Contribution of tillage practices on adaptation to climate change and variability on agricultural productions in semi-arid areas of central Tanzania

Brown Gwambene and Amos E. Majule

Institute of Resource Assessment, University of Dar es Salaam; gwambene@gmail.com, gwambene@ira.udsm.ac.tz, amajule@ira.udsm.ac.tz

Abstract: *Climate change and variability have threatened agricultural productions and adversely affected the natural resource base, which provides a living for more than half of the world's poorest people. Unpredictability of onset rainfall and an increase in the mean temperature have affected the growth and crop yields. Other consequences have been observed in reduced access to water resources, increase of diseases, frequency of food shortage and declining in soil moisture levels over much of semiarid areas due to the prevailing dry conditions. Further decrease in soil moisture has favoured drying up of field crops that were at harvesting maturity. Crop yields are poor as a result of false start and poor rainfall distribution. Farmers have developed coping strategies to adapt to the adverse impacts of climate change. Some of these strategies such as proper tillage practices, use of improved, early mature and drought resistant varieties over semiarid areas have shown a success under the fluctuating climatic conditions. The tillage practices in particular are used for rain water harvest and improvement of soil moisture and fertility. This study investigated the contribution of tillage practices on adaptations to the impacts of climate change and variability in semi-arid areas so as to increase agricultural production and improve food security.*

Keywords: *Climate change and variability, food security, tillage practices and Agriculture production*

Introduction

In dry areas, moisture is a most limiting factor for crop production and it contributes to insecure household food security (Majule *et al.,* 2007a). In these areas average rainfall is less than the potential moisture losses through evaporation and transpiration. The areas receive annual precipitation between 250-600 mm with dryland-farming or rainfed-farming practices (Oicha and Klik 2009). Adverse weather (with low and highly unpredictable rainfall), low soils fertility with low soil organic matter (SOM) and nutrient contents constrain crop production, and there is a high risk of very low production levels or even crop failure, particularly under poor crop/agricultural land management.

The dry land occupy about 63 million km^2 or 47% of the surface of the earth and subdivided in hyper - arid (16%), arid (26%), semi-arid (37%), and dry sub-humid (21%) areas (Oicha and Klik 2009). In Tanzania the semi-arid area occupy about one-third (295,000 km^2) of the total land area and extends from North East to South West across the central part of Tanzania (Swai, *et al.,* 2007).

The sustainability of the dryland ecosystem and its agricultural production depend strongly on proper and effective land-use and management (Gwambene, 2007). Further agricultural production strongly depends on availability and condition of soil and water resources. For example soil aggregation is one of the main factors controlling the chemical, physical, and biological processes that contribute to soil productivity and agricultural sustainability. Managed tillage practices improve soil aggregation that contributes to the improvement of nutrient and water flows in the soil. Tillage increases soil fertility through mineralization of soil nutrients and creates a good soil tilt for root and crop growth (Oicha and Klik, 2009).

In central Tanzania smallholder farmers have for many years been using the hand hoe for tilling, weeding and all other field cultivation practices (Majule *et al.,* 2007a; Kumwenda, 2009). Due to the

nature of this implement and the power required, farmers are not able to plough deep enough and consequently a hard pan has been a key feature in their farmlands. During the rainy season, especially at the beginning of the season the pan prevents water from rapidly sinking into the ground. As a result there is excessive soil and nutrition erosion caused by runoff. Continuous misuse of tillage implements or improper tillage practices is one of the main causes of soil degradation in agricultural lands (Swai and Rwehumbiza, 1998; Gwambene, 2007; Majule *et al.,* 2007b; Kumwenda, 2009). Such factor call for improved tillage practices to managed soil and water resources and breaks the pan to enable rain water permeation into the soil easily. This can be best done by smallholder farmers through the use of power tiller, spring jembe (narrow and long deep tillage tool made from motor vehicle spring attached to a handle which is similar to that of the ordinary hand hoe) and magoye ripper (an oxen drawn tillage implement tool originated from Zambia) that has shown a success in rainwater harvest.

Rainfall fluctuation, increased frequency of abnormal climate related events are the main problems currently facing smallholder farmers with their tillage, soil and water conservation (Swai and Rwehumbiza, 1998; Gwambene, 2007; Kumwenda, 2009). Such factors have increased vulnerability to agricultural production and food insecurity among the small holder farmers. To increasing household food security in semi-arid zone of central Tanzania need to development and adoption the improved tillage methods that could optimize crop production. It is the aim of this study therefore to investigate the impact of tillage practices on agricultural production and greatly boost farm yields and ensure the long term viability of the natural environment, upon which agriculture depends.

Materials and methods

Study Area

This study is part of the action research project that developed experiment of different tillage treatment and crops in four sites of less favoured areas in central Tanzania. The experiment started at the same time in each experimental project site. The sites are Laikala (Kongwa District), Chibelela (Dodoma Manicipal), Sanjaranda (Manyoni District) and Maluga (Ilamba District). These are drought prone areas of Central Tanzania where tillage implements were initiated for cropping seasons of 2008/2009. The tillage practices used in learning plots were slashing and burn, deep tillage, ripping tillage, tie ridging and flat cultivation. Implements used include: magoye ripper, spring jembe, ox-ridger and ordinary hand hoe. Slash and burning is traditional tillage method predominantly practiced by majority of farmers in central Tanzania.

The selected sites are found within the less favoured area that stricken by drought regularly and characterized by long dry spell and short wet season which fall between December and April. The study was conducted in places where a village action groups are working actively with issues of farming. The aim was to identify appropriate tillage practices on soil and water management strategies that will assist smallholder farmers to improve household food security, increase productivity and adapt to climate change and variability impacts in drought prone areas of central Tanzania. The study assessed farmers' perceptions on tillage practices and the effects of tillage practices on sorghum performance which involved conducting leaning visit and the use of data from experimental treatments.

Methods

This study assessed the contribution of tillage practices on adaptation to climate change and variability and evaluated the performance of sorghum (Macia variety) under different tillage practices and implements in semi-arid of central Tanzania. The study employed a survey method that involved interview with focus groups, key informants and data collection from experimental plot.

Leaning Visit

A field study was conducted in all project sites to investigate the performance of experimental plots and have a perception of farmers on the performance of experimental plots. The main target was to explore the attitudes, activities and tillage practices that build and sustain the ability of farmers and farming communities to cope with /adapt to on-going climate change and use the opportunities that offered by changes and thereby improve agricultural production. The study employed focus group discussion and target group interview to collect information on perception and attitudes on performance of different tillage practices and implements.

Experimental Design and Treatments

Experiment was laid out in Randomized Complete Block Design (RCBD). Each farmer's group participated in preparation and management of learning plots with different replication. Each farmer's group had one complete set of tillage treatments. A plot size of 10m by 8m was used. Sorghum was planted at spacing of 0.8m between rows and 0.3m within rows. Alongside promoting conservation tillage, the study also stressed on the adoption of early maturing and drought tolerant variety. In this regard Macia sorghum variety was used. Four tillage treatments were involved, these included the followings:

Treatment 1: Slash and burn (SB): Slash and burn is a traditional tillage practice locally known as "kuberega". It is practiced by majority farmers with limited resource in central regions of Tanzania. Primarily it involves slashing of standing vegetation and burning of crop residues ready for planting using hand hoe before onset rainfall.

Treatment 2: Flat cultivation (FC): This involved the use ox-plough drawn tillage implement during land preparation. This process create semi flat seedbed.

Treatment 3: Tie ridging (TR): This treatment involved the use of ox-ridger drawn tillage implement during land preparation to create ridges on cropland and crops were sown on ridges.

Treatment 4: Ripping tillage (RT) and deep tillage (DT): Treatment Four involved the use of Magoye ripper, spring jembe and power tiller drawn tillage implement which in turn created series of well pronounced furrows on cropland. Due to access to power tiller only one village (Maluga village) managed to use it as a treatment and abandoned the no tillage or *kubelega* practices.

On-Site Training on the Use of Tillage Implements

Multidisciplinary team which composed of researchers, personnel from Agriculture and livestock Office and farmers groups were trained and demonstrated the use of various tillage implements in the study areas. This training was open to all participating and non participating farmers. Farmers were trained on the use of all tillage implements and their importance. Farmers also were trained on afforded with standard formula used for fabricating yokes for ploughing, weeding, proper crop spacing and thinning. Farmers were also advised on early planting whenever it is projected that there will be less soil moisture for crop growth. At harvesting all participating farmers harvested the plots, thresh, winnow and weigh using sensitive balance and compare the yields resulted from different plots with different tillage methods.

Results and discussion

Farmers' perception on adaptation

Basing on survey information, all of the farmers interviewed indicated that seasonal climate forecasts were currently less useful than weather forecasts for most of their farm management decisions. Typically, farmers spoke more about weather than climate as being an issue they concern themselves with on a more frequent basis. Overall, the majority of the farmers interviewed said they did not find

seasonal climate forecasts useful on a regular basis due to their inaccuracy. They reported the fluctuation in rainfall seasons that may not arrive until late in the season or arrive very early and then quickly cut-off that dramatically affects farming practices and production. The same situations were reported by other studies on adaptation to climate change and variability (Gwambene, 2007, Majule *et al.,* 2007a, Lema and Majule, 2009).

Over dependency on rain-fed agricultural production of small holder farmers has increased vulnerability to reduce their crops production. Farmers reported a drought of crops, which are at maturity stage before harvesting and sometimes failed to grow their crops after field cultivation as a result of rainfall fluctuation in the area. They perceive that the viable option for them to adapt to changing climate is to modify the production environment. Such modifications have to do with specific crops and varieties produced, timing of their production-related activities as well as the use of proper tillage practices that conserve soil moisture and water.

Farmers' perception and observation on tillage practices

In gathering farmer's/farmers' perception on tillage practices extensive participatory methods and tools including observation, focused group discussion, interviewing of individual farmers (participating farmers and non participating farmers) through field visits were employed. The perception on and observed performance of each tillage implement in time used for cultivation, crop establishment and crop performances are shown in Table 1.

Table 1. Farmers' perception on conservation tillage methods and tillage implements.

Parameter	Tillage Methods	Tillage implement used	Ranking
	Ability to till the land prior onset of rainy season	Crop establishment/crop emergence	Crop Performance
SB (Hand hoe)	3	5	5
FC (Ox-plough)	2	4	4
TR (Ox-Ridger)	4	3	3
RT (Magoye ripper)	1	2	2
DT (Spring Jembe)	5	1	1

Basing on focus group discussion drought and tillage practices used in past; for instance the slash and burning does not allow some biomass to be left on the fields. Therefore the soil has very little nutrients and soil micro and macro organisms. For them conservation of soil moisture and water resources is an important element in agriculture production. It was reported that the new tillage practices especially TR, RT & DT has shown a positive impacts on soil moisture management, hence increased crop production under fluctuating rainfall. Other studies also suggested the use of proper tillage method that has ability to conserve and utilize all available water for production in areas where rainfall is barely adequate (Swai, *et al.,* 2007; Kumwenda, 2009, Oicha and Klik 2009).

Effect of tillage practices on grain yield

Tillage methods have great impacts on soil management and crop production. Good tillage practices can facilitate management of soil moisture, improve infiltration capacity, and other chemical processes in soil. Improvement in soil moisture and nutrient flows can increase production and reduce vulnerability of losing crops under fluctuating and erratic rainfall. In testing tillage practices on soil moisture management, improved Sorghum variety Macia was used. Four tillage methods under different tillage implements were used and evaluated on their performance as indicated in Figure 1. Deep tillage (DT), Ripping tillage (RT) and tie ridging (TR) have shown good performance followed by flat cultivation (FC) and the last one was a Slash and burn method (SB). The results were evaluated under different tillage implements that include the use of racking or hand hoe, mould board plough, spring jembe, ox-rigger and Magoye Ripper (Figure 1).

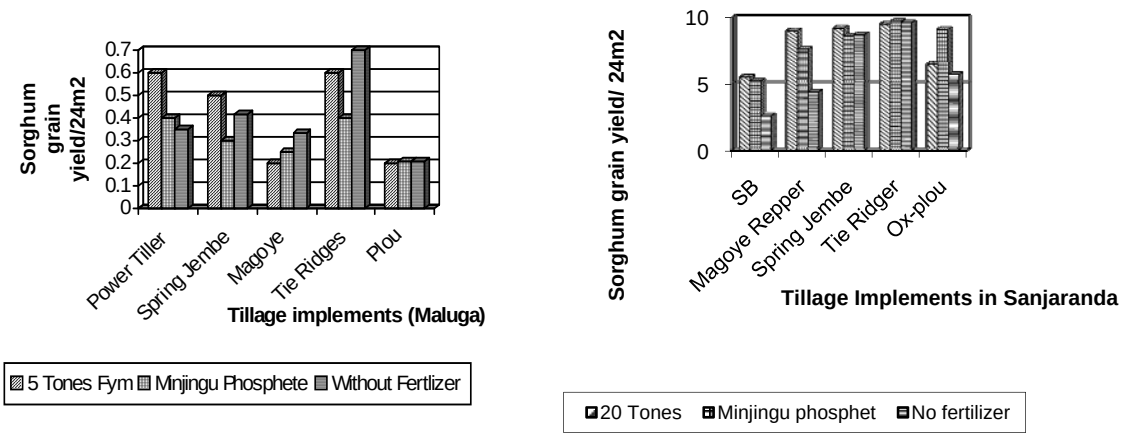

Figure1. Sorghum grain yield under different tillage implements and fertilizers use in learning plots harvest at Maluga and Sanjaranda villages.

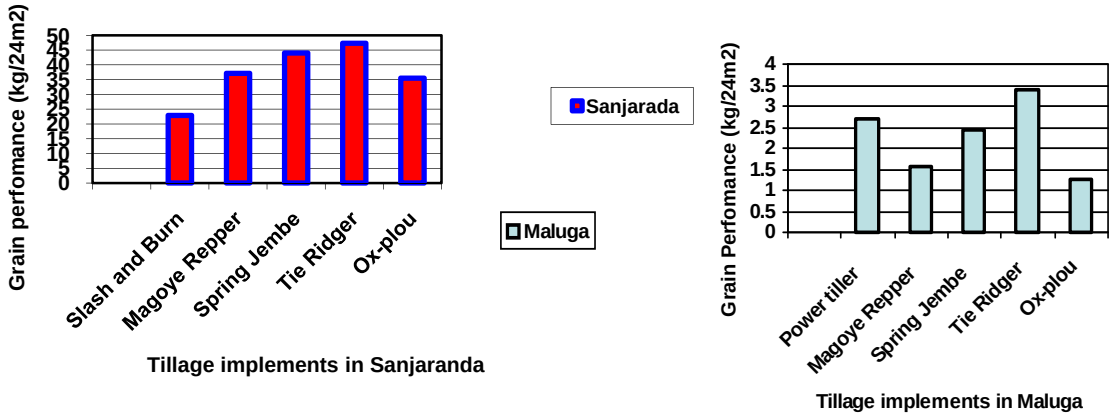

Figure 2. Sorghum grains performance under difference tillage practices in Sanjaranda and Maluga villages.

Average sorghum grain yield across locations varied from one tillage treatment to the other. Consistently, ripping and deep tillage treatment gave the highest sorghum grain yield across locations while SB treatment had significantly lowest grain yield compared to other treatments across seasons. Among the reasons for poor performance of SB practices is the shallow tillage by using hand hoe for tilling and weeding activities. This practice result in formation of hard pan in the fields and thus influencing infiltration capacity and nutrient flows in the soil (Kumwenda, 2009). Under SB practices farmers are unable to plough deep enough due to the nature of implement and the power required, as a result during the rainy season, especially at the beginning of the season the pan prevents water from sinking into the ground. Eventually there is excessive soil and nutrition erosion caused by runoff; and low soil moisture due to low infiltration capacity.

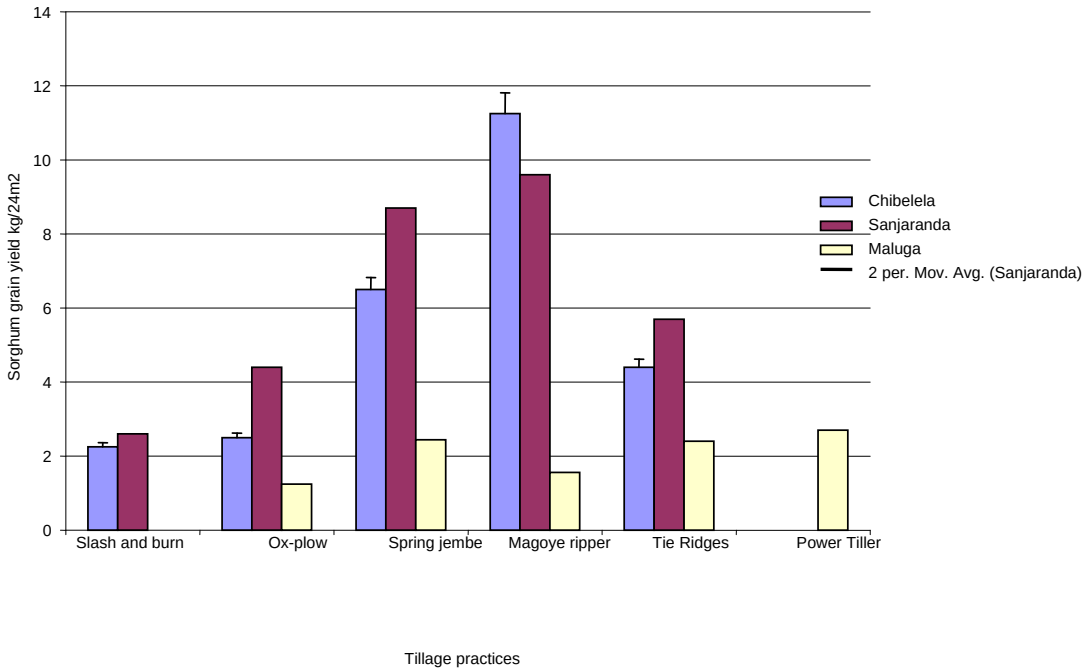

Figure 3. Effect of tillage methods on sorghum grain yields in Chibelela, Sanjaranda and Maluga villages of central Tanzania.

Conclusions and recommendation

The use of different tillage practices has different impact on crop performance and yields in small holder farmers or subsistence farming. They contribute and greatly impact on soil moisture, nutrient flows and water infiltration capacity in the farm fields which are crucial components for crop production. The use of tilling methods under proper tilling implements such as Magoye ripper, Spring Jembe and Power tiller has ability to retain moisture in the soils for every single rain drop available. The retained water helps to improve soil moisture that is of paramount important in crop production and improvement of food security in semi-arid areas of Tanzania. .

Concerted efforts for promoting improved tillage methods and implements which retain/ conserve soil moisture and water such as use of ripping, tie ridge and tilling implements are immensely important in order to optimize crop production in small farming communities. Such method will increase production and adaptability capacity to fluctuating rainfall for farmers through utilization of few rainfall drops within their locality.

References

Gwambene, B. (2007) Climate Change and Variability Adaptation Strategies and its Implication on Land Resources in Rungwe District, Tanzania. MSc. Dissertation, IRA, University of Dar es Salaam.

Kumwenda W.F. (2009) The role of animal traction in soil and water conservation tillage practices among smallholder farmers in Malawi. http://www.fao.org/ag/ags/AGSe/agse_s/3ero/Namibia1/c9.htm accessed on 27/11/2009.

Lema A. M and A.E. Majule (2009) Impacts of climate change, variability and adaptation trategies on agriculture in semi arid areas of Tanzania: The case of Manyoni District in Singida Region, Tanzania. *African Journal of Environmental Science and Technology* 3(8): 206-218.

Majule, A.E., Gibson, R and A. Chiwatakwenda (2007a) Climate Change Adaptations in Low Potential Area of Tanzania: Local perceptions, vulnerability, current adaptations and in future strategies in Maluga Village, Iramba, Singida. CCAA-Tanzania, Malawi Working Paper No. 1.

Majule, A.E., Gibson, R. and A. Chiwatakwenda (2007b) Climate Change Adaptations in Low Potential Area of Tanzania: Local perceptions, vulnerability, current adaptations and in future strategies in Sanjaranda Village, Manyoni, Singida. CCAA-Tanzania, Malawi Working Paper No. 2.

Oicha, T. and A. Klik (2009) Impact of tillage practices on dry soil aggregate distribution in different soil types in Austria. Conference on International Research on Food Security, University of Hamburg, October 6-8, 2009: Institute of Hydraulics and Rural Water Management, University of Natural Resources and Applied Life Sciences Vienna, Muthgasse 18, A-1190, Vienna Austria available at http://www.tropentag.de/abstracts/full/739.pdf

Swai, E.Y, Rwehumbiza, F and H. Chambo (2007) Effect of residual tie ridging on soil hydrological properties and crop performance in Central semi-arid Areas of Tanzania. In: 2nd Scientific Symposium on Opportunity for increasing Water Use Efficiency in agriculture in semi-Arid and Arid areas of SADC Region., 20 -22 February 2007. The Grand Palm Hotel, Gaborone, Botswana. Pp 325 – 336.

Swai, E.Y and F. Rwehumbiza (1998) Residual effects of tie ridging on soil water storage in Central Regions of Tanzania. In: *Proceeding of Tanzania Society of Agricultural Engineers* 8: 7-19.