CHARACTERIZATION OF SMALLHOLDER FARM TYPOLOGIES IN MAIZE-BASED CROPPING SYSTEMS OF CENTRAL KENYA: USE OF LOCAL AND TECHNICAL SOIL QUALITY INDICATORS

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Abstract

In recent years, integrated soil fertility management (ISFM) paradigm has emerged as the best strategy for different resource-poor smallholders to mitigate problems of food insecurity and poverty. This makes characterisation and evaluation of ISFM technologies under different socio-economic and biophysical farmers' circumstances imperative. The study examined how local and technical soil quality indicators (LSQI and TSQI) could be used to delineate farmers in maize-based cropping systems of central Kenya into different inter-farm recommendation domains. Depending on levels of organic and inorganic fertilizers, soil conservation structures and depth of tillage, 3 classes of farmer were identified, based on local soil quality indicators. Analysis of variance (ANOVA) was employed to validate LSQI- and TSQI-based classification. Results depicted significant ($P<0.05$) differences in mean % Carbon, % Nitrogen and ppm Phosphorous within and between different classes. Carbon ranged from 1.4% in Kirinyaga to 2.1% in Maragwa, while Nitrogen ranged from 0.06-0.17% in two districts respectively. Kirinyaga had highest Phosphorous levels (649 ppm) while Maragwa had the lowest (45 ppm). This could help develop more targeted ISFM technologies to suit different recommendation domains, for more productivity in smallholder agro-ecosystems.

Keywords: Integrated Soil Fertility Management (ISFM), Nutrient Depletion, Food Security, Local and Technical Soil Quality Indicators (LSQI and TSQI), Recommendation Domains

Introduction

Agriculture in sub-Saharan Africa is in dire need of transformation if it has to stem deepening rural poverty, food insecurity and environmental degradation. A cereal grain production increase of 1 percent in many African countries is far below the population growth rates of 3 percent (Kimani *et al*., 2003). The per capita food production has fallen in last the 40 years and soil fertility management is now in a crisis. Regrettably, this is taking place in high potential areas best suited to intensive production systems and where highest population densities live, as well as in the marginal areas. Despite investment of considerable time and efforts in development of technologies, soil fertility degradation continues to be an intransigent problem in most smallholder cropping systems. Most technology packages have neglected economic aspects, leading to low adoption of soil management technologies, as their returns do not commensurate with costs of investments.

Soils can be classified into good or bad, productive or exhausted depending on their productive potential or quality. Soil's quality is defined as "capacity of soil to function within its ecosystem boundaries to sustain biological productivity and diversity, maintain environmental quality and promote plant and animal health" (Brady and Weil, 2002). Soil's quality therefore depends on its physical, chemical and biological processes that occur in soil ecosystem. Such includes leaching of nutrients, soil erosion, decomposition and mineralization of soil organic matter, and subsequent release of plant nutrients. While it may take considerable time and resources to measure rates of these processes directly, measurement of specific soil properties could serve as indicators of rates of these processes, the so-called soil quality indicators (SQI). These indicators can be classified into temporal or permanent depending on their permanence and sensitivity to management levels. The former types of indicators are management-dependent while the latter is more dependent on inherent soil profile and is little affected by day-to-day management practices. Temporal indicators includes water contents (WC) and soil PH, mineral nitrogen (N) and active carbon (C), available phosphorous (P) and potassium (K), and bulk density (BD) and soil organic matter (SOM).

Previously, in cash crop economy technical and short-term economic viability were the main driving forces behind most cropping systems. Farmers' co-operatives gave farm inputs to farmers leading to extensive use of mineral fertilizers both in cash and subsistence crops. However, over the last two decades there has been widespread collapse of co-operative movement in Kenya leading to woefully low usage of fertilizers. Different smallholders have different resource endowment and therefore most resource-poor farmers have been unable to afford current blanket fertilizer recommendations. Consequently, soils in smallholders' agro-ecosystems have been degraded due to continuous use with little or no nutrient replenishment. While economic consideration will continue to be the overriding factor, there is a growing need for ecological considerations in all our cropping systems. This presents enormous challenges to current cropping systems, to satisfy ever-increasing demand for food for a spiraling population without degrading natural resource base (NRB). To help understand and reverse present degradation of environment and to safeguard its productivity for future generations, there is need for a close correlation between local soil quality indicators (LSQI) and technical soil quality indicators (TSQI).

The main objective of study was use of Technical Soil Quality Indicators (TSQI) to validate smallholder farm characterization based on Local Soil Quality Indicators (LSQI) in maize-based cropping systems in Maragwa and Kirinyaga Districts in central Kenya.

Materials and methods

Study Sites

The study was carried out in Maragwa and Kirinyaga districts of central Kenya. The Maragwa site at Kariti, Kandara division is a previous fertilizer use recommendation project (FURP) site, which generated agroecological-specific, blanket fertilizer use recommendations for Muranga district. Maragwa District covers about 1065 km^2 and lies at 1100-2950 m (Jaetzold and Schmidt, 1983). It has a population of 409,000 persons with a population density of 488 persons per square kilometre. Average annual rainfall is 1300-1600 mm per annum with mean annual temperatures of 19.7-18.0^oC. The rainfall regime is bimodal with long rains falling in March to May while short rains come in October to November. Kirinyaga district is on the southern slopes of Mt. Kenya and its size is 1437 km^2. It has a population of 457,105 persons and a population density of 309 persons per square kilometre. Average annual rainfall of Mukanduini site is 1100-1250 mm p.a. with mean annual temperatures of 20.1-20.6^oC.

The study districts are representative enough of entire central Kenyan Highlands in many aspects. Population densities are high and land fragmentation is prevalent. The districts are sub-humid with large stretches of upper midland zones (UM). The predominant soil types are deep, well-drained, humic Nitisols with moderate to low inherent fertility. Nutrient depletion is widespread due to continuous cropping with little nutrient replenishment. The average farm size is 0.9 hectares, where the common enterprises mix is made up of maize-bean intercrop, tomatoes, coffee, bananas and dairy.

Participatory Learning and Action Research (PLAR) exercise which helps communities mobilize their human and natural resources in order to define their problems, consider previous successes, evaluate local institutional capacities and prioritise opportunities as well plan for a systematic site-specific plan of action. (Theis and Grady, 1991; Defoer *et al.*, 2000), was carried out in January and February 2003. During the exercise, different Local soil quality indicators (LSQI) were identified and ranked as indices of soil fertility. Such included: stunted crops, yellowing of leaves, poor yields. Presence of certain weeds (poverty grass (*Gaita-ime*), ferns (*Ruthiru*), *Wambui mwikuithia)* and absence of others (Wandering jew, *Amaranthus*, Black jack, *Galinsoga parviflora*) told same story. Other LSQI included soil colour, texture, structure and depth.

To diagnose different physical and chemical properties of soils, 30 samples from sampled farms in different farm typologies were taken at 0-20 cm. In order to evaluate within-farm soil fertility gradients, soil sampling was also done from good, average and poor portions of each farm as perceived by farmers themselves. Soil analysis was carried out using standard procedures to test for TSQI (Anderson and Ingram, 1993; Okalebo, 2002). Samples were air-dried, crushed and passed through a 2 mm sieve. Organic Carbon (C) was analysed by wet oxidation with acidified dichromate, total Nitrogen (N) by Kjeldhal oxidation method while available Phosphorous (P) by Bray 2 method, and Potassium (K), Calcium (Ca), Sodium (Na), and Magnesium (Mg), were analysed from the digest by flame photometry and atomic absorption methods. Analysis of variance (ANOVA) was done on soil test data using statistical analysis system (SAS) computer software. This was to test inter- and within-farm variability in farmers' soil fertility management as identified during PLAR exercise in study sites.

Results and discussion

Local and technical soil quality indicators

Soil tests results (TSQI) were used to statistically validate PLAR classification, as these would reflect levels of nutrients applied by different farmers thus confirming or rejecting PLAR's classification. Soil characteristics for different classes in both sites are presented in Table 1. Results indicated significant differences in some technical soil quality indicators (TSQI) between classes and within different portions of same farms. However, some TSQI did not show such significant differences. TSQI with significant differences and which were used to verify PLAR classification included:

Percent carbon

In Kariti, results show that there is no significant ($P<0.05$) difference in mean percent Carbon in soil samples taken from the same class. However, there were significant differences in percent Carbon contents between different classes. This was observed between classes I, and III and between classes II and III. The highest percent Carbon (2.1%) was recorded in class II while the lowest (1.8%) was recorded in class III. However, no significant difference was recorded in mean percent Carbon between classes II and I. This is in agreement with classification done during PLAR using local soil quality indicators (LSQI). Class I farmers use more of inorganic than organic fertilizers, therefore their soils have lower levels of percent Carbon than class II. Class III uses least of inorganic and organic fertilizers than classes II and I. Class II farmers strike a balance between organic and inorganic fartilizers. Organic fertlizer materials supply all soil Carbon and therefore those farmers who use more of it, their soils contain more carbon than others.

In Mukanduini, there was no significant difference in mean percent Carbon between and within classes. Highest percent Carbon (1.6%) was recorded in class I while the lowest was in class III (1.4%). Farmers in Mukanduini have relatively larger farm sizes and fewer animals than their counterparts in Kariti. Carbon, the foundation of all forms of life, is contained in all plants and animals. Soil organic matter (SOM) contains Carbon and mineralizable Nitrogen in different proportions. Animal manure is the most common organic material used by farmers, but Mukanduini animals are grazed rather being confined therefore losing most of animal manure. Therefore they end up applying less organic fertilizer materials than those in Kariti.

Percent nitrogen

Analysis of soil test data indicated that there was significant difference in mean percent Nitrogen between different classes in both study sites. However, there was no significant difference in percent Nitrogen contents between different portions of the same farm. In Kariti, there was significant ($P<0.05$) difference in mean percent Nitrogen between classes III and I and classes II and I but not between classes III and II. However, there was no significant difference in percent Nitrogen within classes. This is reflective of SFM practices identified during PLAR that farmers use higher levels of inorganic fertilizers in class I than in classes II and III. Class II farmers use more of organic and less of inorganic fertilizer materials than class I. Percent Nitrogen was lowest in Class III reflecting lowest usage of organic and inorganic fertilizers. These results tend to confirm earlier classification of smallholder farm typologies using local soil quality indicators (LSQI). However in Mukanduini, there was no significant ($P<0.05$) difference in mean percent Nitrogen within and between classes.

Phosphorous

Mean Phosphorous contents in parts per million (ppm) showed significant differences between classes in both sites. In Kariti, there was significant ($P< 0.05$) different in Phosphorous contents between classes I and III, and classes II and III but not between classes II and I. In Mukanduini, it was between classes I and III, classes I and II but not II and III. However there were no significant differences in mean Phosphorous (ppm) within classes in both sites. An enormous difference in mean Phosphorous contents between the two sites was depicted by soil analysis data. According to some farm surveys done in the area, farmers in Mukanduini uses huge amounts of compound fertilizers in tomatoes leading to such astounding figures. The mean Phosphorous contents ranged between 441 and 649 ppm while that of Kariti is only 64-101 ppm. All the foregoing confirms classification of farmers that was done using local soil quality indicators (LSQI).

Conclusion and recommendations

The study results could be used in the following ways

1. Soil analysis data provided indices that served as technical soil quality indicators (TSQI) that helped to correlate measured soil parameters with different SFM-based ranking done using LSQI. TSQI reflected soil's ability to supply required nutrients and hence its production potential. This gives all stakeholders a better understanding of interactions between farmer inter- and within class variables. This will be useful in better targeting management options for soil amelioration in different farm typologies and parts of same farms.
2. Once characterisation of farmers based on their soil fertility status both at watershed has been accomplished, experimentation and evaluation of alternative SFM technologies should commence. This would create way for packaging of practical technologies that are appropriate to particular farmers' circumstances for efficient use of resources. This would lead to enhanced food security, income and smallholders' welfare.

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