PhD Research Progress Report (2019-2020)

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Field of study: MSc in Crop Science (Biotechnology)

University: KU Leuven

Timeline of study: February 2019 to February 2023

Research title: Sustainability of maize-legume-banana-coffee-livestock farming systems in the Upper Pangani Basin, Tanzania

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Research Objectives

The overall objective of the study will be to document, quantify and analyse the flows of organic matter and nutrients between the maize-legume fields in the lowlands and the banana/coffee-livestock farms on the slopes of Mount Kilimanjaro in order to assess their importance and develop recommendations to improve productivity and/or environmental sustainability of the ongoing practices.

Specifically:

i. Assess the nutrient status in respective selected inter-connecting farms with nutrient transfers between them and non-inter-connecting on slopes of Mt. Kilimanjaro
ii. Quantify nutrient budgets for the selected farms for major crop nutrients like N, P, K, Ca, Mg and S in order to establish budgets weighed against nutrient stocks
iii. Analyze the cost/benefit relationships of the existing farming system
iv. Develop recommendations on the environmental and economic sustainability of the existing farming system

Achievements

1. Completed pre-doc course work
2. Research activities
   - Achieved objective one (completed baseline survey, soil and plant samples collection)
   - Other objectives on progress

Introduction

The Kilimanjaro region is surrounded by mountains with Mt. Kilimanjaro providing a unique ecological system of which more than three quarter of the population is depending upon, due to its highly fertile soil and optimal rainfall patterns (Misana et al., 2012). Both modern and traditional farming systems have been adopted in the Kilimanjaro region with the latter being the

dominant one, especially on the foothills of Mount Kilimanjaro (Ikegami, 1994). The traditional farming systems are based on planting banana (as food crop), coffee (cash crop) and trees together with livestock. As such, it can be referred to as an "Agro-silvipastoral" system (kihamba system in Chagga) (Kaihura et al., 2001). Trees are usually grown for provision of wood, fodder, fruit, timber and shades for animals, while coffee is grown for household income generation (Andreas 2007). Cattle are kept for milk as well as for manure production, and hence are regarded as the concentrators and transporters of nutrients from grasses grown on surrounding fields to the banana-coffee home gardens (Baijukya and de Steenhuijsen Piters, 1998). This system has been stable for over a century until three decades ago where people in the highlands lost interest in intercropping coffee with banana due to - among other factors - global price fluctuation of coffee and land scarcity. Since then, more emphasis has been put on the banana-tree-vegetable intercropping with less livestock (usually less than five cattle) on the farms (Misana et al., 2012; Maghimbi, 2007). The preference for banana over coffee is based on the double value of the crop, that is, it can serve as a food crop as well as a cash crop. The intensive multiple cropping together with livestock keeping has stabilized the system productivity by providing not only soil cover which ultimately conserves the soil from erosion but also the nutrient cycling that has ensured nutrient use efficiency (Kaihura et al., 2001). More recently, land degradation on the slopes of Mt. Kilimanjaro has become a public concern due to the massive deforestation caused by strong human population growth (Sébastien, 2010; Mbonile et al., 2003).

Contrary to the highlands, the lower plains of the mountain were previously used for growing supplementary food, mainly maize and beans (Misana et al., 2012), since they were regarded as less fertile land characterized by drought spells (Kilasara et al., 2001). However, the drastic change in human population has increased the pressure on arable land on the upper slopes of Mt. Kilimanjaro. This in turn has forced people to migrate and expand their agricultural production to the lower plains of the mountain, in search not only of additional land for food crops but also to generate additional fodder to feed their animals (Mbonile et al., 2003). The lower plains of the mountain hence became characterized by mono-cropping farming systems predominated by cereal crops such as maize and rice, the latter being dominant in the river flood plains (Maghimbi, 2007). Few shrubs and scattered trees can be found in lower plain fields. Other crops grown in the lowland areas include legumes (beans, cowpea,) and tubers/roots (cassava, potatoes and sweet potatoes) (Misana, 1991). It is clear that farming systems in the upper lands of Mt. Kilimanjaro are totally different from those in the lower lands

Research has pointed out that most farming systems in SSA impose great effects on the soil quality. Especially the soil organic matter levels suffer from a partial adoption of sound farming practices (FAO, 2011). Low nutrient returns to compensate nutrient losses due to crop harvest have been attributed to the low soil fertility in most SSA arable lands (Baijukya et al., 2005). Soil organic matter for instance has been a central indicator for soil quality influencing soil biology, chemistry and physics (Onemli, 2004). Soil with large organic matter (OM) content is regarded the best soil since it contains large amounts of C, N, P, and S; it favours microbial activity and thus increases the availability of nutrients (Feichtinger et al., 2004). In addition, soil organic matter (SOM) lowers the surface runoff by improving the physical properties of the soil which consequently affects soil aeration, water infiltration and drainage (Liu et al., 2006).

While many studies in SSA have been focused on issues of soil fertility, erosion and desertification (Faerge and Magid, 2004), limited attention has been paid to nutrient monitoring (balances). The few studies on nutrient balances are dominated by negative nutrient balances, particularly for N and K (Zingore et al., 2007; Cobo et al., 2010). As mentioned before, nutrient monitoring quantifies the system's inflows and outflows resulting in a nutrient balance (Surendran et al., 2005). Despite the revealing stories of NUTMON elsewhere, similar information is rare for Tanzanian soils, and the more so for the Kilimanjaro region with the above evoked specific nutrient transfer system. Data show that the most frequently studied areas in SSA are in Kenya followed by Ethiopia, Mali and Uganda (Cobo et al., 2010). Hence, in view of the absence of data and the peculiarity of the lowland-highland connection in the upper Pangani basin, we felt that NUTMON would serve the purpose well of developing a thorough understanding of the connection between farming practices and nutrient balance, in order to evaluate the economical soundness and sustainability of the ongoing practices

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