Potential sources, application, and contribution of organic matter to soil fertility restoration for lowland rice production in Ghana

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INTRODUCTION

The Republic of Ghana is located on Latitude 4° 44′ N and 11°11′ N and Longitude 3° 11′ W and 1° 11′ E (MoFA, 2013). The country has the following seven agro-ecological zones: the Sudan savanna, Guinea savanna, Forest-Savanna transition, Equatorial forest, Moist-Evergreen, Wet-Evergreen, and Coastal savanna (Figure 1; JIRCAS, 2010).

Figure 1 Agro-ecological zones in Ghana

Rice is Ghana's most important cereal food crop after maize, and its total consumption is rapidly increasing (MoFA, 2009). In 2012, the planted area of lowland rice was 189,500 ha, and the average yield of rain-fed lowland rice was 2.5 t·ha^{-1}. This level of yield accounted for 39 % of the achievable yields (MoFA, 2013). In addition, the self-sufficiency ratio of rice in Ghana was only 24 % in 2006 (MoFA, 2009), resulting in high annual rice imports and decreased foreign exchange saving. Therefore, promoting rice production to address food security and poverty has been a very important policy for many years.

Inherent low fertility of lowland soils has been considered as a major cause of low rice grain yields (Buri *et al*., 2012). Lowland soils in Ghana are infertile compared to those within the West Africa sub-region or tropical Asia, particularly with regard to total C, N, P, and clay content (Buri *et al*., 2012). Single or multiple applications of chemical fertilizers is a common practice for restoring soil fertility. However, the estimated rate of fertilizer consumption in Ghana was approximately 10 kg·ha^{-1} (Owusu-Bennoah, 1997) mainly because farmers are unable to afford mineral fertilizers. Therefore, maintaining optimum levels of rice yields with low fertilizer usage

is difficult. Hence, alternative soil fertilizing materials that are locally available, easily accessible, and affordable by small-scale farmers should be explored. This study is aimed to investigate the abundance and availability of indigenous organic resources that can be used to restore and improve soil fertility for lowland rice production.

MATERIALS AND METHODS

The socioeconomic surveys were performed by the Crop Research Institute (CSIR-CRI) in Kumasi for central and southern parts of Ghana (Equatorial forest zone), and by the University for Development Studies (UDS) in Tamale for northern part of the country (Guinea savanna). A survey focused on rice farmer's view and concern of soil fertility, current local practices for soil fertility management and the related agricultural needs in Ghana. Indigenous resource in Ghana was survey based on literature to quantify, qualify, and localize the kinds of resources for soil fertility management.

RESULTS AND DISCUSSION

Locally available organic resources, particularly from plant and animal origins, occur abundantly throughout Ghana. Rice straw and husk are abundant in the Northern, Volta, Upper East, Western, and Eastern Regions. The total production of straw and husk has been estimated to be 430,000 tons (Figure 2). The estimated nutrient equivalents of total rice residues produced per annum for N, P_2O_5, and K_2O amounts to 2,500; 1,000; and 5,500 tons, respectively (Table 1).

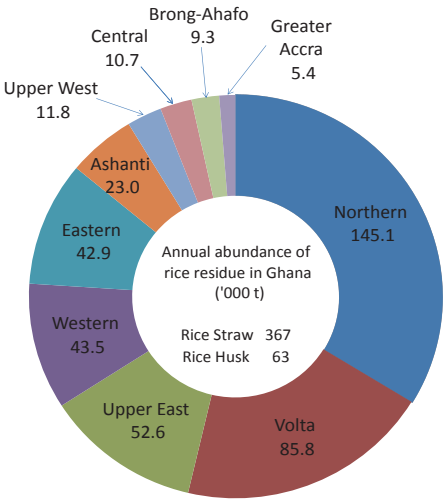

Figure 2 Annual abundance of rice residue in Ghana

Table 1 Nutrient equivalents of organic resources produced annually as nitrogen (N), phosphorus (P_2O_5), and potassium (K_2O) in '000 ton

Sources		N	P_2O_5	K_2O
Rice (Straw+Husk)		2.5	1.0	5.5
Animal (Dung+Urine)	Cow	41.8	31.8	32.4
	Goat	16.4	4.1	11.4
	Sheep	13.4	3.3	9.3
	Chicken (dung only)	5.8	3.1	2.9
	Pig	3.1	2.3	3.2
	Toal	83.0	45.5	64.6

Estimated daily manure and urine excretions were 3.6 kg and 3.4 L for cow, 0.36 kg and 0.25 L for goat and sheep, and 0.66 kg and 0.6 L for pig, respectively; chicken produced 6.0 kg dry matter of manure per year. Nutrient contents (%) of N, P_2O_5, and K_2O in manure and urine were 1.12, 1.72. 0.48, and 1.21, 0.01, 1.38 for cow; 1.95, 0.70, 0.70, and 1.47, 0.05, 1.96 for goat and sheep; and 2.28, 1.82, 1.80, and 0.38, 0.01, 0.99 for pig; and 2.6, 1.4, and 1.31 for chicken manure, respectively (Adapted from Yagodin, 1984, Mahimairaja *et al*. 2008, and McCalla, 1975).

Livestock excreta (dung and urine) are also ample resources, particularly from cows. Estimated nutrient equivalent of livestock excreta for N, P_2O_5, and K_2O per annum amounts to 80,500; 44,500; and 59,200 tons, respectively (Table 1). However, the amount of excreta differed among regions. Cow and pig excreta were largely produced in Northern, Upper East, and Upper Western Regions. Poultry manure was plentiful in the Greater Accra, Ashanti, and in the major municipalities and cities (Figure 3).

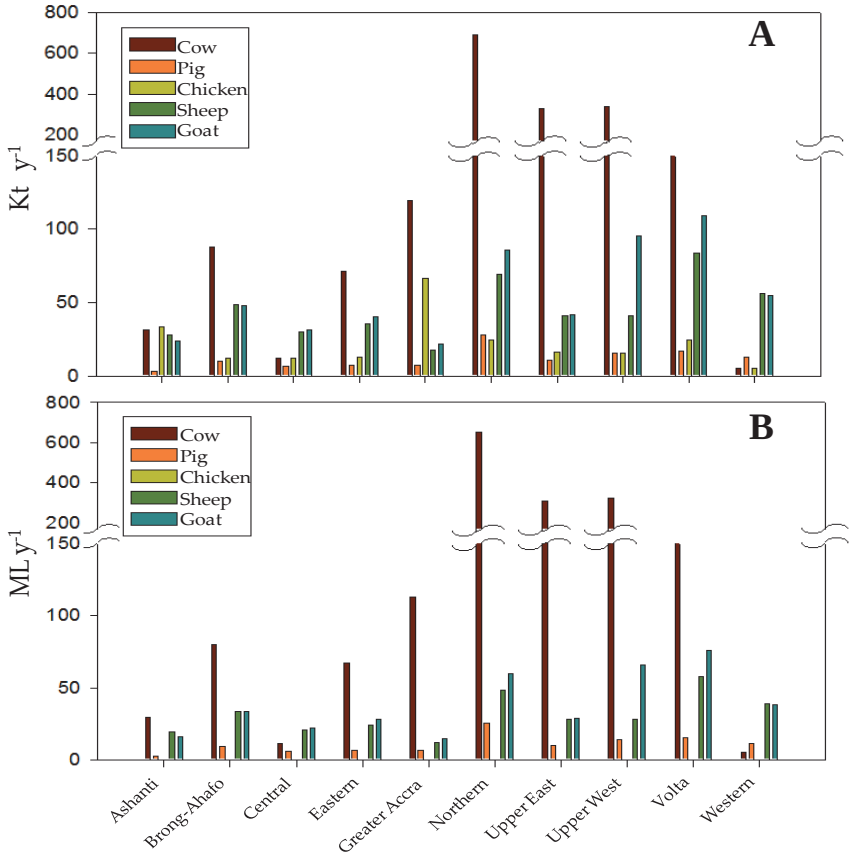

Figure 3 Quantities of dung (A) and urine (B) of the five most common livestock broken down by region in Ghana

In Ghana, most of the straw is burnt while some are removed from the rice fields. While, animal manures are accepted by most farmers either in small-scale house holder and commercial levels. There is an exception with pig manure due to religion belief.

Regarding various kinds and quantities of organic resources which are distributed across the regions. The utilization of these materials for soil fertility improvement is essential and should commence from a community in which they are found or in areas adjacent to such communities. This is a sustainable way for farmers to economically and effectively contribute to soil fertility restoration. For instance, in the Northern region where rice is the most dominant crop, an approach such as incorporating rice straw into the soil would compensate for approximately 20 % of N and P and most K requirements of the soil compared to that obtained by application of chemical fertilizers. In addition, some technical treatments to raw materials such as composting and bio-charring are also attractive options to enhance the effectiveness of rice residues on soil fertility improvement and rice production (Tobita *et al*., 2012; Issaka *et al*., 2012; JIRCAS, 2011).

In Ghana, if only 20 % of the estimated organic fertilizer resources from livestock can be

utilized annually, this could substitute for the total requirement for chemical fertilizers for rice cultivation in the entire Northern regions (Tobita *et al*., 2012). Although collecting livestock (i.e., cow, sheep, and goat) excreta/droppings is slightly difficult, especially liquid waste, because of unrestricted animal movement; such collections could be made when the animals are housed during the night. Ensuring that farmers obtain good quality and amounts of animal excreta requires that livestock enclosures should be constructed near houses, or animals should be directly led to the fields so that they can excrete directly onto the target field.

Poultry manure is another very good material because it contains all the major nutrients. However, poultry manure is now in high demand and not available free of charge. Farmers have to purchase poultry manure (Issaka *et al*., 2012). This might be a constraint to most farmers since they cannot afford to pay for fertilizers. Composts derived from droppings of poultry or grazing livestock and plant residues are rich in plant nutrients and should be applied to the soil. Other organic resources such as human excreta, sawdust, and oil palm shells can also be used effectively as per recommended guidelines.

CONCLUSION

In Ghana, local organic resources are plentiful and available across the country. Such organic resources provide large quantities of plant nutrients. The effective utilization of these organic resources would overcome the need for chemical fertilizers, leading to the restoration of soil fertility and increase in grain yield of lowland rice. Organic resources available to farmers also play a major role in the gradual restoration of soil organic matter and macro- and micronutrients.

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