学 位 論 文 要 旨

Soil quality and crop yield improvement potentials: the case of two agroecological zones of Ghana

ガーナの２種の農業生態地域における土壌と作物収量の改良方法の解析

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Ghana's agriculture, though constrained with low soil productivity accounts for an estimated 50% of the country's total employment base. With the dwindling land availability influenced by human population growth, continuous cropping system has become inevitable resulting in degradation of inherently low fertile soils. To identify potential options for soil fertility and crop yield improvement in Ghana, an interdisciplinary-based study, including farm surveys (Chapter 4), farmland productivity characterization (Chapter 5) incubation trials (Chapter 6) and field trials (Chapter 7 & 8) were conducted in the Guinea Savannah (GS) and deciduous forest (DF) zones from 2015 to 2017.

The farm survey, targeting 114 farmers in five communities at the GS zone aimed to evaluate primarily farmers' local fertilization management practices. The study found that inorganic fertilization was mostly practised among farmers, although the applied amount was below recommended rates. Farmers exhibited knowledge in soil management although high soil fertility management deficiencies were noticed. Farmers' local indicators of soil health, in congruent with earlier scientific reports were predominantly limited to visually observable signs. The

choice of indicator plants as determinants of healthy or non-healthy soil appeared to be influenced by the ease of control-, uses of weeds, benefits to the soil and threats posed on cultivated crops.

To evaluate the impact of farmers' current fertilization practice and the corresponding soil quality status, soil samples under four different fertilization schemes (inorganic, inorganic and organic, organic, and no fertilization) were collected from 20 farmers' field in both agroecological zones. Results show that all average soil quality parameters except extractable C, potential mineralizable nitrogen and CEC were significantly higher in DF sites compared to GS. Furthermore, inorganic fertilization proved superior in soil chemical and microbial biomass especially in DF zone. Our results revealed that soil quality could be improved in the long term with increased chemical fertilization rate in both zones.

The incubation study was conducted to analyse the decomposition dynamics of contrasting organic residues (ORs) in three soils. The study showed that inherent quality of ORs controlled nitrogen (N) mineralization and pH changes while soil type differences influenced by total carbon (C), CN ratio, sand and silt accounted for the microbial biomass dynamics. Furthermore, soil N dynamics was induced in low fertile soil while microbial biomass activities were triggered in silt loam compared to sandy loam soils. The results demonstrated similar decomposition pattern of ORs, though at varied decomposition rates, suggesting the applicability of the ORs in each soil type.

The two-season field experiments, conducted with the aim of quantifying the short term effects of contrasting ORs with chemical fertilizers revealed consistent maize yield improvement in maize treatment at both sites compared to the other treatments. The low fertile GS site amended with low to intermediate quality ORs showed positive interactive effects on maize yield compared to the relatively fertile DF site. Maize residues, followed by centrosema with chemical fertilizers appeared applicable in both study sites in contrast to the high quality crotalaria which showed less efficiency although its amendment enhanced soil microbial activity. Thus, low quality ORs with chemical fertilizer is suitable for low fertile soils while sole application of high quality ORs may be applicable in fertile soils.

The final field study sought to clarify the effects of sole ORs or their combined application with chemical fertilizers on soil microbial biomass and crop yield. The results revealed positive synergistic effect of combined application of chemical fertilizers with ORs. Combined application enhanced microbial activities in Centrosema, but inconsistently represented in the other amendments. However, the enhanced microbial activities did not necessarily translate into inorganic N availability and subsequent maize yield increases. The study further clarified positive interactive effects of maize straw with chemical fertilizer on grain yield as opposed to the negative effects with Centrosema and Pueraria with the magnitude of the interaction being larger in the minor rainfall season.

The findings from the study suggest the need to combine ORs with chemical fertilizer for soil and crop productivity improvement. To ensure their effective utilization, knowledge on residue quality characteristics and inherent soil properties along with farmer sensitization on site-specific fertility management is necessary.