1 INTRODUCTION

Per capita agricultural production and crop yields per unit area of production in Uganda, like in other sub-Saharan African countries, is declining (IBSRAM 1994; Sanchez et al. 1996; FAO 1999). The main contributing biophysical factors are low inherent soil fertility, particularly nitrogen (N) and phosphorus (P) deficiencies (Nye and Greenland, 1960; Ssali et al. 1986; Bekunda et al. 1997), exacerbated by nutrient/soil fertility depletion (Vlek 1993; Sanchez et al. 1997a). In addition, a large number of the poorest people in sub-Saharan Africa live in marginal areas where markedly increased land, and labour productivity is unlikely (Vlek 1990).

A soil survey conducted in the late 1950's revealed that about a tenth of the total land area had soils with a productivity rating above medium, more than a quarter had soils rated as unproductive, hence leaving about one half of the land surface with soils rated as medium (Harrop 1970). A medium rating implies that the soils will only yield good crops under good management (Harrop 1970; Stephens 1970). The soil fertility is associated with soil organic matter (Foster 1981) and is found mainly in the top 0 - 30 cm. If topsoil is lost through erosion, the fertility and productivity are permanently lost (Stephen 1970). However, loss of nutrients as components of crop harvests as well as through runoff and soil erosion is on the increase in many of the farming systems. Smallholder farmers are unable to compensate for these losses by using crop residues and manures or purchasing mineral fertilizers, resulting in the negative nutrient balances reported at the national level for sub-Saharan Africa countries (Stoorvogel and Smaling 1990) and at the regional scale for the farming systems of eastern and central Uganda (Wortmann and Kaizzi 1998).

Smallholder farmers use low-input production technologies without appropriate soil and water management practices. They sustain their households through extensive production of food crops using most of the available land and labour resources (Vlek 1990). The farmers lack financial resources to purchase fertilizers to correct the inherent low fertility levels and replace the nutrients removed from the fields. Yet farmers either abandoned the traditional systems of restoring and sustaining soil fertility such as leaving land under fallow, use of animal manure and proper crop rotation, or, where these are being used, they are no longer able to cope with the rate of soil fertility decline.

Replenishing and enhancing soil N, P and K is essential for sustained productivity and for the rehabilitation of eroded and depleted soils. Soil fertility replenishment and enhancement will result in positive benefits such as increased soil cover with protective vegetation, and increased soil biological activity associated with enhanced crop production (Sanchez et al. 1997b). Soil fertility replenishment can be achieved through the use of inorganic fertilizers, organic fertilizers or their combination. Inorganic fertilizers are the only option available to improve and balance the loss of P and K. For N it can be achieved through the use of both inorganic fertilizers and Biological Nitrogen Fixation (BNF).

Unfortunately, social and economic factors do not favour the use of inorganic fertilizers by the smallholder farmers. In sub–Saharan Africa, inorganic fertilizers cost two to six times as much as those in Europe (Bumb and Baanante 1996; Sanchez 2002) mainly due to transport costs, and other charges (Vlek 1990). In addition, the profitability of fertilizer use is highly variable and dependent on agro-climatic and economic conditions at local and regional levels (Vlek 1990). Most farmers do not have access to credit, and the returns to fertilizers are low and variable (Badiane and Delgado 1995; Heisley and Mwangi 1996). Inorganic fertilizers are mainly used on cash crops such as tobacco, tea, and sugarcane, which can be marketed on a profitable basis (Vlek 1990). In addition, farmers are not aware of the forms of fertilizers, methods of their use and the potential benefits accruing from their use (Bekunda et al. 1997).

There are also constraints limiting the use of organic materials, including labor for collecting and applying the materials as in the case of biomass transfer (Ruhigwa et al. 1995), limited quantities and variation in quality of organic materials (Palm et al. 1997), and the demand for crop residues as fuel and fodder (Palm 1995). In the case of green manure or in-situ biomass production, farmers have to sacrifice land by keeping it out of food production (Giller et al. 1997), which they cannot afford especially in areas with high population density. Organic materials are not only frequently in limited supply, where they are used alone, the quantities may not provide the productivity boost needed by the smallholder farmers. Hence a judicious combination of available organic materials with inorganic fertilizers may be an appropriate option.

Cereals are important crops for the smallholder farmers in Uganda, and N is one of the factors limiting cereal production in the region. Only with a secure N supply can farmers increase cereal production and contribute to food security for the smallholder farmers. Their main concern to date is having enough food to take them up to the next harvest.

The strategies investigated in this study include the use of inorganic N fertilizers and the exploitation of BNF through the use of *Azolla* and Velvet bean (*Mucuna pruriens*), either as relay crops, or as an improved fallow. Since the study covered contrasting agro-ecological zones and contrasting soils, application of P and K fertilizers was required especially for poor soils and at high levels of N. The agronomic and economic benefits of these different strategies were evaluated in a series of production environments comprised of low and high productivity soils in favorable and marginal agro-ecological zones. Thus, the overall objective of the study was to determine the most suitable strategy for soil fertility maintenance for resource poor-farmers in eastern Uganda cultivating maize and rice on contrasting soils, and in contrasting agro-ecological zones. Specifically this study aims:

1. To determine mucuna biomass production and BNF with and without P fertilizers, on contrasting soils and in contrasting agro-ecological zones
2. To determine the decomposition and N release pattern of mucuna residues in these contrasting agro-ecological environments
3. To determine the N balance following the application of mucuna and inorganic fertilizer N on contrasting soils
4. To determine maize yield in response to the application of inorganic-N, and to a preceding mucuna fallow or relay crop on contrasting soils in contrasting agro-ecological zones
5. To evaluate rice yield in response to *Azolla,* mucuna or inorganic N fertilizers in contrasting rice production systems
6. To determine the economic benefits of using mucuna, *Azolla* and inorganic N fertilizers as N replenishment strategies for cereal production on contrasting soils in key agro-ecological zones of eastern Uganda