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Editorial: Sustainable soil fertility practices for smallholder farmers

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Editorial on the Research Topic
Sustainable soil fertility practices for smallholder farmers

Introduction of improved farming technologies to the resource constrained farmers was meant to increase the agricultural output by use of improved and high-yielding farming systems. These smallholder farmers contribute significantly toward food security in the developing countries, so their production methods and output are of concern to food security. However, these newly introduced technologies are high input systems and do not sync with the majority of smallholder farmers in the developing countries. Hence, productivity is still low among smallholder farmers due to the high financial investment per season required for these improved technologies. One of these technologies that smallholder farmers have adopted is the use of synthetic fertilizers, that mainly feeds the crop whilst not feeding the soil, which has driven soil degradation among the smallholder farmers. Furthermore, most of these smallholder farmers use these fertilizers at sub-optimal levels, which has further driven nutrient mining. Therefore, this Research Topic focused on compiling current research on sustainable soil fertility management practices and technologies that are applicable to resource poor smallholder farming systems. Published articles from this topic can be grouped into four sub-themes as follows:

Conservation agriculture

Conservation agriculture (CA) is one of the affordable soil fertility management practices among the smallholder farmers. The CA has offered numerous socio-economic and environmental benefits to the smallholder farmers. Climate change is real and leading to low productivity through recurrence of droughts and shifting of planting dates to mention a few. However, the adoption of CA and climate-smart agriculture (CSA) technologies can be a panacea to the negative impacts of climate change and low fertility among the smallholder farming systems. The CSA technologies have been widely promoted among the smallholder farmers, unfortunately there is marginal adoption or dis-adoption due to wrong designing and implementation of such technologies. In a way to understand causes of the low adoption, Musara et al. assessed the impact of adopting farmer-oriented CSA practices combined with hybrid sorghum variety and partial-organic fertilizer on household income and productivity. A set of farm specific factors such as arable land and off-farm factors were noted to influence the decision to adopt CSA technologies. Therefore, it is essential to design farmer-imitated CSA practices that will be easier to adopt unlike practices generated outside the farmers' context. The end-users (farmers) should be therefore included during the designing phase of the sustainable soil fertility management practices and technologies to allow easy implementation.

The CA is a viable technology for ameliorating the low soil fertility among the smallholder farmers, especially in the developing countries like Zimbabwe, Malawi and South Africa. Chauke et al. explored how no-till and varied P fertilization can be used to improve soil properties. Soils in the smallholder farming systems are usually low in available phosphorus (P) and poor utilization efficiency of applied P which negatively affect crop production. In this regard, Chauke et al. hypothesized that addition of phosphorus, growing of high-yield varieties and suitable cropping systems can enhance crop productivity under dryland conditions. Briefly, two tillage systems [no-till (NT) and conventional tillage (CT)], three varieties, and three phosphorus rates (0, 30, and 60 kg/ha) were evaluated for soybean productivity. The P uptake was increasing with P application rates. The grain yield was high at 30 kg/ha P application under NT but varied with variety. Nevertheless, high availability of soil P lowered the soybean oil content and increased protein content, activities of acid phosphatase (ACP) and alkaline phosphatase (ALP). Conclusively, addition of P fertilizers to appropriately selected crop varieties can improve both quantity and quality of the crop. The smallholder farmers should use no-till with optimum fertilizer application rates so as to maintain ideal soil fertility status at their farms.

The smallholder farmers can change their production model from non-cyclic conventional agriculture to conservation agriculture (CA). However, the change has yield penalties so farmers are reluctant to take the risk. Quantification and of the yield penalties especially at the early transition stage to CA is necessary. Knowing the amount of yield reduction incurred during the conventional to CA transition is crucial for decision making especially in cash crop production. Yemadje et al. studied the combined impact of no tillage (NT) and different fertilizer application rates on cotton agronomic performance in cotton-cereal rotations. This study applied multilocation experimentation in three-different agroclimatic zones. Three different forms of soil preparation (tillage: strip tillage, and no tillage or direct seeding) and four fertilization regimes at these sites were evaluated. Direct seeding reduced below-ground biomass growth and seed cotton yields in an early transition to CA. Yemadje et al. recorded limited yield penalties in the studies cotton-cereal rotations which suggested that if well planned, the transitional phase from the conventional tillage to CA may not be very costly in terms of yield reduction to the smallholder farmers. Therefore, sustainable soil fertility management practices in the context of degraded soils and poor productivity are required among the smallholder farmers. Farmers are willing to change to CA if low yield penalties are reasonable trade-offs especially in the early years of a transition.

Intercropping and productivity

Good agronomic practices are also essential in enhancing soil fertility among the smallholder farmers. In this regard, Dzvene et al. carried a 2-year study to determine effects of intercropping sunn hemp (*Crotalaria juncea* L.) into maize (*Zea mays* L.) at different time and densities on productivity under rainwater harvesting technique. The study had three sunn hemp planting times which were intercropped at different maize growth stages (simultaneous, early and late vegetative). Generally, the growing season conditions were affected by the rainfall distribution. The planting period affected the biomass production of the sunn hemp which was highest when intercropped at early maize vegetative stage. Additionally, Dzvene et al. found that incorporation of sunn hemp at early maize vegetative stage had economic benefits by having a high-income equivalent ratio which translated to income. Inclusion of sunn hemp at early maize vegetative stage was an ideal for the smallholder farmers under rainfed conditions as it increased the economic benefits in a sunn hemp-maize intercrop.

In another study, Ekyaligonza et al. looked at strategies to improve soil health through increasing soil organic matter (SOM). The smallholder farmers can use sustainably cheap and environmentally friendly soil fertility management options e.g., the farmyard manure, cereal-legume intercropping and crop residue mulch cover to increase their agricultural productivity (Ekyaligonza et al.). Regrettably, there is limited information on the economic benefits accrued from these strategies by the smallholder farmers, hence their low adoption. Interestingly in this unique article, Ekyaligonza et al. noted similar accrual of farm revenues and gross margins for synthetic fertilizer plus maize monocrop and from various organic matter management (OMM) strategies. Hence integrating the OMM strategies in smallholder farming systems can increase farm income. The price sensitivity analysis showed that farmers should also include at least two legumes in their cropping rotations so as to achieve high socio-economic benefits.

Inappropriate crop management practices are a common problem causing reduced agricultural productivity among the smallholder farmers. Crop management practices like incorrect planting time, fertilizer application rates, weeding time etc are some of the common malpractices among the smallholder farmers. Awio et al. concluded that improved agronomic management resulted in improved crop yield. According to Awio et al., the farmers who used the recommended agronomic practices (RAP) but were lower-yielding under farmers' practice (FP) got improved yield, compared to both the middle- and top-yielding farmers prior to the adoption of the RAP. This suggests that there will be increased crop productivity among smallholder farmers if they can adopt standard crop management practices.

Sustainable soil fertility amendments

Dryland agriculture is common among the smallholder farming systems unfortunately with low productivity. Mataranyika et al. reviewed how natural existing plant microbe interactions can increase dryland agriculture productivity in the context of Namibian climate and soil profiles. These interactions have some microbes such as bacteria which can promote plant growth and with extensive research can be a potential form of sustainable soil fertility management under the dryland agriculture that also reduces the impact of agriculture on climate change. According to Mataranyika et al. these plants associated bacteria used to develop biofertilizers which are both economically and environmentally sustainable while increasing soil health and crop yield. Besides being biofertilizers, these microbe-plant interactions produce essential biochemicals and enzymes e.g., indole-acetic-acid (IAA) and amino cyclopropane-1-carboxylate deaminase. They can also improve the plant health by actively protecting plants from pathogens e.g., fungal pathogens. Regardless of all these potential benefits, such interactions have not been fully exploited especially under the smallholder farming systems. Low land productivity is another constraint that causes low crop yields in dryland agriculture. In order to avert this situation, Pierre Tovihoudji et al. worked on hill-placement of microdose biochar-compost-based amendments on agronomic and economic performance of cotton in Northern Benin. The biochar-compost-based amendments are carbon-rich hence can sustainably improve soil health by increasing the soil organic carbon (SOC) content. The SOC is proportional correlated soil productivity so the cotton yield was improved by >86% under the biochar-compost-based amendment compared to absolute control without any amendments. The biochar-compost-based amendments also enhanced the cotton economic performance. Measured value Cost Ratio (VCR) and Benefit Cost Ratio (BCR) values under the organic rich soil management practices were better than in mineral fertilized soils. Therefore, use of mineral fertilizers alone as the common practice among smallholder farmers has no economic advantage hence not a sustainable soil fertility management strategy among the resource constrained smallholder farmers.

Soil degradation

Land degradation is one of the major causes of low soil productivity among the smallholder farming systems in the developing countries. Therefore, to achieve a sustainable improvement in soil productivity, protecting cultivated land from any form of degradation is mandatory among the smallholder farmers. Land protection and enhancing its quality should be carefully implemented in order to reduce ecological and environmental pressure which lead to land sustainability. According to Xu et al. it was necessary to know the differences and causes of cultivated land protection behavior (CLPB) between different sets of farmers (i.e., smallholder vs. professional farmers) because this will assist in the formulation of effective targeted protection policies on the management of agricultural lands. This study used survey data obtained from 422 mango farmers in Hainan province, China where internal and external characteristics between the two different sets of farmers were explored. Cultivated land protection behavior between the sets of farmers was different and sources of differences in CLPB between the farmers was also different. Interestingly, the internal characteristics of the farmers had more influence to the cause of the differences in CLPB of the farmers. It is therefore important to design separate land protection policies for the smallholders and professional farmers so as to achieve sustainable land management practices.

Accelerated soil erosion is the worst form of land degradation among the smallholder farming systems. Rates of soil erosion are very high among these smallholder farmers and negatively impact on the soil productivity through loss of soil fertility. Ineffective control of the soil erosion is a persistent problem among the smallholder farmers. In the last published article, Tibassima et al. aimed at re-aligning soil erosion management toward a nature-society-inclusive strategy. The study hypothesized the effective control of soil erosion is increasingly require bridging the mismatch between science, policy, and practice. The issue of soil erosion control goes beyond the understanding it as an assemblage or hybrid of biophysical and anthropogenic facets but also an epistemology that brings the scientists, policymakers and farmers to a common understanding. Tibassima et al. tested a newly proposed hylomorphic (disaster risk management) framework as a sustainable soil erosion management strategy. Briefly, the framework structures the procedure of bridging lived experiences of those at risk with theoretical knowledge so as to co-create knowledge and co-designing options for managing soil erosion. Interesting this study is the first to test the new framework in a case of soil erosion where it confirmed that lived experiences exposes blind spots in understanding the local context of soil erosion. The lived experiences also flatten the ontology-specific epistemology toward a more nature-society-inclusive soil erosion management strategy among the smallholder farming communities.

Hopefully these published articles are going to impact to a wide range of readers with an insight into practical sustainable soil fertility management and technologies among the smallholder farming systems.

Author contributions

CP: manuscript drafting and final write-up. AM, HM, and RM: manuscript review and final write-up. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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