Topographic distribution of the soil total carbon content and sulfur deficiency for rice cultivation in a floodplain ecosystem of the Northern region of Ghana

River floodplains, consisting of wide and flat alluvial plains bordering rivers, are expected to support a large expansion in the rice cultivation area and production, the major share of which is currently unexploited in West Africa. An understanding of the spatial variation in soil fertility is fundamental for developing appropriate fertilizer management practices and extending rice cultivation in this floodplain ecosystem. This study focuses on a floodplain along the White Volta River in the Northern region of Ghana, the major rice-producing region of the country. Here, we proposed a topographic distribution model to estimate the total carbon contents of soils, and then identified specific nutrient deficiencies in growing rice by combining satellite imagery analysis, soil chemical analysis, and phytometric pot experiments.

The total carbon (TC) contents of soils (0-15 cm in depth) largely differed from 2.0 to 40.2 g kg^{-1}, among 89 samples in the target floodplain. In the analysis using the four different topographic parameters, i.e., ‘Elevation’, ‘Distance to the White Volta river’, ‘Distance to reservoirs’, and ‘Slope angle’, the single logarithmic model of the ‘Distance to reservoirs’ was selected for estimating the soil TC contents with the greatest determination coefficient at 0.54 (Fig.1). The estimation model depicted the distribution map of soil TC contents as shown in Fig. 2, where we can find non-cultivated areas with high soil TC contents relatively close to the village compound. The soil TC contents showed close correlation with the N uptakes of rice grown under non-fertilized pot experiments (Fig.3). This result indicated that soil TC content can be used as an appropriate parameter of the soil N-supplying capacity for rice in the target ecosystem. Limited sulfur concentrations in plant tissues and a significant response to S application indicated that inherent sulfur deficiency restricted rice growth (Table 1). Therefore, fertilization of N, P, and K without S should increase only the concentration levels of these elements in rice plants but not biomass production. The effect of sulfur application on rice growth was greater with increased proximity to reservoirs.

The distribution of soil TC contents corresponded to the length of waterlogging period, which also logarithmically increased with proximity to reservoirs, as estimated by satellite imagery images. This corresponding pattern indicated that extension of rice cultivation areas near reservoirs can be regarded productive in terms of both water availability and soil fertility. Internal (soil-derived) and external nitrogen can be efficiently utilized for rice production by supplementing S-containing forms of fertilizer (e.g., ammonium sulfate). The potential risks of complete submergence should be further studied for extending rice production in this floodplain ecosystem.

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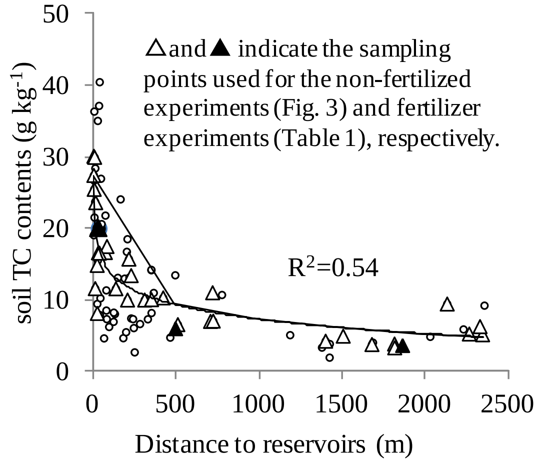

Fig. 1. Relationship between soil total carbon (TC) contents and distance to water resources (river and backswamp)

The approximate equation is 'soil TC = 29.28-3.3 x ln (Distance to reservoirs)'. The main Volta River, backswamps, and ponds were extracted as 'reservoirs' by the visual classification of the Quickbird image captured at the beginning of the dry season in November 2009.

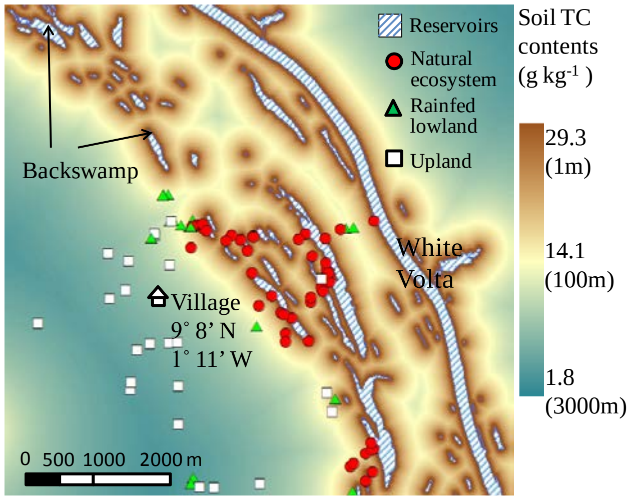

Fig. 2. Spatial distribution in the soil total carbon (TC) contents within the floodplain using the model equation in the Fig. 1

Based on interviews with local farmers, the sampling points are classified into ● natural ecosystem with no cropping history, ▲rainfed lowland, and □upland.

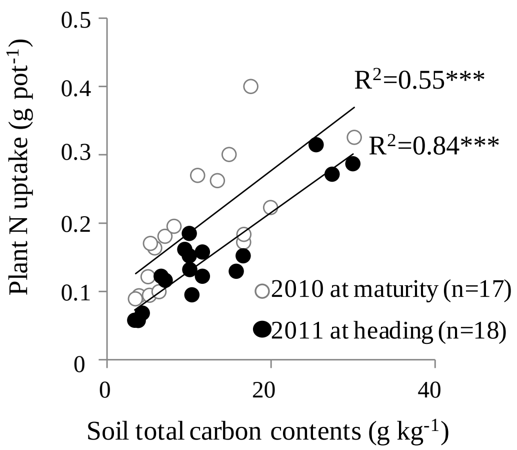

Fig. 3. Relationship between soil total carbon contents and plant N uptakes under non-fertilized treatments.

Table 1. Top dry matter yields and N:S concentration ratios as affected by soils and fertilizer treatments.

	Distances to reservoirs (river and backswamps) of the 3 experimental soils		
	Near(40m)	Middle(501m)	Far(1870m)
Fertilization	Dry matter g pot^{-1} (N:S conc. ratio)		
control	14.7 (29.2)	23.5 (13.0)	12.7 (12.9)
N	12.4 (**51.6**)	27.0 (25.4)	10.1 (**47.9**)
P	14.6 (27.8)	22.2 (11.3)	12.8 (14.7)
K	18.6 (26.9)	17.1 (12.5)	11.5 (14.9)
NP	10.7 (**45.0**)	24.5 (**31.6**)	9.3 (**50.4**)
NK	14.6 (**57.1**)	20.3 (**34.0**)	7.9 (**50.8**)
NPK	16.5 (**51.8**)	16.5 (**43.8**)	5.9 (**47.1**)
NPKSi	18.9 (**49.6**)	25.2 (**33.6**)	12.0 (**48.3**)
NPKZn	19.5 (33.7)	**12.0** (**44.6**)	**3.2** (**56.5**)
NPKS	**95.2** (**13.4**)	**71.2** (6.6)	**42.4** (7.1)

Bold numbers are significantly different from control at 5%. Nutrient rates are N=0.70g, P=0.22g, K=0.36g, Si=1.87g, Zn=0.05g, S=0.23g per pot.