Present status of soil fertility in lowland rice fields of Ghana and recommended management practices

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INTRODUCTION

The Ministry of Food and Agriculture (NRDS of MoFA, 2009) has stated that the per capita consumption of rice in Ghana increased to 63.0 kg by 2015, and the country's rice requirements will be in the range of 1.4–1.6 million tons per annum by 2018. At present, rice is the second-most important staple cereal food, the consumption of which continues to increase because of the changes in consumer habits, population growth, and urbanization. Ghana produces less than 40 % of it rice requirements. Of the potential yield target of 6.5 $t \cdot ha^{-1}$, less than 2.0 $t \cdot ha^{-1}$ (about 31 % of the target yield) is the mean rice yield recorded across the country.

In Ghana, rice cultivation is achieved via three main production systems: rain-fed upland, rain-fed lowlands, and irrigation. The rain-fed lowland ecology (mainly inland valleys and river flood plains) is considered to be the dominant type, accounting for over 78 % of the total cropped area. Ghana is estimated to have over four million hectares of unexploited rainfed lowlands, which have been identified as the most profitable sites for rice production provided the water management and cultural practices are improved. In order to ensure food security, import substitution, and savings in foreign exchange, Ghana needs to ensure increased and sustained domestic production of good-quality rice. With greater emphasis and production concentration shifting to lowland ecologies, the major production constraints, especially with regard to soil fertility, need to be identified.

Low inherent soil fertility has been a major constraint in the tropics. With increased cropping intensity, the situation might further worsen unless sustainable and effective management practices are applied. Therefore, this study aimed to determine the soil fertility status of Ghana's lowlands in order to provide a basis to develop sustainable and effective management technologies.

MATERIALS AND METHODS

A review of studies on soil fertility (Abe *et al*., 2010; Buri *et al*., 2011; 2010; 2007; 2004; 2000; 1998; Issaka *et al*., 1996) of rice growing environments, particularly the lowlands of Ghana, the entire West Africa sub-region, and other similar areas, was conducted. Results obtained were then compared with those obtained in similar environments of tropical Asia (Kawaguchi and

Kyuma, 1977) and some major rice-growing sites worldwide. Recommendations for sustainable and effective utilization of these ecologies were provided for improved rice cultivation and increased productivity.

RESULTS AND DISCUSSION

The mean levels of selected fertility parameters of lowland soils in Ghana and West Africa were generally lower than those in tropical Asia (Table 1). Lowland soils of Ghana had low total carbon and basic cations (Ca and Mg) levels, thus reflecting lower levels of effective cation exchange capacity. In particular, soil phosphorus (P) was very limited across Ghana (mean, 3.2 $mg \cdot kg^{-1}$) and West Africa (8.4 $mg \cdot kg^{-1}$) compared to that in tropical Asia (17.6 $mg \cdot kg^{-1}$). In Ghana, the savanna zones (1.5 $mg \cdot kg^{-1}$) showed greater P deficiency than that in the forest zones (4.9 $mg \cdot kg^{-1}$) as shown in Tables 2a & 2b). The clay content of lowland soils across Ghana was also generally low. Furthermore, active clay minerals were less, leading to lower activity of these minerals.

Table 1 Soil nutrient levels of lowlands in Ghana compared with that in the lowlands of West Africa, tropical Asia, and Japan

Lowland site	pH H_2O	TC (g·kg^{-1})	TN	Av. P (mg·kg^{-1})	Ex. K (cmol$_c$·kg^{-1})	Ex. Ca	Ex. Mg	eCEC	Clay (g·kg^{-1})
Ghana	5.2	9.1	0.88	3.2	0.3	4.8	2.5	8.6	97
West Africa	5.3	12.3	1.08	8.4	0.3	2.8	1.3	5.8	230
Tropical Asia	6.0	14.1	1.30	17.6	0.4	10.4	5.5	17.8	280
Japan	-	33.0	2.90	57.0	0.4	9.3	2.8	12.9	210

Modified from Buri et al., 2010; Kawaguchi and Kyuma, 1977.

In Ghana, most lowlands within the Guinea savanna and semi-deciduous rainforests were mainly inland valleys and river flood plains. Rectilinear valleys occurred within the savanna agro-ecological zone, whereas convex valleys were common within the forest agro-ecological zone. However, concave valleys occurred in both the zones. The major soil types in these two zones were Gleysols and, to a lesser extent, Fluvisols. *Volta* and *Lima* series were prominent within the savanna, whereas *Oda, Kakum*, and *Temang* series were prominent in the forest zone (Buri *et al*., 2010).

Soil fertility levels for selected parameters were low across locations, particularly within the savanna zone (Buri *et al*., 2009). Available P was the most deficient nutrient in both the zones. Soils of the savanna were also considerably acidic (Table 2a).

Table 2a Mean soil fertility characteristics of lowlands within the Guinea savanna zone

Parameter	Mean	Range	SD
pH (water)	4.6	3.7–7.4	0.5
Total C (g·kg^{-1})	6.10	0.6–19	3.0
Total N (g·kg^{-1})	0.65	0.1–1.6	0.3
C:N ratio	9.3	5.0–14.3	1.4
Available P (mg·kg^{-1})	1.5	Tr–5.4	0.9
Exchangeable K (cmolc·kg^{-1})	0.22	0.04–1.1	0.17
Exchangeable Ca (cmolc·kg^{-1})	2.10	0.53–15	1.9
Exchangeable Mg (cmolc·kg^{-1})	1.00	0.27–5.87	0.27
Exchangeable Na (cmolc·kg^{-1})	0.12	0.1–0.72	0.11
Exchangeable acidity (cmolc·kg^{-1})	1.00	0.05–1.80	0.48
Clay content (g·kg^{-1})	66	40–241	39
Silt content (g·kg^{-1})	607	347–810	107

Number of samples: 90; Source: Buri *et al*., 2009; Topsoil, 0–20 cm

Table 2b Mean soil fertility characteristics of lowlands within the semi-deciduous rainforest

Parameter	Mean	Range	SD
pH (water)	5.7	4.1–7.6	0.89
Organic C (g·kg^{-1})	12	3.6–36.5	0.58
Total N (g·kg^{-1})	1.1	0.30–3.20	0.05
C: N ratio	11	4.9–14.2	1.26
Available P (mg·kg^{-1})	4.9	0.1–28.5	5.36
Exchangeable K (cmol$_c$·kg^{-1})	0.42	0.03–1.28	0.25
Exchangeable Ca (cmol$_c$·kg^{-1})	7.5	1.1–26.0	5.1
Exchangeable Mg (cmol$_c$·kg^{-1})	4.1	0.3–12.3	2.6
Exchangeable Na (cmol$_c$·kg^{-1})	0.32	0.04–1.74	0.26
Exchangeable acidity (cmol$_c$·kg^{-1})	0.31	0.04–1.15	0.29
Clay content (g·kg^{-1})	127	41–301	8.2
Silt content (g·kg^{-1})	502	187–770	45.8

Number of samples: 122; Source: Buri *et al*., 2009; Topsoil, 0–20 cm

Exchangeable cations (K, Ca, Mg, and Na levels) were considerably moderate levels across areas within the forest agro-ecology, but relatively low for the savanna, particularly Ca. Both total carbon and nitrogen levels, even though low, were comparatively higher in the forest than in the savanna zone. The yield levels can be increased under these conditions by improving the fertility levels of the soils (Tables 2a & 2b).

Introduction of the *Sawah* eco-technology might ensure increased and sustained rice production (Ofori *et al*., 2005). The *Sawah* technology is an integrated soil, nutrients, and water management that consists of bunding, ploughing, puddling, and leveling with inlets for irrigation and outlets for drainage. This technology ensures appropriate water control and, with the application of additional good agronomic practices, rice yields of above 4.0 $t \cdot ha^{-1}$ can be easily obtained (Issaka *et al*., 2009).

CONCLUSION

Rice-growing environments in Ghana include heterogeneous topographies with low inherent fertility and low clay content. For effective exploitation and utilization, careful site-specific development and management technologies (improved soil/water management), which need to be disseminated through intensive on-the-job training, are necessary. The *Sawah* technology for rice production is ideal for this situation and can play a significant role in increasing the productivity of these lowlands. While rice farmers should be encouraged to use mineral fertilizers, the development of low-input integrated nutrient (using local materials) management systems would be ideal for farmers with limited resources.

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