Research Application Summary

Improving water storage in soils to enhance nutrient use efficiency and crop yields for enhanced livelihoods of small scale farmers in semi-arid eastern Kenya

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Abstract

The current food situation in Kenya is alarming so that food is extremely expensive for the larger Kenyan population. This is largely due to the frequent droughts in the country and especially because more than 80% of the land is arid to semi-arid. There is therefore urgent need to put into practice existing technologies to spur food production in the semi-arid fragile ecosystems. This study is investigating the effect of trapezoidal bund technology and use of manure on soil moisture storage and retention, impact of soil moisture on nutrient availability and nutrient use efficiency by crops, nutrient dynamic changes in soil and effect on crop yields and long-term soil fertility maintenance. The study also aims to quantify microbial biomass and nitrogen mineralisation potentials in soils. The project is in progress at Katumani, Dryland Research Station in Machakos. Trapezoidal bunds for run-off water collection and storage have been constructed according to the recommended pattern. Plots measuring 4.5 m× 4.5 m will be used for the treatments where maize (var.SC Duma 43) and common beans are the test crops, and manure and NP fertilisers as source of plant nutrients. Three levels of both manure and NP fertilisers 0, 5 and10 tons/ha manure and 0,50 and 75 kg/ha of each N ad P fertilisers) will be used. Treatments will be factorial and randomised in a complete block. Soil moisture content will be measured by a gravimetric method. Simulation models for nutrient dynamics and crop performance will be done using CMKEN and NCSOIL models. Data will be subjected to analysis of variance and regression. Nutrient use efficiency and gross returns will be calculated.

Key words: Nutrient use efficiency, run-off water collection, simulation models, soil moisture storage, Trapezoidal bunds

Résumé

La situation alimentaire actuelle au Kenya est alarmante de sorte que la nourriture est devenue extrêmement chère pour la plus grande population kenyane. Ceci est largement dû aux fréquentes sécheresses dans le pays et surtout parce que plus de 80% des terres sont arides ou semi-arides. Il est donc urgent de mettre en pratique les technologies existantes pour stimuler la production alimentaire dans les écosystèmes semi-arides fragiles. Cette étude examine l'effet de la technologie des digues en forme de trapèze et l'utilisation du fumier pour le stockage et la rétention d'humidité du sol, l'impact de l'humidité du sol sur la disponibilité des nutriments et l'efficacité d'utilisation des nutriments par les plantes, les changements dynamiques des éléments nutritifs dans le sol et l'effet sur les rendements des cultures et le maintien à long terme de la fertilité des sols. L'étude vise également à quantifier la biomasse microbienne et les potentiels de minéralisation de l'azote dans les sols. Le projet est en cours à Katumani, la Station de Recherche des Zones Arides à Machakos. Les digues trapézoïdales pour la collecte des eaux de ruissellement et leur stockage ont été construites selon le modèle recommandé. Les parcelles mesurant 4,5 m × 4,5 m seront utilisées pour les traitements là où le maïs (var.SC Douma 43) et les haricots communs sont les cultures d'essai, et le fumier et les engrais NP en tant que source d'éléments nutritifs. Trois niveaux de fumier et d'engrais NP (0, 5 et 10 tonnes / ha de fumier et 0, 50 et 75 kg / ha de chacun des engrais N et P) seront utilisés. Les traitements seront factoriels et randomisés dans un bloc complet. La teneur en humidité du sol sera mesurée par une méthode gravimétrique. Les modèles de simulation pour la dynamique des nutriments et la performance des cultures seront réalisés en utilisant les modèles CMKEN et NCSOIL. Les données seront soumises à une analyse de la variance et de la régression. L'efficacité d'utilisation des nutriments et le rendement brut seront calculés.

Mots clés: Efficacité d'utilisation des nutriments, collecte des eaux de ruissellement, modèles de simulation, stockage de l'humidité du sol, digues trapézoïdales

Background

Food production in Kenya has been declining for the last three decades (FAO, 2002). Similar trends are being experienced in other developing countries. The situation is worsening due the current worldwide shortage of grain and the sharp increases in food prices in the recent years. Consequently, the basic nutritional needs of the large populations in poor countries are not met. This is particularly critical in ecologically unstable semi arid lands

with greater constraints to food production. In this region, efforts to achieve food security, reduce poverty and improve people's livelihoods have been slowed due to biophysical constraints including low and erratic rainfall, low soil fertility and low use of organic matter and mineral fertilisers (Giller *et al*., 1997). The problem of food insecurity is further exacerbated by the effects of climate change and socio-economic situations inherent with small scale farmers who produce most of the staple foods.

The long term effects of improved soil fertility interventions under rain water harvesting (RWH) structures that incorporate cereal-legume intercropping, organic manure and inorganic fertiliser interactions on the dynamic properties of the soil have not been documented. There is need for better understanding of the dynamic soil processes arising from cropping patterns, manure and fertiliser amendment, and improved water storage in the trapezoidal bund structures to enable optimise their use and lead to better prediction of crop yields. This information is required also for the development of computer simulation using NCSOIL and CMKEN models.

Literature Summary

Recent research to improve food production in dry-lands and to reduce poverty has concentrated on the development of new strategies that enhance soil and water management through conservation tillage; rain water harvesting (RWH); micro-management of soil fertility through manuring, composting, mulching; and production of high value market crops such as horticulture and maize under irrigation where the potential exists (Ekaya, 2007; Ngigi, 2001; Prinz, 1994). Although the problem of rain water lost as runoff in a semi arid environment is critical, it can be more easily corrected than the long term effects of depleted soil fertility. In semi-arid Israel, Igbadun *et al*. (2008) demonstrated under irrigated maize that extending moisture availability in the maize root zone at critical growth stages by just one week can improve cereal maize yield by up to 20% .This indicates that under improved moisture conditions of a crop, yields are improved through increased nutrient use efficiency.

Use of manure is necessary for increasing the level of organic matter in the soil and improving moisture retention and its availability for crop yield (Mochoge *et al*., 1997; Lampkin, 1992). In some trials that have been carried out in Kenya, increased maize yields of 40-80% have been reported

(Mochoge *et al.*,1997). Maintenance of soil organic carbon (SOC) is considered essential for sustainable soil productivity since declining levels generally lead to declining crop productivity (Allison, 1973). SOC is an index of soil quality that influences soil physical properties positively (Lal *et al.*, 1977) by improving soil aggregate stability, bulk density, and water retention. Further, manure incorporation is important in maintaining soil health indices such as C/N ratio, soil microbial biomass and soil fertility (Danga *et al*. 2009, Pandey *et al*.2009).

Study Description

This study involves both field and laboratory experiments and is being done by two MSc. students as part of their studies. Field experiments are being carried out in a semi-arid part of Kenya, at Katumani, Machakos County. The site represents the low midlands, agro-ecological zone LM3. The study is investigating the effectiveness of trapezoidal bunds on run-off water collection and subsequent water storage in soil for plant use, nutrient use efficiency and crop yields, and bio-chemical dynamics changes taking place in soils. Trapezoidal bunds (TBs) have been constructed on a slope of 2-3 % and are being used to collect and store surface runoff in soil. The plots of the experiment have been laid and all the treatments are carried out within the bunds. A control experiment with all the treatments but without trapezoidal bunds has also been included. The test crops are maize (Duma 43 var.) and common beans. Beans are intercropped with maize. Treatments are at three levels of manure (0, 5 and10 tons/ha) and three levels of NP fertilisers for each nutrient (0, 50 and75 kg/ha). Fertilisers and manure are applied only to maize while beans intercrop are to benefit from fertiliser applied to maize. This study will be done for 2 seasons. Plots measuring 4.5m x 4.5m will be used and these plots are within and outside the bunds. Maize will be planted at 0.75 m x 0.6 m with 2 plants per hill. Beans will be planted between the maize rows at spacing of 0.20 m immediately after maize first weeding. Daily rainfall amount will be measured with standard, non-recording rain gauge installed in the experimental sites. Soil sampling for soil properties characterisation is to be done at the start and end of the experiment from 0-60cm soil profile while soil samples for dynamic soil property changes are to be sampled from 0-20 and 20-40 cm depths. Grain yield data will be determined at 12.5% moisture content. Treatments will be arranged in a factorial arrangement and randomised in a complete block design with three replicates. Data will be subjected to analysis of variance using the general linear model of SAS. Treatment

differences will be examined using Tukey-Kramer significant difference (HSD) test. Regression and correlation analyses between various variables will be done to show different interactions.

For soil nitrogen mineralisation studies, soils have been sampled from 0-20cm depth within one square metre area in the experimental site, carried to the laboratory in polythene bags and in cool boxes to slow down bio-chemical soil changes and prevent soil moisture losses. The soil samples are being incubated in the lab for 90 days (reflecting the effective growing seasonal period in the agro-ecological zone). Mineralisation rates of N in soil organic matter under controlled moisture and temperature conditions will be monitored. Sampling of available N (NH_4 and NO_3) will be done at 0, 30, 60 and 90 days of incubation period. pH-H_2O will also be monitored in the incubated soils. The results of incubation, that is NH_4-N, and NO_3-N production will be used for model NCSOIL to compute optimal amount of the organic content that ensures efficient production and utilisation of soil nitrogen, and to predict rates of C and N mineralisation.

Research Application

This research is expected to better peoples' incomes, livelihoods and increase food security in the semi arid regions through improved crop yields. Trapezoidal bunds are expected to enhance run-off collection and water storage in soils together with use of manure and inorganic fertilisers manure application for crop production. The study is also expected to contribute to the knowledge and importance of trapezoidal bund technology use on food production to farmers and researchers. The research is also expected to increase capacity through the trained students at MSc. level.

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