CHAPTER 2

Literature Review

"Agriculture plays a crucial role in addressing the needs of a growing global population, and it is inextricably linked to poverty eradication, especially in developing countries".

(Paragraph 38 of the Draft Plan of Implementation of World Summit on Sustainable Development)

2.1 Concept of sustainable agriculture

Definitions of sustainability are often controversial. In terms of agriculture, sustainability has many meanings (Smit and Smithers, 1993; 1994). But most definitions are fundamentally similar. Consider two representative definitions of sustainable agriculture: Agri-food systems that are economically viable, meet society's need for safe and nutritious foods, while conserving . . . natural resources and the quality of the environment for future generations (Science Council of Canada, 1992).

Agricultural system that can indefinitely meet demands for food and fibre at socially acceptable economic and environmental costs (Crosson, 1992).These definitions suggest that sustainability implies (1) meeting human needs for food and fiber, (2) conserving environment or natural resources, and (3) maintaining economic viability.

Although there are literally hundreds of definitions of sustainable agriculture, one of the more widely accepted definitions, developed by the United States Department of Agriculture is "a way of practicing agriculture which seeks to optimize skills and technology to achieve long-term stability of the agricultural enterprise, environmental protection, and consumer safety".

It is achieved through management strategies which help the producer select hybrids and varieties, soil conserving cultural practices, soil fertility programs and pest management programs. The goal of sustainable agriculture is to minimize adverse impacts to the immediate and off farm environments while providing a sustained level of production and profit. Sound resource conservation is an integral part of the means to achieve sustainable agriculture.

Excessive and unbalanced use of agro-chemicals has led to increased production costs and dependence on external inputs and energy, decline in soil productivity, contamination of surface and ground water, and adverse effects on human and animal health (Edwards, 1989, Conway, 1985 and Biswas, 1994). Therefore, there is growing emphasis on sustainable agriculture in concerning with the adverse environmental and economic impacts of conventional agriculture (Hansen, 1996). In contrast, sustainable agriculture is viewed as low-input and regenerative (O'Connell, 1991), which makes better use of a farm's internal resources through incorporation of natural processes into agricultural production and greater use of improved knowledge and practices. It uses external and non-renewable inputs to the extent that these are deficient in the natural environment (Pretty, 1995).

Despite the diversity in conceptualizing sustainable agriculture, there is a consensus on three basic features of sustainable agriculture which are: (i) maintenance of environmental quality, (ii) stable plant and animal productivity, and (iii) social acceptability. Consistent with this, Yunlong and Smith (1994) have also suggested that agricultural sustainability should be assessed from the perspectives of ecological soundness, social acceptability, and economic viability. 'Ecological soundness' refers to the preservation and improvement of the natural environment. 'Economic viability' refers to maintenance of yields and productivity of crops and livestock, and 'social acceptability' refers to self-reliance, equality and improved quality of life.

2.2 Indicators of sustainable agriculture

For any study on sustainable agriculture, the question arises as to how agricultural sustainability can be assessed. Some argue that the concept of sustainability has yet to be made operational (Webster, 1997). Although precise measurement of sustainable agriculture is not possible, "when specific parameters or criteria are selected, it is possible to say whether certain trends are steady, going up or going down" (Pretty, 1995). According to Lynam and Herdt (1989), sustainability can be assessed by examining the changes in yields and total factor productivity. The workshop organized by the Institute for Low External Input Agriculture (ILEIA (Institute for Low External Input Agriculture), 1991) mainly emphasized productivity, security, continuity, adaptability and integrity as indicators of sustainability. Beus and Dunlop (1994) considered agricultural practices such as the use of pesticides and chemical fertilizers, and maintenance of diversity as measures of sustainability. For sustainable agriculture, a major requirement is the sustainable management of land and water resources. An International Working Group (Smyth and Dumanski, 1993) has concluded that the maintenance or enhancement of productivity, reduced risk, natural resources conservation, promotion of economic viability and social acceptability are essential conditions for sustainable land management. Gowda and Jayaramaiah (1998) used nine indicators, namely integrated nutrient management, land productivity, integrated water management, integrated pest management, input self-sufficiency, crop yield security, input productivity, information self-reliance and family food sufficiency, to evaluate the sustainability of rice production in India.

Although many indicators have been developed, they do not cover all aspects of sustainability. Moreover, due to variation in biophysical and socio-economic conditions, indicators used in one country are not necessarily applicable to other countries. In Myanmar, where the majority of farmers are smallholders and average land holding size is less than 2.5 hectare, farmers' immediate concern for agricultural development is how to increase crop yield, income, and food security and reduce the risk of crop failure. The overwhelming majority of farmers lack the capital required for the purchase of inputs, but normally have an adequate labor force. Thus, in view of biophysical and socio-economic conditions in the study area, nine indicators, representing ecological, economic and social dimensions of agricultural sustainability were selected for the evaluation of rice-based cropping systems in the study area.

2.3 Sustainability assessment

It is widely accepted that a reliable measure of sustainability should be the result of integrating economic and natural resources accounts. However, this is not readily achievable due to lack of data and yet unsolved methodological problems (Kaufmann and Cleveland, 1995).In the field, especially in farming systems, sustainability is extraordinarily complex measure. Operationalizing sustainability on the ground involves considering numerous aspects, variously identified as physical, environmental, social, cultural and/ or economic dimensions. This complexity leads to the need for integrated, interdisciplinary assessments that can consider the sum of its parts.

The fundamental principles of sustainability postulate the following: multidimensional approaches considering ecological, economic and social aspects at an equivalent level; a systematic investigation conceiving not only single factors but also complex functions and processes with various interactions between elements. This point of view entails also the assessment of sustainability with regard to a suitable temporal and spatial scale; a consensus based process of decision finding with special focus on ecological aspects of sustainability (Giampietro and Bukkens, 1992).

According to Giampietro and Pastore (2000), agriculture operates on the interface of two complex, hierarchically organized systems: the socio-economic system and the ecosystem. So in any defined farming system one will always find legitimate and contrasting perspectives with regard to the effects of changes in the system, and the effects are not likely to result in absolute improvement for all stakeholders. Hence, a 'correct' assessment of agricultural performance should best be based on an analysis of trade-off that reflect the various perspectives, both positive and negative, with regard to the effects that a proposed technological or policy change will induce on the various scales and actors involved. A methodological tool, the AMOEBA multi-dimensional reading that can be used to characterize farming system performance in an integrated way on various scales and according to various perspectives.

Approaches commonly known by researchers in monitoring sustainability include environmental or extended cost-benefit analysis, MCDM and sustainability indicator analysis (SIA) (Muller, 1997). Among them, the SIA is considered as the least formal approach. It simply aggregates diverse information into a meaningful form. With less data and analytical skill required, this indicator becomes a significant and flexible analytical tool for sustainability assessment.

2.3.1 Sustainability Assessment by Fuzzy Evaluation (SAFE)

FL is a problem-solving control system methodology that lends itself to implementation in systems. The concept of Fuzzy Logic (FL) was conceived by Lotfi Zadeh, a professor at the University of California at Berkley, and presented not as a control methodology, but as a way of processing data by allowing partial set membership rather than crisp set membership or non-membership.

Fuzzy Logic is a departure from classical two-valued sets and logic, that uses "soft" linguistic (e.g. large, hot, tall) system variables and a continuous range of truth values in the interval [0,1], rather than strict binary (True or False) decisions and assignments (Kaehler, 1998).

The use of the fuzzy logic reasoning is justified by the following two basic features. (i) Fuzzy logic has the ability to deal with complex and polymorphous concepts, which are not amenable to a straightforward quantification and contain ambiguities. In addition, reasoning with such ambiguous concepts may not be clear and obvious but rather fuzzy. (ii) Fuzzy logic provides the mathematical tools to handle ambiguous concepts and reasoning, and finally gives concrete answers (crisp as they are called) to problems brought with subjectivity. Sustainability is, indeed, quite subjective. What appears unsustainable for an environmentalist may be sustainable for an economist and the ingredients signifying sustainability may differ for these specialists. Fuzzy logic is a scientific tool that permits to simulate the dynamics of a system without a detailed mathematical description. Knowledge is represented by "IF-THEN" linguistic rules, which describe the logical evolution of the system according to the linguistic values of its principal characters that we call linguistic variables. Real values are transformed into linguistic values by an operation called fuzzification, and then fuzzy reasoning is applied in the form of "IF-THEN" rules. A final crisp value is obtained by defuzzification, which does the opposite to fuzzification (Andriantiatsaholiniaina, 2000).

The major advantage of fuzzy logic is that it can be used both as compensatory and non-compensatory in a single model at different context, by using inferences through rules extracted from the experts. In this view, Andriantiatsaholiniaina (2000) studied the usage of fuzzy logic in sustainability assessment. Interestingly though all his inputs were easily quantifiable in nature, he has chosen fuzzy approach to include assumed vagueness and impreciseness in the interpretational measure while representing sustainability. Cornelissen *et al*., (2000) have given the conceptual idea of how to include fuzzy set theory in assessing sustainable development and he has demonstrated a simple one level example of agricultural production sustainability.

Membership function is used as a way to interpret the meaning of the input data and its strength. Hence the nucleus of fuzzy model is its membership functions and it is considered to be the strongest and weakest point of fuzzy set theory (Munda et al. 1992).

2.3.2 Multi- criteria Evaluation (Amoeba approach)

The basic idea of the Amoeba reading is to provide a graphic representation of system performance as assessed over a certain number of aspects or qualities that cannot be expressed as a function of the others. In this way, it is possible to have an overall assessment by a visual recognition of the existing difference between the profile of expected (or acceptable) values and the profile of actual values over families of indicators of performance referring to non-comparable qualities.

In the field of natural resources management, the Amoeba approach have proposed by Brink *et al.*, (1991) as a tool for dealing with the multi-dimensionality of environmental stress assessment by using different space-time scales. The graphic representation of the system is simply based on a division of the plane of a 'radar diagram' into different parts, each describing a distinct view on the system. Within Amoeba diagram, a number of axes referring to different indicators of performance are then drawn. This diagram shows, in qualitative terms, to what extent the objective has been met for each indicator and it enables a simple, yet comprehensive, graphical comparison of advantages and limitations of management systems being evaluated.

2.3.3 Sustainability Indicator Analysis (SIA)

In the case study of Mae Chaem Catchment in North Thailand, Praneetvatakul *et al.* (2001) assessed the sustainability of agriculture at various levels including household, village, and sub-catchments. In general, sustainability of agriculture in the context of development efforts has to meet: (i) production efficiency, (ii) resilience of ecosystems, (iii) appropriate technology, (iv) maintenance of the environment, (v) cultural diversity, and (vi) satisfaction of the basic needs (Muller, 1997). Sustainability indicators were established based on the criteria and scoring technique was used for assessment. All the indicators have been assumed to have equal importance in terms of their contribution to agricultural sustainability. Score identified for each indicator were ranked into three classes as non-sustained (N), conditional sustained (C) and sustained (S). The scores were aggregated and used to classify the households into different sustainability classes.

To assess the sustainability at the village level, the household aggregated scores are grouped at village level. For the village level comparison, coefficient index (N=0.2, C=0.4 and S=0.8) are multiplied with number of samples in respective class to calculate sustainability index, performance and performance percentage.

The sustainability index of each indicator is the percentage of the sustainable score relative to maximum score. It indicates the significance of each indicator in sustainable agriculture. It is used to compare indicators within cropping systems. The performance percentage indicates the overall performance of sustainability from all indicators. It is used to compare the relative sustainability levels of the cropping system.