CHAPTER 2

LITERATURE REVIEW

Sugarcane is one of the major industrial crops and it has been cultivated in Myanmar for the traditional use as juice and tonic since the Inwa era (AD 729-762). With the continuous rising demands for local use and trade, extension of areas and the commissioning of a number of sugar mills had already been in process since pre-war days. Sugarcane production plan was adopted in 1932 and its sown area was increased. Establishment of sugar mills and expansion of sown area were also made in 1950 by the Pyi-daw-tha project. Myanma Sugarcane Enterprise (MSE) was instituted under the umbrella of ministry of agriculture and irrigation on 25th May, 1994 to promote sugar production through cane area expansion and yield increase. Nowadays, 21 modern sugar mills were constructed and commissioned in Myanmar (M.O.A.I, 2011).

Pujar *et al.* (2010) stated that the productivity of sugarcane is affected by many factors, one of them is soil nutrients, the imbalance of which constraints the cane productivity. The soil fertility status determines the level of crop productivity. In Myanmar, a common system in sugarcane production is continuous monoculture and this system leads to decline cane yield and soil fertility depletion.

Nowadays, because of the limitation of natural resources such as land and water, the importance of this field is still expanding, sustainable agriculture and concern about environmental problems (Fageria, 2007). The fertilizer responsive crop varieties and shortages of manure had seriously depleted soil fertility and creating secondary crop pest problems that contributing to stagnating yield (Listinger, 1993).

2.1 Inorganic fertilizer management

As much as 75% of crop yield increases since the mid-1960s were directly or indirectly attributable to fertilizer use. The low use of chemical fertilizer is a major worry from both the environmental and food production perspectives (Reardon and Christopher, 1999). There is no doubt that sugarcane crop needs fertilizers. A crop of 125 tons per hectare removes 83 kg nitrogen, 37.2 kg phosphorus and 168 kg potassium per hectare from soil. The tendency to supply all these nutrients through chemical fertilizers, however, has to be avoided as these have deleterious effect on soil productivity on long-term basis.

In sandy soils, especially in upland ecologies loss of mineral nutrients, water and herbicides through leaching is very high there by making the soil unproductive. The application of organic manure is needed not only to replenish lost nutrients but also to improve the physical, chemical and biological properties of such ecologies which will enhance the performance of soil applied inputs. In Myanmar, the farmers used to apply only urea and do not apply P and K fertilizers. In the long term, imbalance nutrient occurred and damaged the natural balance of social and environment (Win, 2010).

At the low levels of soil nutrients, it has been noted that inorganic fertilizer is highly needed to reverse the declining soil fertility (Sanders and Ahmed, 2001). Everywhere else in the world where crop yields have been substantially increased, inorganic fertilizer has been noted as a basic component, often complemented with other soil fertility improving techniques. A moderate addition of N fertilizer tends to increase net returns and reduce the risk from year-to-year variability in weather and prices (Singh *et al.*, 2001). Most improved varieties are responsive to fertilizer and economic yields are usually obtained after fertilizer application. However, the use of fertilizer is constrained by high prices and farmers' lack of knowledge on proper fertilizer application (Kaliba *et al.*, 1985).

2.2 Organic fertilizer management

Sustainable crop production can never be achieved by using only chemical fertilizer or by applying organic manure alone (Bair, 1990). Daramola (1989) found that balanced use of organic and inorganic fertilizers is very essential for the stable soil fertility where nutrient turn over in the soil plant system is faster and larger. Sugarcane produces higher yield in the soils with sufficient level of organic matter and available nutrients.

The continuous use of chemical fertilizer without organic fertilizer not only leads to environmental problems but also reduce land productivity. Worldwide, there is growing interest in the use of organic fertilizer due to depletion in the soil fertility because continuous used of chemical fertilizers create potential polluting effects due to chemicals in the environment (Berry and Fourier, 2002). The recycle and use of nutrients from organic manure has been given more consideration for insuring sustainable land use and agricultural production development. The long term effects of the combined application of organic and inorganic fertilizers improve soil fertility and crop yield (Chen *et al.*, 1988).

2.3 Integrated Soil Nutrient Management Technology Development

The major challenge facing agriculture of the small-scaled and resource poor households is how to increase farm production to meet food security without degrading the natural resource base. Soils are an integral component of the ecological system which serves as the natural resource base to supply the production of our basic food and fiber needs (Hailu, 1990). Soils are the fundamental medium for plant growth and basically act as the store house for water and nutrients requirement for plant growth and development. A factor that limits sustainable productivity increases is the inherent low soil fertility of the soils.

Integrated soil nutrient management technology is a combination of organic and inorganic soil nutrient sources, including biological nitrogen fixation, crop rotation, cereal legume intercrops, improved fallows, composting, green manuring, animal manure, and chemical fertilizers (Nair, 1993; Conway, 1997; Waddington *et al.*, 1998). Bokhtair and Sakurai (2005) stated that a balanced use of organic and inorganic fertilizer is very essential for the stable soil fertility where nutrient turn over in the soil plant system is faster and larger. Application of organic manure in combination with chemical fertilizer has been reported to increase absorption of N, P and K in sugarcane leaf tissue in the plant and ratoon crop, compared to chemical fertilizer alone.

A judicious combination of mineral fertilizers with organic and biological sources of nutrients is being promoted. Such integrated applications are not only complementary also synergistic as organic inputs have beneficial effects beyond their nutrient content (Wang *et al.*, 2001). Therefore, nutrient needs of such production systems can best be met through integrated soil management. The concept of ISNM aims to increase the efficiency of use of all nutrient sources, such as mineral fertilizers, organic manures, recyclable wastes or bio-fertilizers (Roy *et al.*, 2006).

Soil nutrient management influences agricultural productivity, and hence food security and livelihoods. Soil problems and potentials are often over-generalized at national and regional levels, while soil and their management options are location-and situation-specific. The low nutrient status of soils and the loss of organic matter (through continuous cropping, burning and overgrazing) and nutrients (erosion and leaching) are key issues (Checkland, 1992). Farming systems, especially combinations of crops and livestock, also influence management options. Replacing multiple crops with mono cropping may raise demand for external inputs and increase pressure on the soil. Suitable socio-economic and policy environments to maintain and improve soil fertility are also important to be considered (DFID, 2002).

In 1976, the government encouraged the implementation of production programs that combined the use of high yield varieties and increased application of chemical fertilizers in Myanmar. However, in the long term, the high yields will not be sustained unless there is an adequate provision of supply of fertilizers including appropriate amounts and types. As high yielding plant varieties take up a large amount of nutrient from the soil, the inability to replenish the lost nutrients will cause severe nutrient depletion and corresponding to decline crop production (Win, 2010).

2.4 Farmers' Soil Nutrient Management Practices

2.4.1 Crop rotation

The improper cropping systems and cropping patterns which is centered on the increase in the crop density per unit area and mono-cropping to compensate for less arable lands caused the increasing depletion of soil fertility status (Win, 2010).

In the period between harvest and re-sprouting, green manure legumes can and should be grown. Growing legumes as a rotation break crop has a long history (Chorley, 1981). Biederbeck *et al.* (2005) reported that it is widely practiced today in both industrial and subsistence production systems worldwide, including sugarcane (Garside and Bell, 2001). Shoko and Zhou (2009) stated that the inclusion of a legume fallow within a sugarcane cropping cycle is practiced to reduce populations of detrimental soil organisms provide nitrogen (N) through biological fixation and for weed suppression.

2.4.2 Cereal legume intercrops

Wolfswinkel (2004) stated that in order to maintain soil fertility is often one of the main challenges in agricultural production. Intercropping is a way of increasing the diversity of farming system and one of the options available to maintain soil fertility and crop yields. The risk spreading, weed control and the decrease of pest and disease incidence are other benefits of intercropping. By combining crops that have different growth patterns, the available air, water and nutrients can be better utilized (Schöll and Nieuwenhuis, 2004).

Yadav and Yaduvvanshi (2001) reported that in India, the use of intercropped legumes in sugarcane as a green manure to enhance yield and maintain soil fertility has been largely superseded by the use of inorganic fertilizers. However, there have been several reports that exclusive use of inorganic fertilizers or organic manures has failed to sustain the long-term soil fertility and the productivity of sugarcane. The slow early development of the leaf canopy in widely spaced cane makes it ideal for intercropping especially that new short duration, dwarf legume varieties are available.

2.4.3 Improved fallows

Garside *et al.* (2001) reported that fallow legumes have traditionally been a part of the sugarcane farming system. A legume-based sugarcane farming system is likely to be more sustainable than the current monoculture system. The utilization of well grown legume fallows can produce major benefits in a sugarcane farming system. Part of this benefit arises through a nitrogen contribution from the legume but other factors, probably associated with improvements in soil health from breaking the monoculture, are involved. The value of the legume crop will be directly related to the selection of the right species for the conditions along with a high level of management. It is becoming more obvious that the PO/RP system is non-sustainable and break crops are destined to play an increasingly important role in sugarcane cropping systems, either as green manure crops or for cash flow through grain production.

An improvement of existing fallow management systems with sown legumes has the potential to enhance the restoration of soil fertility through the accumulation to organic matter and fixation of atmospheric nitrogen, or through an improvement of physical soil properties (Wilson *et al.*, 1982). Suitable legumes also have the potential to alleviate feed constraints for cattle, especially during the dry season, through their higher nutritive value compared with the natural fallow vegetation. Increasing crop yield after the fallow period is a major objective of improved fallow systems. Thus, nutrient exports including P and K by crops will also be higher when compared with cropping systems based on natural fallowing (Muhr *et al.*, 1999).

2.4.4 Composting

Viator *et al.* (2002) found that the compost could be applied to sugarcane without reducing yields, and that it is better to subsoil compost into the row at the compost rate. Also, compost and gypsum did not affect plant root growth, except for decreased root surface area where compost was row-applied. Neither the gypsum rates nor the compost application rate used in our study increased nutrient metal accumulation in cane leaves beyond acceptable limits. Compost application to agricultural soil should provide better long-term fertility and lower off-site impacts compared with other means of waste disposal. Consequently, converting municipal bio-solids into compost for agricultural production should be a desirable alternative to land filling or burning.

Brito *et al.* (2007) studied that the use of sugarcane residues with initial C and N contents, submitting sugarcane residues to a composting process treatment would allow the achievement of an organic product (compost) with a lower C/N ratio and improve its mineralization and nutrients availability on N uptake by plants.

2.5 Integrated soil nutrient management in sugarcane production

Among various reputes of sugarcane production, although fertilizers contribute maximum to the increase in yield but these cannot help to maintain and enhance soil organic matter content which is ultimate key to sustainability. Paul *et al.* (2005) found that the integrated use with organic materials and inorganic fertilizers is extremely important for sustaining production of ratoon sugarcane and maintaining or improving soil fertility. Bokhtair and Sakurai (2005) reported that the press mud and FYM manure incorporation are extremely important for maximizing and sustains the productivity of sugarcane and maintains the fertility status of soil.

Sugarcane produces higher yield in the soil with biomass and activity. It is being well accepted that soil organic matter is a key factor in maintaining long-term soil fertility, as it is the reservoir of metabolic energy, which derives soil biological processes involved in nutrient availability (Sumner, 1990). Kumar and Mishra (1992) reported that application with suitable combination of organic and inorganic nutrients increase fertilizer use efficiency and sugar yield. The main objective of integrated nutrient management is to improve and sustain soil fertility for providing a sound basis for crop production systems and to meet the changing needs (FAO, 2001).

The basic concept underlying the principal of integrated plant nutrient management is the maintenance and the possibility increase of soil fertility for sustaining increase crop productivity through optimizing all possible sources, organic and inorganic plant nutrients required for crop growth and quality in the integrated manner appropriate to each cropping system and farming situation within its ecological, social and economic possibilities (FAO, 1995).

2.6 Local knowledge levels and ISNM

Knowledge has varied meanings based on its own epistemology, i.e. its own theory of what knowledge is. What knowledge depends on who does the interpretation and the purpose for which it is done (Hillbur, 1998)? An information or knowledge source provided the content or expertise of interest to the information seeker while channels refer to the methods or vehicles by which information is transferred or received (Tucker and Napier, 2002).

Rogers (1995) characterized farmers' and general public knowledge into three levels. The awareness-knowledge is information that an innovation exists and it is this knowledge that motivates individuals to seek how-to knowledge and principles knowledge. The how-to knowledge is the information that one needs to properly adopt an innovation. It involves the understanding of how much of the innovation to use and how to use it correctly. Principles-knowledge is information regarding the functioning principles that underlie how the innovation operates. One important variable that influences knowledge acquisition is experience.

Local knowledge is the human capital and the main asset they invest in the struggle for survival, to produce food, provide for shelter or achieve control of their own lives. Local knowledge is developed and adapted continuously to a gradually changing environment. It is passed down from generation to generation and closely interwoven with people's cultural values (FAO, 2004).

Warburton and Martin (1999) stated that local knowledge is a collection of facts and relates to the entire system of concepts, beliefs and perceptions that people hold about the world around them. This includes the way people observe and measure their surroundings, how they solve problems and validate new information. It includes the processes whereby knowledge is generated, stored, applied and transmitted to others. Indigenous knowledge systems are often associated with indigenous people thus rather limiting for policies, projects and programs seeking to work with rural farmers in general.

Adolwa *et al.* (2010) stated that the dissemination and communication of information on knowledge-intensive ISFM technology has proved challenging as transfer of technical knowledge from scientist and researcher to farmer is difficult. ISFM knowledge, consequently, has not been optimally used to solve soil fertility management problems. One of the primary ways by which uncertainty may be reduced is by acquiring information. Sources of ISFM knowledge and information include farmers' field schools, agricultural research institutions, learning institutions, community-based organizations, websites, non-governmental organizations, temples, local administrative organization, agricultural companies, and extension workers.

Sanginga and Woomer (2009) described that there is a number of channels available for the dissemination of ISFM technology among small-scaled farmers. These could include community-based (demonstration and field days, farmer field schools, farmer-to-farmer training), print-based (extension brochures, booklets), mass media (radio programs) and ICT-based audio-visual systems (video documentaries, CD video documentaries).

2.7 Farmers' knowledge of soil nutrient management

Marenya *et al.* (2008) indicated that scientists, policy makers, and extension workers concerned with land management strategies in agricultural areas can benefit from understanding the local knowledge and perceptions of agricultural resource managers. Collaboration among these groups can result in a more complete understanding of local environments and determinants of environmental outcomes, the design of appropriate management strategies for specific agro-ecosystems, and more successful implementation of alternative management strategies. A first and necessary step in such collaboration must be arriving at a shared understanding of the differences and commonalities among each group's environmental knowledge and management goals (Tabor, 1992).

It is particular interest to know whether farmers' perceptions of their resource conditions and the returns to proposed responses to resource deficiencies diverge from those suggested by scientific measurements and, if so, by how much and why. The study of farmers' indigenous knowledge has taken place primarily within ethnopedology, the study of how local peoples classify their soils based on their collective experience (Marenya *et al.*, 2008).

Several studies have documented farmers' knowledge of different soil types, management skills, and farmers' ability to help scientists classify soils (Tabor, 1992). Other researchers have focused on the social, economic, and/or cultural rationale behind farmer knowledge and practices. Another group of authors has promoted using farmers' indicators as the basis for environmental management and monitoring in recognition of the fact that farmers' perceptions can offer accurate indications of environmental conditions (Ericksen and Ardon, 2003).

Understanding indigenous knowledge of soils has become to be seen as essential in understanding the local realities of farmers and may be critical for the success or failure of agricultural development (Winkler Prins and Sandor, 2003). The centrality of knowledge to agriculture has been highlighted by a number of commentators (Morgan and Murdoch, 2000), with knowledge described as the 'fourth factor of production' because of the widely differing knowledge, skills and aptitudes farmers need for production food (Winter, 1997).

Local people have significant knowledge of soil and environments, acquired by experiences that have been tested by many generations living close to the land. Farmers' soil knowledge offers a different set of temporal and spatial scales with regarded to land use, which has important implications for sustainable agriculture (Sandor and Furbee, 1996).

For continuing practice of a new technology by the farmers needs their interest and adequate knowledge to use it properly so that maximum benefit can be obtained. It is observed that in many cases farmers do not continue to practice even an improved technology due to lack of technical support, unavailability of inputs and other limitations (Farouque and Takeya, 2007).

Improving farmers' knowledge, and their capacity to observe and experiment, is an essential element in the development of ISFM technologies (Deugd *et al.*, 1998). Corbeels *et al.* (2000) stated that It is also important to build on local systems of knowledge, as they relate to specific locations and are based on experience and understanding of local conditions of production. Such systems are a source of site-specific ecological information, and provide the key to understanding peoples' socio-cultural conditions. Many development projects and policies have collapsed because of a failure to understand local knowledge, and how this influences the way farmers manage natural resources.

Osbahr and Allanb (2003) described that farmers hold complex ecological knowledge (local knowledge) and there is great variation in the kinds and depth of such knowledge. The choices made by individual farmers depends on their capacity to enact successful agricultural performances and to exploit an evolving range of opportunities, and these in turn are based on the use of their local knowledge, as well as on their communication and creative capacities.

On an individual basis, knowledge is acquired through personal experiences and over-lapping communication pathways, both of which are influenced by social factors, including age, gender and family ties. Network mapping can capture some of the farmers' everyday experiences and 'common' knowledge.

2.8 Farmers' knowledge and Extension Service

FAO (1985) reported that in many developing countries wide adoption of research results by majority of farmers remain quite limited. This situation calls for a system which allows adequate information flow from farmers to researchers and from researchers to farmers. Agircultural extension services have a central role in facilitating the exposure of farmers to a variety of information. Greater exposure of farmers to their information sources is a sign of interest taken by them infarming (Muhammad and Garforth, 1999).

Breman *et al.* (2001) stated that the technical options themselves are developed in a participatory process, combiningsystems approach and local knowledge derived from "on-farm" trials with farmers, researchersand public and private extension personnel.At the national level, the project supports and reinforces dialogue between all stakeholders (e.g., government, private sector, and farmers' organizations) for an improved socioeconomic and policy environment. These improvements enable farmers to invest in their soils and the private sector to invest in agricultural inputs and output market development.Regional cooperation for a common input market is organized to enable countries tocreate the benefit of scale and to improve the global competitiveness of their agriculture.

Agricultural technologies were developed on research stations and the task of extension was to promote their adoption by farmers to increase productivity (Coutts, 1997). Agricultural extension was considered as the transmission of research results and extension officers concentrated on understanding the research rather than consideration of the information requirements of farmers (Drew, 1974). Extension teaching is the major source of information about the range of different methods that exist for carrying out farming and other operations. Delivering useful information to its consumers is an ongoing process; therefore, it is essential that farmers are able to acquire the necessary knowledge, skills and attitudes that will allow them to utilize information and technology effectively, with the ultimate aim of raising their efficiency and achieving a higher standard of living (Okunade, 2007).

Nowadays, nearly everybody agrees that local knowledge and practices should be recognized in development initiatives aimed at technology development by and for rural farming communities. Interest amongst research, education and development institutions to investigate and document local knowledge has grown significantly over the last few years (Moss *et al.*, 2001).

2.9 Constraints of integrated soil nutrient management implementation

Gruhn *et al.* (2000) stated that the climatic conditions in several parts of Sub-Saharan Africa contribute to soil erosion. Rapid water evaporation and inadequate and highly variable rainfall deprive plants of the water necessary for growth. High atmospheric temperatures, strong light, and heat-retentive, sandy soils can make the local environment too hot for proper plant growth.

Together, these harsh climatic factors, coupled with poor soil management, have reduced soil fertility by contributing to soil and water erosion. Slight to moderate erosion slowly strips the land of the soil, organic matter, and nutrients necessary for plant growth. This degradation increases the opportunity for drought and further erosion because it reduces the water-infiltration and water-holding capacity of the soil status (Crosson, 1986).

Bista *et al.* (2010) revealed that the soil fertility management system involved traditional methods of soil and crop management and relied maximally on the available local resources. FYM was the main source of SOM and nutrients for the major crops, although there were many other sources and considerable differences in the amount of fertilizers applied in the fields. However, there are several constraints like erosion, soil acidity and faulty management practices, which are caused by the low technical knowledge and resource compulsions and which hindered better soil fertility management in hills and valleys of Nepal.

Gruhn *et al.* (2000) stated that the insecure and crumbling farming land tenure contribute to declining soil fertility. The communal right to graze land without any effort to maximize long-term returns has led to serious overgrazing, which is reported to be the main cause of human-induced degradation in Africa. Ill-defined property rights and insecure tenure rights have also reduced the incentive for farmers to undertake soil fertility-enhancing investments.

Gruhn *et al.* (2000) indicated that in resource poor environment, effective soil management becomes absolutely essential. But socio-economic and other factors often make it difficult for farmers and their families to manage the soil for long-term profitability and sustainability efficiently.

Onduru *et al.* (2007) studied that the socio-economic status was small-scaled households' inventory and their relation to farm nutrient management. The study has shown that the presence of livestock in smallholder farming systems is a major determinant of nutrient stocks, flows and balances with farm households having the high livestock density experiencing less plant nutrient mining or having positive plant nutrient balances.

The study showed that the economic profitability of the farming system was indicated by a negative correlation between farm nutrient balances and major farm economic indicators, poor performance of economic indicators and the high dependency of the studied household's on off-farm income. Sustainable improvement of soil fertility will require a better understanding of the rationale behind this farmers' preferential use of inputs, nutrient use efficiencies of such farmer strategies and the derived benefits within wider socio-economic and policy contexts.

Butterworth *et al.* (2003) mentioned that marginal farmers face comparatively less problems than small farmers in appropriate ways of soil fertility management at Andhra Pradesh in India. However, lack of knowledge about ISF and NM system, financial inability to buy fertilizers in time and unavailability and unstable market price of fertilizers during crop seasons were the constraints. (Chuma *et al.*, 2000) concluded that scarcity of inputs, labor and capital are the main constraints faced by the farmers in Zimbabwe.

However, easy access to credit and available of chemical fertilizers, and supply of electricity and gas with reasonable price and organize training programs on appropriate methods of soil fertility and nutrient management are major driving forces the poor farmers to improve the existing situation (Farouque and Takeya, 2007).

2.10 Ordered Probit Model, Local knowledge and Soil Nutrient Management

The ordered probit model, also known as the ordinal probit model, is commonly used for analyzing data sets that include categorical and ordered dependent variables (Xie, 2009). When the dependent variable takes more than two values and these values have a natural ordering, the use of an ordered probit is indicated (it is estimated using the maximum likelihood method). Like many models for qualitative dependent variables, this model has its origins in bio-statistics (Aitchison, 1957), but was brought into the social sciences by two political scientists (McKelvey, 1975).

Jackman (2000) reported that when the dependent variable takes more than two values, but these values have a natural ordering, the ordered probit model is often appropriate. The dependent variable is ordinal, when such a variable appears on the left-hand side of a statistical model it is obvious that LS regression will suffer from many of the short-comings. Winshik and Mare (1984) stated that it describes measurement models for ordinal variables and discusses specification and estimation of models with ordinal dependent and independent variables. In above case, the ordered probit model is proper to be conducted. Ordinal variables may be independent or intervening variables in structural equation models.

Like many models for qualitative dependent variables, this model has its origins in bio-statistics but was brought into the social sciences by two political scientists (McKelvey and Zavoina, 1975). The ordered probit model is assumed that a fairly straight forward extension of the binary probit model that can be used in cases where there is multiple and ranked discrete dependent variables (Nagenthirarajah and Thiruchelvam, 2008).

Nagenthirarajah and Thiruchelvam (2008) applied the ordered probit model approach to study the impacts of socio-economic factors like farmers' age, education, family size, occupation, and experience in farming, operational holding, annual income, extension contacts and social participation on farmers' knowledge on pesticides use practices and their awareness about the ill effects of pesticides on their health and environment in Vavuniya District in the Northern Province of Sri Lanka.

Adolwa *et al.* (2010) found that the ordered probit regression model was used to evaluate the Integrated Soil Fertility Management (ISFM) information and knowledge sources and channels and assess the influence of socioeconomic factors on access and usage of ISFM knowledge among smallholder farmers in western Kenya. The ordered probit regression could indicate that off-farm income, education level, distance from nearest information centre, livestock value, and district of residence were the socio-economic variables that significantly influenced farmers' access and uptake of ISFM knowledge. The investigation of farmer field days and farmer groups as vehicles of information dissemination and communication should be continued.

Oladele and Tekena (2010) applied the ordered probit model to examine the factors influencing agricultural extension officers' knowledge on practice and marketing of organic agriculture in North West Province, South Africa. Knowledge of extension officers could provide research based information, educational programs and technology on farmers' needs and enabling them to make informed decisions about their economic, social and cultural well-being.

Kuiper *et al.* (2006) studied that the ordered porbit model was applied to analyze the role of non-farm activities in rural households' livelihood strategies and the implications for the sustainability of natural resource in the seven survey regions of Africa.

The ordered probit model was conducted to investigate the impacts of ISFM on crop productivity and production efficiency and stated that the socioeconomic and biophysical conditions under which ISFM may provide greater positive significant impacts on yields, which is useful information in guiding targeting of ISFM promotion (Kato *et al.*, 2011).