Impact of land use on soil physicochemical properties in the semiarid climate zone in Benin (West Africa)

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1. The problem

In the semiarid climate zone of Benin, commercial cotton production intended to increase farmers' income, has been claimed to induce substantial land degradation, amplifying soil degradation and in particular soil erosion, which negatively affects the livelihood of farmers. However, little is known about the magnitude of change in soil physicochemical characteristics caused by cotton production in the semiarid climate zone in Benin in comparison with staple food production and in relation to soil properties of natural vegetation in the area.

2. The research hypothesis (RH)

We hypothesized that soil fertility would be significantly reduced on crop lands in comparison with the natural vegetation, following the order natural vegetation > cereal food crops and legume food crops > cash crops.

3. How we addressed the RH

Study area: Banikoara (11°18' N and 2°25' E), situated in the semiarid climate zone in Benin (Fig. 1) characterized by unimodal rainfall regime with a rainy season (May-October) with 950-1,000 mm of rainfall and a dry season (November-April). The area is considered the breadbasket of Benin and agriculture plays a major role in people's livelihoods.

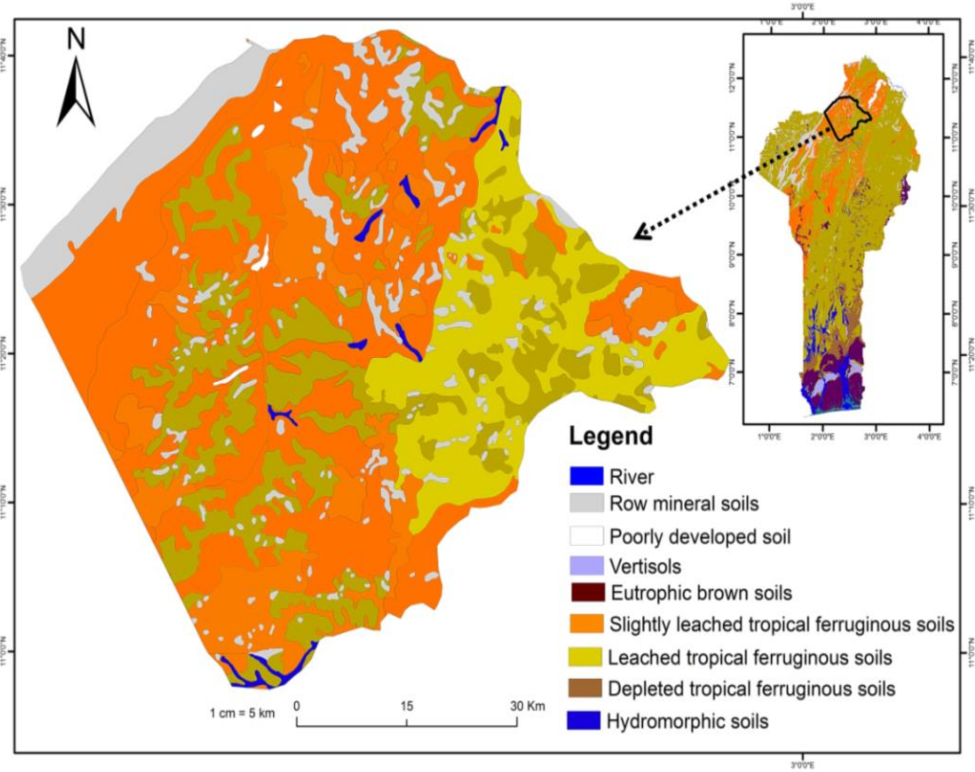

Figure 1. Study area

Soil sampling and experimental design: Four typical land use types including six crops were selected: cash crops (cotton [*Gossypium hirsutum*), cereals (maize [*Zea mays*], sorghum bicolor [*Sorghum bicolor*] and millet [*Eleusine coracana*]), legumes (cowpea [*Vigna unguiculata*] peanut [*Arachis hypogaea*] and soybean [*Glycine max*]) and natural vegetation (woodland).

Soil analyses: Soil texture assessed by particle size analysis using a pipette method. Soil bulk density analyzed based on the ratio of oven-dried mass of soil cores to a volume of 100 cm^3. Soil pH (H_2O) and electrical conductivity (EC in µS/cm) measured using a calibrated meter. Total soil carbon (C), nitrogen (N) and sulphur (S) content measured in dried and milled soil subsamples after combustion at 1050 °C in a vario Pyrocube® elemental analyser. Water-stable aggregates measured by exposing a soil's small macroaggregates (250 – 2000 µm) to wet-sieving disruptive forces, with the aggregates retained by the sieve representing the stable fraction. Soil water-holding capacity determined by weighing water saturated soil before and after being oven-dried.

Figure 2. Oxidization of soil samples with H_2O_2 (left) and breaking down the aggregates in the wet-sieving machine (right)

Data analysis: All data analyses performed using R statistical software Version 4.0.5. Means of soil variables compared between land uses using ggplot with the package "ggpubr". One-way ANOVA p-values added to the plot. The TukeyHSD post-hoc test used when a significant difference observed. No data transformation was applied, as data met the assumption of normality (Ryan-Joiner test) and homoscedasticity (Levene test). Principal Component Analysis (PCA) used to assess the relation between the variables and the crop.

4. What we found

The findings revealed variation in the soil physicochemical properties between land uses with significant differences in bulk density (high in crop fields and low in woodland) and the C/N ratio (low in crops fields and high in woodland) (Table 1, Fig. 2).

Table 1. Mean (m) and standard deviation (s) of particle size and bulk density of soils under different land uses (n = 5).

Crops	Sand (%)		Silt (%)		Clay (%)		Bulk density	
	m	s	m	s	m	s	m	s
Cotton	77.34	2.57	12.40	3.57	10.26	1.00	1.34c	0.01
Maize	61.97	2.89	25.82	0.53	12.21	3.42	1.54a	0.01
Sorghum-Millet	75.69	3.25	11.97	2.10	12.34	1.14	1.58a	0.02
Cowpea	82.32	2.92	5.42	2.07	12.27	4.99	1.44b	0.01
Peanut	77.74	10.60	15.25	7.64	7.01	2.95	1.35c	0.02
Soybean	77.51	5.72	13.88	8.89	8.61	3.17	1.52a	0.01
Woodland	84.11	5.49	9.67	9.62	6.22	4.13	1.40b	0.02

Bulk density values with similar letter are not significantly different at p-value 0.05 (Tukey-HSD)

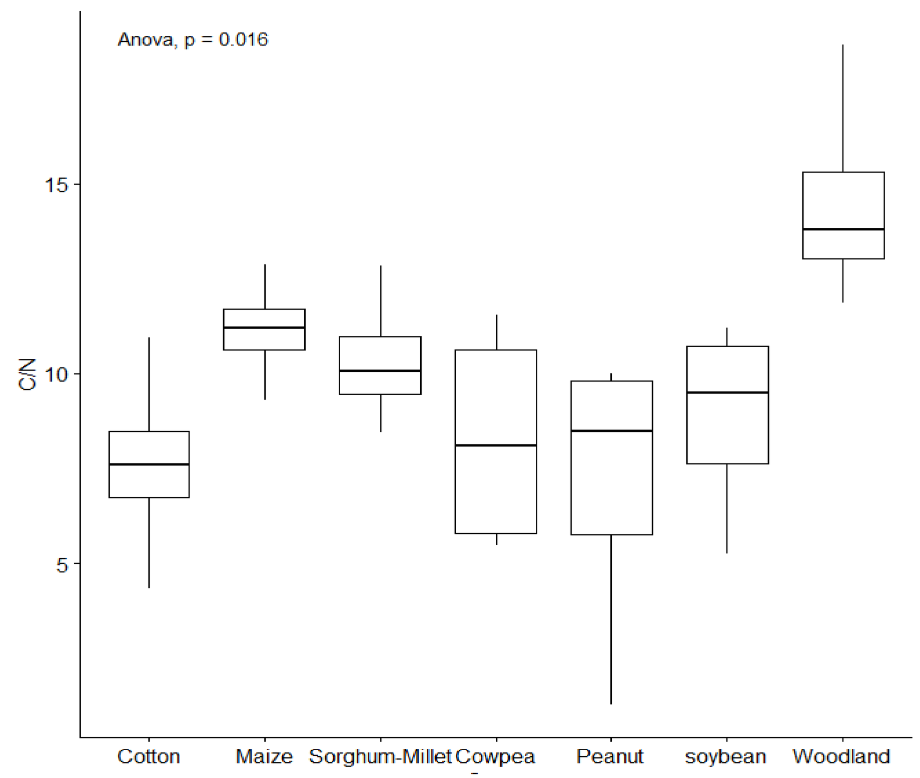

Figure 2. C/N ratio (b) of soils under different land uses (n=5).

The pH of the crop fields was mildly acidic to neutral, except sorghum-millet fields which had mildly neutral to basic pH, as did the woodland soil.

Woodland had high values of EC, WSA, SOC, N and C/N while the opposite was found in crop fields mainly cotton fields (Fig. 3). Maize, cowpea and sorghum-millet were mainly produced in soils with high clay that can hold more water while peanut was mainly produced in soils with high sand content as this crop needs less dense soil for the development underground

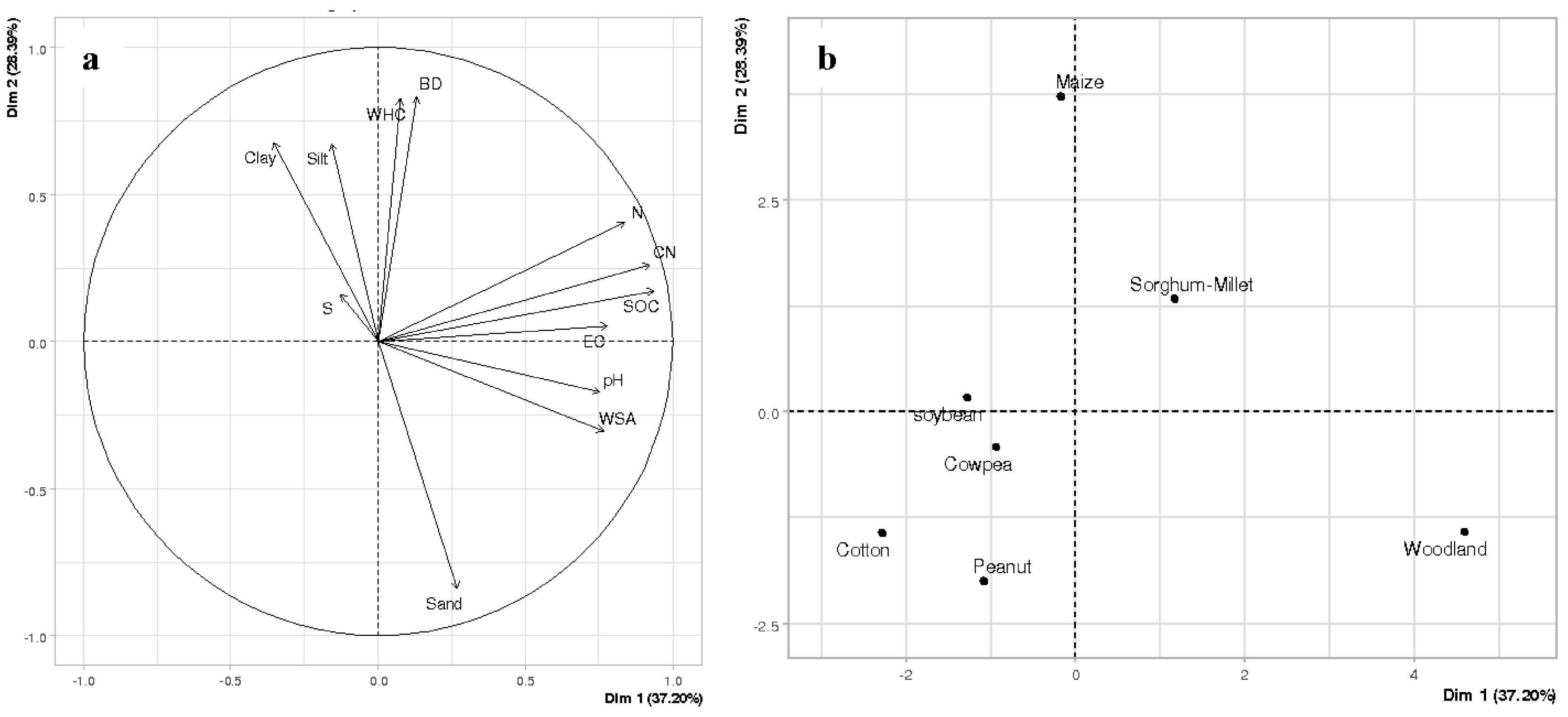

Figure 3. Correlation between the variables and the principal components 1 and 2

5. Conclusion and Perspectives

The farmers select the appropriate soil for each crop before the production. However, more attention should be paid to cotton crop fields in order to reduce the negative impact of this crop production on soil physicochemical properties.

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