analysis, then the second aspect left was to determine the one to represent that of the Nimboran farmers. From the estimated equations it seems obvious that the two groups mentioned earlier have distinctive coefficients of risk aversion (λ). The coefficients of the first group. In this case, based on the available information and the author's subjective belief, the utility function of the first group, i.e. the ones containing steeply ascending and almost flat parts, is assumed to represent that of the Nimboran farmers. Two reasons may be put forward. First, two of the household samples included in the second group belong to the progressive families. Besides their formal education, the heads of the families of the second group have attended extension courses outside their villages. Back in their villages they serve as agricultural 'contact men'. They have also better educated family members, some of whom have reached Junior High School: a level which is considered high for this region. Therefore they cannot be taken to represent the average farm household in the region, where education of most of the older generation does not exceed three years primary school. Second, the area where the utility curves turn from steep to flat appear to be near the amount of money income needed to fulfill the realised cash consumption. It can therefore be assumed that the feature of the utility curves of the first group does not depend purely on a risk aversion attitude; to a certain extent it seems to depend also on 'subsistence mindedness'. If this is true then the function must be suitable to represent those of the Nimboran farmers who are assumed to be subsistence oriented rather than commercial.

Further, from the three samples included in the selected group, one is selected randomly to be specified as the objective function in the proposed programming model. The selected curve is further divided into three linear segments, description of which can be given as follows:

(i) Utility segment 1 lies between 10 530 and 100 035 Rupiahs, thus amounted to 89 505 Rupiahs which corresponds to 87.5 utils. This means one Rupiah corresponds to 0.000978 utils.

(ii) Utility segment 2 lies between 100 035 and 236 425 Rupiahs, thus amounted to 136 390 Rupiahs which corresponds to 6.25 utils. This means one Rupiah corresponds to 0.0000458 utils,

(iii) Utility segment 3 lies between 236 425 and 829 237.5 Rupiahs, thus amounted to 592 812.5 Rupiahs which corresponds to 4.6875 utils. This means one Rupiah corresponds to 0.00000 791 utils.

The amount of utils correspond to each unit of money income (in Rupiahs) for each segment is the marginal utility that enter the objective function as explained in sub-section 4.3.4 using the notation u.

4.4.4 Elicitation of the subjective probabilities : method and results

In the initial plan, yield and price were considered stochastic factors in the model. However, during preliminary observation to test the interview guide, price was dropped and instead, sales quantity was introduced as a stochastic factor. Local farmers view yearly crop prices as fixed. Uncertainty is attached to the amount they can sell. Apparently, risk in selling activities considered by the farmers comes from lack of transport vehicles and irregularities in transport time schedule, as well as unpredictable buyers in the market place. Sometimes, after farmers had prepared everything to go to the market in Jayapura, they found no vehicle or no space in the vehicles to take their goods. Often, their goods can not be sold out in the market place, especially in the local ones.

From experience, most farmers tend to have a certain perception of the amount of crop products that can be sold each year. This is expressed in terms of portion of total products - D_a and D_p in the model - which varies for good, average, and bad expectations. The results are presented in Table 4.1. For example, at bad selling conditions, none ($D_a = 0$), at normal selling conditions, 2.2 per cent ($D_a = 0.022$) and at good selling conditions, only 5.6 per cent ($D_a = 0.056$) of total Xanthosoma produced can be sold. It can be seen (Table 4.1) that cocoa, betelnuts, coconut, corn and banana are the main cash generating crops, whereas the others are produced mainly for consumption.

The stochastic events of yield are assessed by asking the farmers to state the highest, the normal and lowest yield of each crop they have had during the last five years from a certain area of land. Further, they were asked to name the main reason - according to their experiences and beliefs - why yield of that particular crop may be good, normal or bad. From their answers, several main factors affecting yield variability of particular crop were obtained, a summary of which is presented in Table 4.2. The average figures of the corresponding yields under good, normal and bad conditions are presented in Table 4.3. According to farmers' beliefs, high rainfall during fruit development or growing period of vegetables is usually followed by good harvest of crops like cocoa, coconut, amaranthus, betelnut, banana and corn. On the contrary, too much rain is not good for xanthosoma and yam. Local farmers usually go on sago extraction only when they expect no rainfall for the whole week; because rain, beside hindering them from continuous work, also accelerate decaying process of the sago pith. Wild pigs are the main threat in xanthosoma and yam production, where damage can exceed 50 per cent of the whole crop. Insect plague especially locust (Nomadacris spp.) for amaranthus, and capcids (Helopeltis spp.) for cocoa, are also considered by the farmers as unpredictable threat. Other factors like crop variety and age, soil structure and fertility are considered to be under farmers' control. This control is manifested in the selection of the seedlings, and garden site respectively.

It can be summarized from the preceding discussion that two single stochastic factors are considered in the model, each with three mutually esclusive and exhaustive events. Those single factors are yield and sales conditions. Their events are yield good, yield normal and yield bad, and sales good, sales normal and sales bad. During fieldwork, the probabilities of the events of each single factor were elicited separately.

Table 4.1

Proportion of Total Production Per Year of Selected Crops that can be Sold; Based on Nimboran Farmers' Experiences for Good, Normal, and Bad Selling Conditions

Crops	Sales Good	Sales Normal	Sales Bad
	In Portion of Total Product		
Xanthosoma	0.056 (0.034)	0.022 (0.012)	0
Yam	0.131 (0.044)	0.104 (0.039)	0.064 (0.012)
Amaranthus	0.457 (0.072)	0.292 (0.07)	0.113 (0.032)
Banana	0.646 (0.08)	0.457 (0.083)	0.235 (0.077)
Corn	1.0	0.905 (0.048)	0.792 (0.078)
Coconut	1.0	0.74 (1.112)	0.58 (0.134)
Sago	0.134 (0.035)	0.057 (0.011)	0.03 (0.008)
Betelnuts	1.0	0.65 (0.086)	0.43 (0.074)
Cocoa	1.0	1.0	1.0

Table 4.2

Natural Factors Affecting Yield Variability
of Selected Crops According to Farmers
in Nimboran

Crops	Natural Factors Affecting Yield Variability
Cocoa	Rainfall and insect plague
Coconut	Rainfall - theft
Xanthosoma, Yam	Damage of wild animal, rainfall, soil structure and fertility
Banana	Crop variety, rainfall
Amaranthus	Rainfall, insect plague
Betelnut	Rainfall
Sago	Rainfall, crop variety and age
Corn	Rainfall, soil structure and fertility

The interview was conducted with the farmer and most or all household members were present. The group was firstly asked to state their preceding year yield expectation. They answered by allocating 20 matches to the good, average and bad categories of yield. The category with the highest expected chance got more matches, and vice versa. Often, the last match was broken into two pieces, and each half of it allocated to different events. After the result was recorded, the group was asked to state their preceding year sales expectation by allocating 20 matches to the good, average and bad categories of sales. After the results were recorded, the conversation was directed to setting a picture of the farmers' expectations about the chances of rain, animal plague, transport to the market, and market conditions. Its aim was to get a rough proxy to assure that the chances assigned earlier to yield and sales events were consistent with the chances of the events of main factors affecting yield and sales. It seems that probabilities assigned to yield events tended to be highly consistent with the farmer's statement on the chances of rainfall and animal plague. The chances of sales events seemed to follow the statement of the chances put on transport availability, rather than buyers availability. Perhaps local farmers already have a fixed idea about the amount of products they can sell. What they are not sure about is whether their product can be transported to the market.

The model representing Nimboran farmers' annual decision is assumed to be non-sequential or simultaneously made decision model. Due to different types of causes underlying their variabilities - as explained previously - the factors yield and sales can be assumed to be independent of each other. Hence, to incorporate subjective probabilities into the programming matrix, the single events of both factors are combined using conventional probability calculus to form nine compound, mutually exclusive and exhaustive events. Those are yield good-sales good (θ_1), yield good-sales normal (θ_2), yield good-sales bad (θ_3), yield normal-sales good (θ_4), yield normal-sales normal (θ_5), yield normal-sales bad (θ_6), yield bad-sales good (θ_7), yield bad-sales normal (θ_8), and yield bad-sales bad (θ_9). The results of the analysis is presented in Appendix Table A4.1. Because the utility function of respondent number nine is selected to represent that of the Nimboran farmers, then correspondingly, the subjective probabilities of the same respondent is also used in further analysis.

Table 4.3

Average Yield Figures of the Main Crops Grown by the Nimboran Farmers Under Good, Normal, and Bad Natural Conditions

Crop		Yield Good	Yield Normal	Yield Bad
Xanthosoma (ton/ha)	$\bar{Y}$	23	14	8
	SD	(7)	(5)	(3)
Yam (ton/ha)	$\bar{Y}$	15	9	6
	SD	(6)	(3)	(2)
Amaranthus (ton/ha)	$\bar{Y}$	4	3	2
	SD	(2)	(2)	(0.7)
Banana ('000 combs/ha)	$\bar{Y}$	46	27	12
	SD	(20)	(10)	(6)
Corn (ton/ha)	$\bar{Y}$	7	4	2
	SD	(2)	(2)	(0.3)
Coconut (Nr of nuts/ man-hour)	$\bar{Y}$	3	2	1
	SD	(.9)	(0.7)	(0.3)
Sago (Kg/man-hour)	$\bar{Y}$	1.5	1.1	0.8
	SD	(0.8)	(0.5)	(0.4)
Betelnut (Nr. of bunch/ man-hour)	$\bar{Y}$	1.4	1	0.5
	SD	(0.7)	(0.05)	(0.3)
Cocoa (Kg/man-hour)	$\bar{Y}$	2.5	1.5	0.7
	SD	(0.6)	(0.5)	(0.4)

$\bar{Y}$ = The average figure

SD = Standard deviation.

4.5 Selection of the Representative Farm

Carter (1963) has reviewed and generalized the advantages and weaknesses of representative farms as guides for decision making. For example, it is acknowledged that each farm has a unique management problem and it might be incorrect to be represented by one farm only. However, two reasons has been mentioned which necessitates the use of a representative farm. First, from the practical standpoint of research study. Funds, time, and data as well as complexity of the analysis may inhibit modelling each individual farm in a region. Barnard (1963), and Heyer (1971) as well as Whardani (1976) support this view. Second, farms may vary in size, but be similar in types of elements involved. Thus, while absolute budgeted changes in organization due to technological developments on representative farms may never be duplicated on individual farms, relative effects can be demonstrated. Individual farmers can appraise these in the light of their own resources and wider application can be made, than would be possible by budgeting changes on individual farms (Becker 1963).

Hence, considering the size of the programming matrix used and laborious work required to detail the operation of small, traditional farms as well as the similarities in types of indigenous farms in Nimboran, a representative farm approach was used. The representatives farm in this study is the medium farm, basic indices of which lie in the middle of the distribution of all indices, exhibiting all prominent features from all farms in the region. The reason for selecting median rather than average or the mode is that sample data are not normally distributed, and in many cases more than one mode occur.

The median farm household in Nimboran has seven members and comprises two nuclear families. In terms of age, five members are assumed to be adults - the family labour force - and two are children. About 15 ha of land is available for cultivation, and 2 ha is planted with perennial crops. Other characteristics of the representative farm are presented in Table 4.4. All the figures in the table become the components of the basic matrix, representing Nimboran farmers' annual decision making model.

Table 4.4

Main Characteristics of the Representative (Medium) Farm in Nimboran

Indices		
Number of household members		7
Nuclear families		2
Number of male family labour		
- Available male family labour time per year (thousand man-hours)	7.2	
- Male labour time per Ha for shift cult in one year (thousand man-hours)	8.6	
Number of female family labour		3
- Available female family labour time per year (thousand man-hours)	7.7	
- Female labour time per Ha for shifting cultivation in one year (thousand man-hours)	4.8	
Non family male labour time available per year (thousand man-hours)	1.9	
Non family female labour time available per year (thousand man-hours)	2.2	
Total land area available (Ha)		15
- Area in coconut (Ha)	0.110	
- Area in sago (Ha)	1.250	
- Area in betelnut (Ha)	0.035	
- Area in cocoa (Ha)	0.570	
- Other perennial	0.035	
	2	
- Area for shifting cultivation	13	

Yield per Hectare	If Good	Normal	Bad
- Xanthosoma (ton)	23.4	15	7.6
- Yam (ton)	13.7	8.7	5.3
- Amaranthus (ton)	4.2	27.6	1.4
- Banana (thousand combs)	42.2	26	10.4
- Corn (ton)	6.6	3.6	1.8
Yield per man-hour			
- Coconut (Nr. of nuts)	2.6	1.8	0.9
- Sago (kg)	1.4	1.0	0.7
- Betelnut (Nr. of bunches)	1.3	0.8	0.4
- Cocoa (kg)	2.3	1.3	0.7