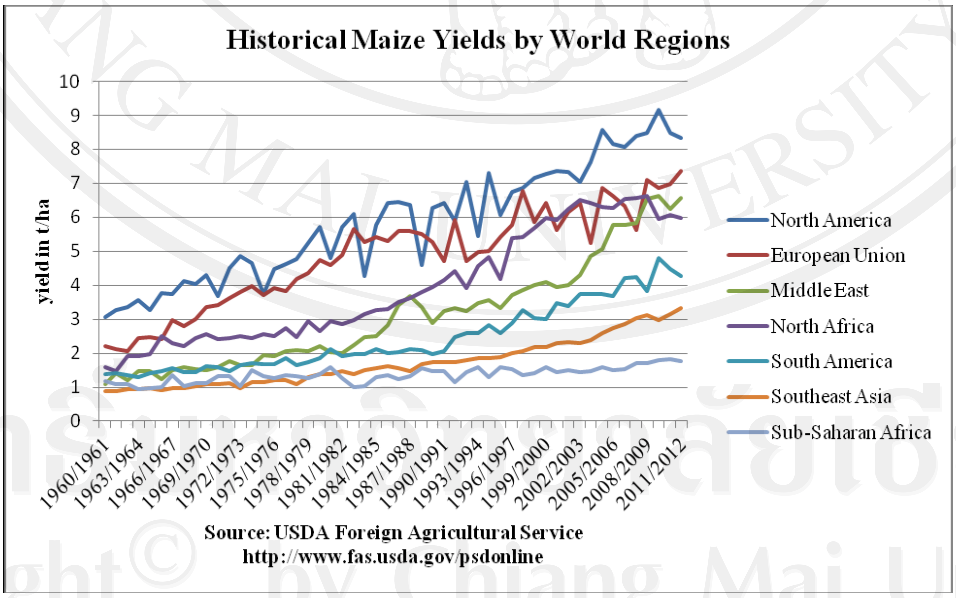
CHAPTER 1

INTRODUCTION

1.1 Statement of the Problem

While most regions of the world have seen significant improvement in staple food production in the past fifty years, Africa's yields have stagnated (FfF, 2012). The dominant crop and staple food of southern Africa is maize (*Zea mays*), accounting for 50-90% of calories consumed (Erenstein et al., 2008). However, current maize production in sub-Saharan Africa (SSA) remains critically low, averaging 1.78 t/ha in 2012, less than a 1 t/ha improvement in over 50 years (FAS, 2012) (Figure 1).



Source: USDA Foreign Agricultural Service
http://www.fas.usda.gov/psdonline

Figure 1: Historical maize yields by world regions.

[a] Adapted from FAS (2012).

African farming occurs mainly on small farms. Nagayets (2005) defines smallholder farms as owned or rented land with 2 ha or less in size. The average farm size in Africa is reported at 1.6 ha. (FAO, 1997 as cited in von Braun, 2005). Most African smallholder farming is extensive low input farming heavily dependent upon manual labor with an estimated 65% of African farming achieved with a hoe, 25% with draught animals, and 10% with mechanized equipment (Bruinsma, 2003).

The causes of insufficient agricultural production on SSA smallholder farms are diverse, complex and confounded by individual histories, economics, policies, cultures, climates, landscapes, farming systems and beyond. However, land degrading farming practices have long been associated with declining productivity in SSA. Sanchez, et al., (1997) links nutrient depletion in African soils as the primary biophysical factor to low agricultural output. Lal (2004) highlights the loss of soil organic carbon (SOC) as a primary cause of low productivity and rather bluntly describes extractive farming practices in this way, “Simply put, poor farmers have passed on their suffering to the land through extractive practices. They cultivate marginal soils with marginal inputs, produce marginal yields, and perpetuate marginal living and poverty.”

Nutrient depletion, SOC losses, and overall land degradation stem from practices that include overgrazing, excessive tillage on fragile soils, bare ground cultivation, and a constant loss (e.g. erosion) and harvest of nutrients without sufficient inputs and/or farming systems for conserving nutrient stocks and soil quality (Mrabet, 2002). Because low crop production in SSA is historically associated with both poverty and land degradation due to poor agricultural practices, a myriad of agricultural improvement programs have been implemented from local, national, and international sectors.

One such effort to deal with low staple food production and land mismanagement is a farming system called CF (Conservation Farming) which significantly raises yields of smallholder maize farmers in Zimbabwe (Mazvimavi et al., 2008). CF combines the soil enhancing benefits of minimum till and residue retention with annually enriched permanent planting stations managed under high agronomic standards. Adapted from a large-scale no-till farm in Zimbabwe in the 80s, the method was modified for hoe farmers (Twomlow et al., 2008). After early successes in Zambia and Zimbabwe, it has been promoted by many research organizations and NGOs throughout southern Africa as one alternative for improving smallholder production and land care practices (ZCATF, 2008). There are variations of the CF method, for example that uses ripping with draught animals, but the principle method discussed in this study is the hoe-based station technology pioneered by Brian Oldreive with Foundations for Farming (FfF).

1.2 CF System

While there are various definitions and attempts to describe CF (see FfF, 2012; ZCATF, 2008; Twomlow et al., 2008b), most agree the central components of the technology are (1) to use no ploughing, (2) encourage crop residue retention, (3) rotate crops, and (4) establish a uniform grid of fixed planting stations that are managed under a suite of high management standards and practices. These standards include timely field preparation, seeding, and weeding; application of manure and other crop-enhancing organic inputs; uniform and precise basal and topdress fertilizer applications; a final pre-harvest weeding to prevent reseeding of weeds and rid fields of perennial creeping grasses; and crop rotations at least every 3rd year with legumes (Twomlow et al., 2008b). The method is primarily used by rain-fed hoe-based farmers in which there is one cropping season per year.

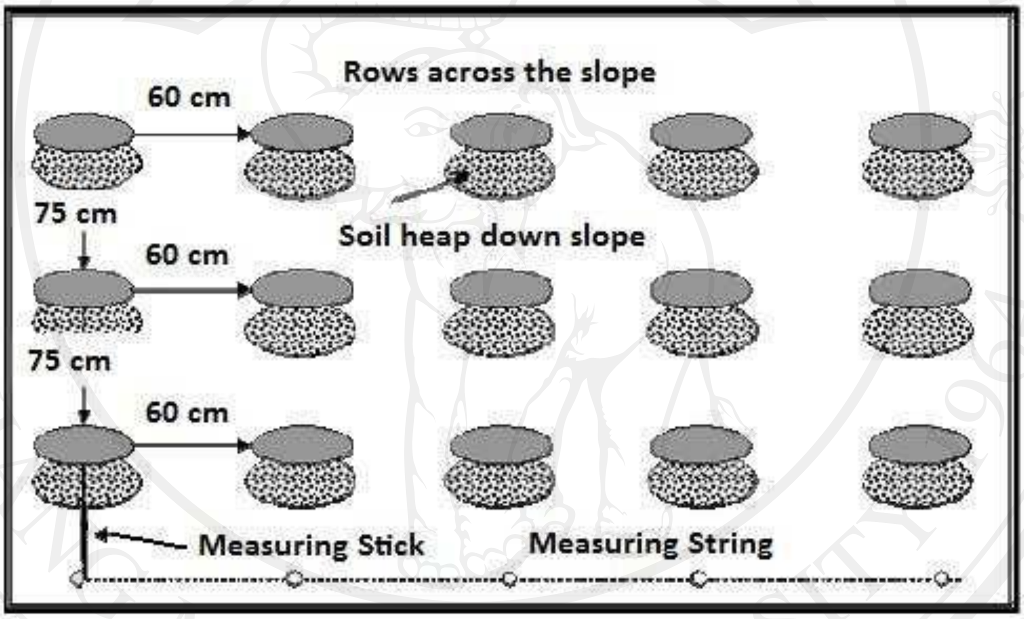


Figure 2: Planting station diagram for maize. Spacing for moderate to high rainfall areas (>650 mm).

[a] Source: Oldreive (2011).

Figure 3: CF field, Masembura Village, Zimbabwe 2010.

Figure 4: CF field in Zambia without mulch, 2005.

1.3 Research challenge

In general, decreased tillage with residue retention has demonstrably supported increased soil organic carbon levels, one of the most critical indicators of soil health and productivity (Hobbs et al., 2008). CF adds a further dimension combining minimum tillage with enriched planting stations. The combined effects of station enrichment and minimum-till have been less examined as there is little published research on CF's impact on soil quality. While there have been thorough investigations into CF by Haggblade et al. (2003a, 2003b, 2011) in Zambia and by ICRISAT scientists in Zimbabwe (Twomlow et al., 2008a, Mazvimavi et al., 2008), the majority of research has appropriately investigated the "big picture" results where effects such as labor or fertilizer inputs are largely quantified in yield, adoption rate, and profitability analyses. Less attention has been devoted to how CF fields change over time in their physical, chemical, and biological dynamics. One of the only known soil studies is by Belder et al. (2007) who investigated CF's impact on yield and soil physical and chemical parameters for 37 households in Zimbabwe across different soils and rainfall conditions. The timeline study involved farmers practicing CF mainly between 1-3 years (33 farmers) with 4 farmers beyond 3 years. CF maize yields were double the yields of conventional tillage across all regions. Bulk density, infiltration rates, and pH were significantly improved in CF stations compared to ploughed fields while little significance was found in other chemical parameters (SOC, nitrogen, and total phosphorous). While this study provides evidence of modest improvements in soil quality during the early years of CF, it stands alone as a published timeline study on CF and did not correlate CF's impact with individual soils.

What is lacking in other research—and what this research begins to overcome—are more extended timeline studies investigating CF's impact on soil quality with emphasis to specific soil types. Chivenge et al., (2007) demonstrated that in a 9 year tillage study in Zimbabwe, reduced tillage methods that significantly improved SOC were different for sandy and clay soils. This study underscores the importance of investigating CF's impact on specific soils and for longer time frames. Therefore, the aim of this study is to investigate CF's impact on soil fertility development in an extended timeline study on one soil type. Soil sampling occurred on farmers' field that have continuously employed CF for different time periods—4 and 8+ years—and then compared them with conventional fields. Specific fertility parameters (e.g. total carbon and other important plant nutrients) are examined in how they react to the CF treatment ("quality of fertility increase") and how fast these changes take place ("velocity of fertility increase"). Understanding fertility dynamics under CF can lead toward improvements in research, technology development, and promotion among farmers.

A secondary aim of this study was to examine the effectiveness of a carbon analysis, called active C. Active (labile) carbon describes the "active" pool of carbon available for turnover in nutrient cycling and is a subset of the larger pool of total carbon that includes recalcitrant forms of carbon more slowly changed by soil microorganisms (Weil et al., 2003). Active carbon is considered by Weil et al., (2003) a more sensitive analysis to agricultural management changes than soil organic C and a less expensive analysis than using an elemental carbon analyzer. Because active (labile) C is validated as a good indicator of soil quality changes, active C was compared against other soil quality parameters (e.g. total C, N, P, K) to identify any possible relationships and determine whether this less expensive carbon testing method is a reliable analysis in estimating soil quality under different management practices and time frames.