Suitability of soils for cereal cropping in northern Ghana

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Through action research and development partnerships, Africa RISING will create opportunities for smallholder farm households to move out of hunger and poverty through sustainably intensified farming systems that improve food, nutrition, and income security, particularly for women and children, and conserve or enhance the natural resource base.

The three regional projects are led by the International Institute of Tropical Agriculture (in West Africa and East and Southern Africa) and the International Livestock Research Institute (in the Ethiopian Highlands). The International Food Policy Research Institute leads the program's monitoring, evaluation and impact assessment. http://africa-rising.net/

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Contents

Acknowledgements

This summary document is based on two reports for the Africa RISING West Africa Project by the Soil Research Institute (Senayah et al. 2012; Tetteh et al. 2013), which contain detailed survey results and soil maps for the regions studied.

Glossary

Base saturation: Closely related to cation exchange capacity (CEC), percentage base saturation is the proportion of CEC that is saturated with base cations (calcium, magnesium, potassium, and sodium)

Buffering capacity of soil: is a function of a soil's cation exchange capacity (CEC), which in turn is determined by the clay content of the soil, the type of clay, and the amount of organic matter present. Soils with high clay content and soils with high organic matter have a higher buffering capacity. Soils with high buffering capacity require a greater amount of lime to be added than a soil with a lower buffering capacity for the same incremental change in pH.

Cation exchange capacity (CEC): A measure of the total amount of exchangeable cations that can be held by the soil. It is expressed in terms of centimoles of charge per kilogram of soil. Soils with high CEC retain more nutrients than low-CEC soils.

cmolc /kg: the SI unit for milli-equivalent/100 g soil. It is the measure of the amount of charge per kg soil (CEC) because CEC can also be defined as the total amount of charge per kg soil

Concretion: Hard pellets, grains, or nodules of compounds (iron, manganese, calcium, carbonate, etc.) formed during soil development by cementation of soil mineral particles

ECEC: Effective CEC (ECEC) is the sum of all the exchangeable cations measured at the natural pH of the soil. This is equal to the sum of exchangeable Ca^{2+} + Mg^{2+} + K^{+} + Na^{+} + H^{+} + Al^{3+} (cmolc /kg). The ECEC levels are <10 cmolc /kg.

EDTA: Ethylenediaminetetraacetic acid

Indurated: Very strong, cemented, brittle; does not soften under prolonged wetting; breaks only with a sharp blow with a hammer

Phyllite: Fine-grained metamorphic rock with a well-developed laminar structure, intermediate between slate and schist

SSP: Single superphosphates

TSP: Triple superphosphates

Vertisol: a soil in which there is a high content of expansible clays (smectites), that forms deep cracks in drier seasons

Key points

Farming communities in the Upper West, Upper East, and Northern Regions of Ghana are the focus of the Africa RISING West Africa Project[1].To support the project, the physical, chemical, and fertility characteristics of soils at 71 sites in these regions have been characterized and mapped, and appropriate soil management practices for production of maize, millet, and sorghum have been determined. This document summarizes the results and recommendations[2].

Soil characteristics

Generally the soils in the three northern regions of Ghana are suitable for cereal crop production. However, most sites are marginal, with shallow soil depth as the major limitation (52% of the sites have a soil depth <50 cm).

Soil texture is generally sandy and 80% of the sites have a clay content <6%. The topsoil tends to be droughty, while the subsoil has a high level of gravel and concretions (hard, compact masses). The soils are therefore prone to erosion and have low moisture- and nutrient-holding capacity. As a result, crops are adversely affected by drought.

The presence of indurated (very strongly cemented) ironpan and ironpan boulders restricts root movement.

The soils are generally low in plant nutrients and contain little organic matter.

The status of exchangeable calcium and magnesium is low and declining.

Soil fertility improvement is important in the region, particularly organic matter build-up and integrated fertility management. Organic material is not easily available in the savanna environment due to bush burning and the use of crop residues as fuel and for animal grazing. Any strategy to build up organic matter (e.g. mulching, cover cropping, improved fallow, composting, minimum tillage, non-burning of crop residues, application of organic manure, and fodder banks) will depend on the conditions and practices of the specific locality.

Erosion prevention practices should be taken seriously, firstly to maintain or preserve the current precarious soil depth, and secondly to prevent the already depleted soil nutrients being washed away. Where possible, the use of tractors for ploughing should be limited, and animal ploughing and ridging should be encouraged.

Unlike potassium, which is a constituent of most compound fertilizers, calcium and magnesium are not normally applied to crops. Addition of calcium and magnesium by liming should be done with great care since most of these soils are poorly buffered. Organic sources (cow dung, compost, crop residues) are preferred.

[1] https://africa-rising.wikispaces.com/west_africa

[2]This publication summarizes two reports for the Africa RISING West Africa Project by the Soil Research Institute (Senayah et al. 2012; Tetteh et al. 2013), which contain detailed survey results and soil maps for the regions studied.

Study sites in northern Ghana

Ecological zones

The study sites form part of Ghana's Interior Savanna ecological zones, consisting of the Guinea and Sudan savannas, which cover more than one-third of the country's land area (Figs 1 and 2). The Sudan savanna has a similar climate and vegetation pattern to the Guinea savanna zone, except that the rainfall is lower, the dry season more prolonged, and vegetation sparser.

Climate

There are well defined wet and dry seasons of about equal length, with annual rainfall of 700–1100 mm, with one rainy season per year. Monthly rainfall increases gradually from March until a maximum is reached in August or September. There is a long dry season from November/December to March/April, with January and February being the driest months. There is considerable variation between years in the time of onset, duration, and amount of rainfall.

Mean monthly temperatures are high throughout the year, with mean monthly figures ranging from 25 °C (December) to 38 °C (April). Relative humidity is high during the night and early morning in the rainy season.

Geology and relief

The underlying geology consists mainly of shales, mudstones (Northern Region), and granites (Upper West and Upper East Regions). Alluvial deposits occur within river valleys. Most parts of the study area are gentle undulating to flat terrain. The wide river valleys and depressions are almost flat with slopes of 1–3%.

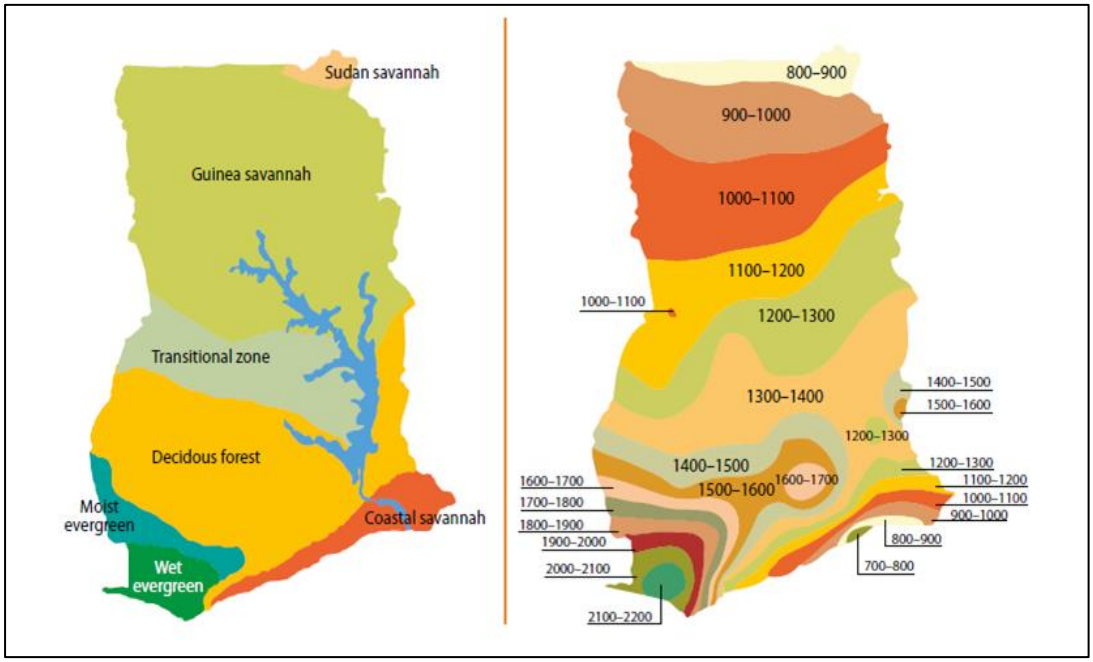

Figure 1. Ecological zones (left) and annual rainfall (mm) (right).

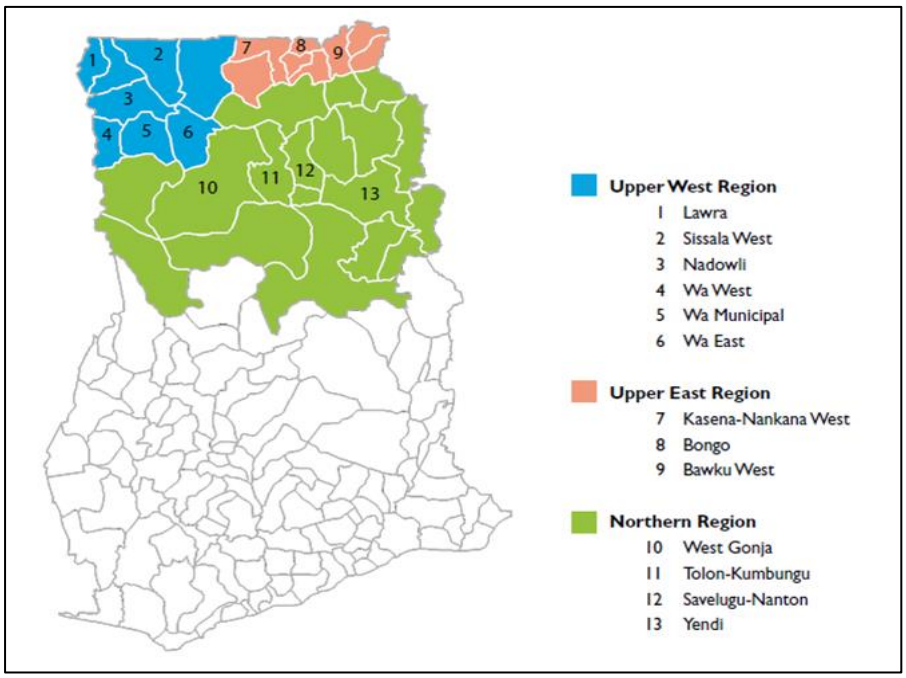

Figure 2. Regions and districts surveyed

Soil physical properties

- The soils in the Upper West Region are mostly developed over granite, with a few areas developed over Lower Birimian phyllite (only one of the study sites, Furo, is on Lower Birimian phyllite). The major limitation of the soils is their sandy nature, particularly the topsoil, which makes them highly susceptible to erosion (see Table 1; see Appendix 4 for particle size analysis).
- In the Upper East Region, the soils are developed from granite or Upper Birimian phyllite. All the sites visited in Bongo and Bawku West districts have soils originating from granite and are similar to those of the Upper West Region.
- The soils in the Northern Region are developed from Voltaian shale and sandstone. The sites in Tolon-Kumbungu and Yendi districts are over shale; those in West Gonja and Savelugu-Nanton are over sandstone (with the exception of Jana and Manguli in Savelugu-Nanton, which are over shale). Soil depth and coarse fragment content affect soil quality in the shale areas. Soils developed over sandstone are relatively deeper than those in the shale areas, and slopes are more pronounced (3–5%).

Table 1. Soil physical properties.

	Region					
	Upper West		**Upper East**		**Northern**	
Physical character	Granite	Lower Birimian phyllite (Furo only)	Granite (Bongo and Bawku West)	Upper Birimian phyllite	Shale (Tolon-Kumbungu and Yendi	Sandstone (West Gonja and Savelugu-Nanton except Jana and Manguli)
Soil depth	20 cm (shallow) to >80 cm (moderately deep)	60+ cm (moderately deep)	25 to 60+ cm	n/a	Shallow (15–30 cm) to very shallow (<15 cm), underlain by iron pan	30–80+, underlain by iron pan
Soil texture	Loamy sand or sandy loam for both topsoil (0–20 cm) and subsoil (20–40 cm	Loam or sandy loam	Topsoil texture is coarse sandy loam or loamy sand; subsoil texture is sandy loam	n/a	Soil texture is generally sandy loam at the top and sandy loam or silty loam in the subsoil	Sandy loam to loamy sand
	Concretionary, gravelly and stony underlain by indurated iron pan		Several soils are characteristically gravelly and concretionary	n/a	Concretionary, gravelly, containing iron pan boulders	Concretionary, gravelly, containing iron pan boulder
Terrain	Slopes of 2–3%, moderately well drained			n/a	Flat with gentle slopes (1–3%)	Slopes more pronounced (3–5%)

*Soils were grouped by depth using the following descriptions: very shallow (<15 cm), shallow (15–30 cm), slightly deep (30–60 cm), moderately deep (60–100 cm), deep (100–150 cm), very deep (>150 cm).

*For detail on specific sites see Appendix 1.

*For an explanation of soil texture classification see Appendix 3

.

Soil chemical properties

Fertility
Nutrient levels are generally low to moderate, with some communities showing higher values than others for some nutrients.

pH
The topsoil pH range of 5.5 - 6.5 is good for cereal production in general. Most of the sites gave pH values suitable for maize, rice, sorghum, and millet production. Soil pH decreases slightly with depth (Appendix 4). Total exchangeable acidity is generally low and partly explains the generally slightly acidic soil pH values.

A few sites (in Nadowli, Wa East, Yendi, Bongo, and Savelugu-Nanton districts) gave neutral to slightly alkaline topsoil pH values. Some sites in Nadowli and Bongo districts have soils that are strongly acidic and will require proper management to ensure these values do not decline further.

Organic matter
Only 16% of the sites had soils with ≥15 g/kg organic matter, and 44% had soils with ≥10 g/kg. In general, the organic matter status of the three northern regions is not encouraging. Parts of the Upper West (Lawra, Nadowli, Wa East) and and Northern (Yendi, Savelugu-Nanton) Regions showed better organic matter status, probably due to large tracts of land allowing for long fallow.

The situation is most critical in the Upper East region, where land is continuously under cultivation. Soil organic matter is vital for both nutrient, and water retention, acting as a nutrient reservoir that holds and releases nutrients during mineralization. Low soil organic matter is even more critical when soils are sandy.

Total nitrogen
Soil nitrogen originates mostly from decomposing organic matter. Total nitrogen of 1.0 g/kg and above is good enough for plant growth. Most of the sites show moderate to low values, with a higher proportion of low levels across all sites (<0.1%) (Appendix 4). Thus an adequate nitrogen supply is needed for better crop performance.

Exchangeable bases
The measurement of exchangeable bases is used for the assessment of soil fertility and is part of the determination of cation exchange capacity (CEC).

- Exchangeable calcium levels are low except at a few points where they measure >5.0 cmolc/kg. Bawku West, Sissala West, Yendi, and most parts of West Gonja are particularly low in exchangeable calcium. A desirable level of exchangeable calcium would be 5–15 cmolc/kg (see Fig. 3).

- Exchangeable magnesium levels are generally low (<1.0 cmolc/kg). Forty per cent of the sites have values in the low to medium range (<3.0 cmolc/kg). Parts of Nadowli, Savelugu-Nanton, Wa East, Bongo, and Yendi show relatively moderate values, a desirable magnesium level is 2–4 cmolc/kg (Fig. 3).

- Exchangeable potassium levels are very low (<0.15 cmolc/kg). A few locations (e.g. Nadowli, Tolon-Kumbugu) showed adequate or moderate potassium levels (0.15–0.25 cmolc/kg). A desirable level of exchangeable potassium is 0.20–0.30 cmolc/kg (Fig. 3).

- Exchangeable sodium levels are low, but within acceptable limits at all sites, with values of <5% of effective CEC.

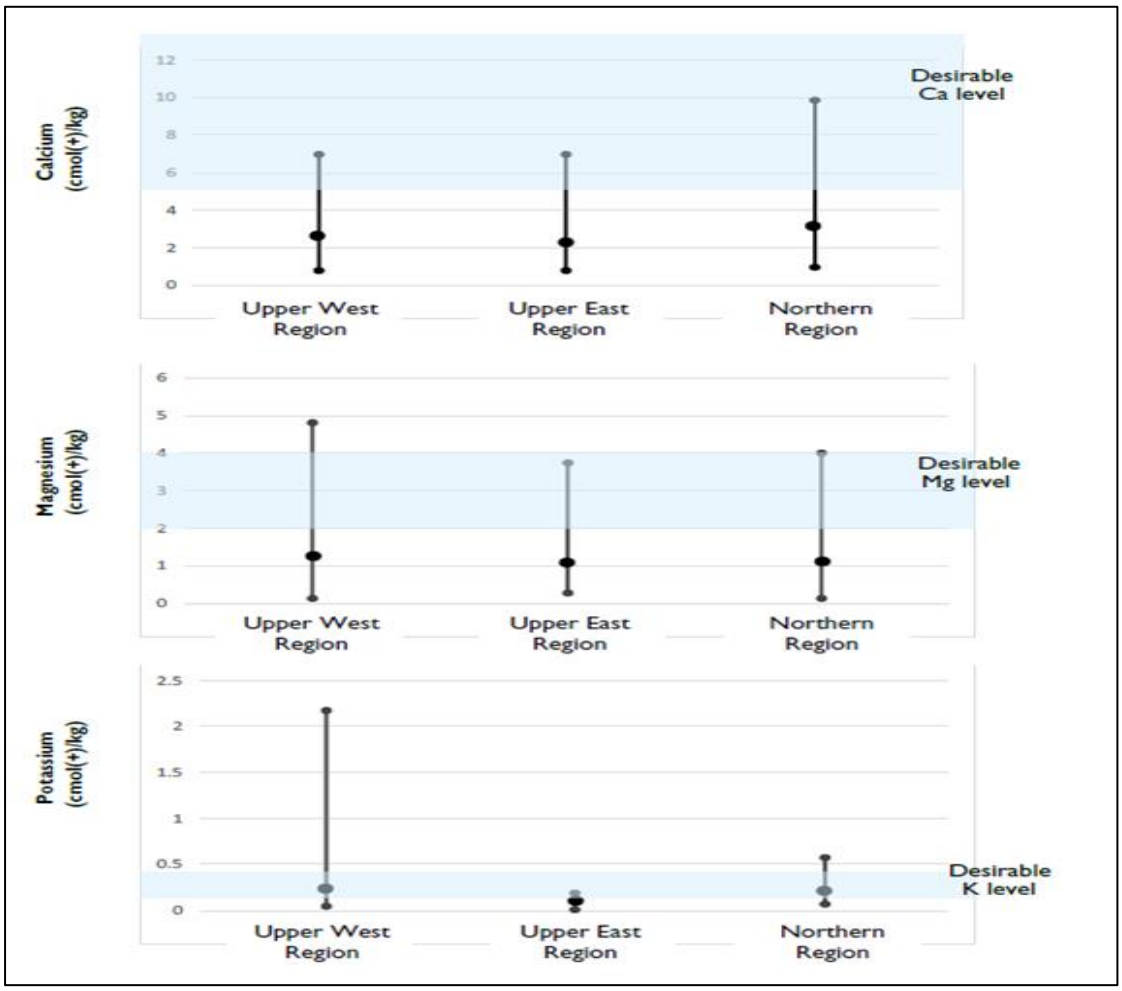

Figure 3. Average, maximum, and minimum exchangeable levels of calcium, magnesium, and potassium recorded at the study sites (for detailed results see Appendix 4).

Effective cation exchange capacity

Effective CEC (ECEC) is the sum of all the exchangeable cations measured at the natural pH of the soil. The ECEC levels are <10.00 cmolc/kg). Only one point, in Savelugu-Nanton, had a value of 13.54 cmolc/kg.

Base saturation

Base saturation is the proportion of cation exchange that is saturated with basic cations. Most of the sites are highly saturated despite the low values of exchangeable calcium, magnesium, and potassium. This is because the CEC of the soil is very low so it is easily saturated with basic cations in soil solution. The total exchangeable acidity is very low; coupled with the low buffering capacity of the soils; the base saturation shows high values.

Management practices that can improve CEC—application of organic manure, compost, and soil conservation practices—are recommended.

Available phosphorus

Over 60% of the sites have soils with very low to low phosphorus content (<10 ppm) (Table 2), and phosphorus concentration declines from topsoil to subsoil. In Savelugu-Nanton, however, four of the sites had moderate to high phosphorus levels.

Most Ghanaian soils are low in available phosphorus, and the problem becomes more serious when the organic matter status of the soil is low. Application of phosphate fertilizers is recommended—either rock phosphate, or single or triple superphosphates (SSP, TSP).

Table 2. Fertility ratings for soil indicators

Parameter	Soils sampled		Fertility rating
	Range	Mean	
pH	5.0–7.6	6.21	Good
Soil organic matter (%)	0.3–3.9	1.09	Low
Available phosphorus (mg/kg)	1.0–67.8	7.23	Low
Exchangeable potassium (cmolc/kg)a	0.0–0.6	0.14	Low
Effective CEC (cmolc/kg)a	2.1–13.5	4.74	Low

*cmolc/kg = centimoles of charge per kilogram of soil.

Suitability for cereal production

Soil texture is generally sandy loam and loamy sand, particularly in the topsoil (see Appendix 3 for soil texture classification). Fewer than 20% of the sites have a clay content of ≥6%. The soils are therefore highly susceptible to erosion and have low moisture- and nutrient-holding capacity. This situation is aggravated by the generally low and erratic rainfall.

Thus, as noted on page 1, the following practices are recommended.

- Soil fertility improvement, particularly organic matter build-up and integrated fertility management. Organic material is not easily available in the savanna environment due to bush burning and the use of crop residues as fuel and for animal grazing. Any strategy to build up organic matter (e.g. mulching, cover cropping, short fallow, fodder banks, application of organic manure, stone bunds, crop rotations, and composting) will depend on the conditions and practices of the specific locality.
- Erosion prevention practices, firstly to maintain or preserve the current precarious soil depth, and secondly to prevent the already depleted soil nutrients being washed away. Where possible, the use of tractors for ploughing should be limited, and animal ploughing and ridging should be encouraged.
- Unlike potassium, which is a constituent of most compound fertilizers, calcium and magnesium are not normally applied to crops. Addition of calcium and magnesium by liming should be done with great care since most of these soils are poorly buffered. Organic sources (cow dung, compost, crop residues) are preferred.

Table 3. Topography and soil requirements for maize, millet, and sorghum (adapted from Sys et al. 1993).

Land characteristics	**Suitability for growing maize, millet, and sorghum**			
	High	**Moderate**	**Marginal**	**Unsuitable**
Slope (%)	0–4	4–8	8–16	>16
Drainage	Good to moderate	Somewhat poor	Poor	Poor to not drainable
Texture	Silty clay Silty clay loam Sandy clay Sandy clay loam Loam	Clay Sandy loam Loamy fine sand Loamy sand	Fine sand Sand Loamy coarse sand	
Coarse fragments (vol %	0–15	15–35	35–55	>55
Soil depth (cm) Maize Millet Sorghum	 >100–75 >90–50 >100–75	 75–50 50–20 75–50	 50–20 20–10 50–20	 <20 <10 <20

Table 4. Climate and soil requirements for cereals

Crop	Climate					Soil		
	Temperature (°C)		Rainfall (mm/growing cycle)		Notes	Type	pH	
	Range	Optimum	Range	Optimum			Range	Optimum
Maize 	14–40	18–32	500–1500	900–1200	Very sensitive to moisture stress from start of flowering until grain formation (50–100 days after planting).	Well drained, well aerated, deep loam, and silty loam with adequate organic matter. Avoid waterlogging	5.2–8.5	5.8–7.8
Millet 	16–32	21–32	150–1350	300–600	Distribution of rainfall throughout growing season more important than total precipitation; drought resistant but water required at flowering (however, heavy rain at flowering interferes with fertilization and reduces yield).	Loamy to clay soils. Well drained and aerated. At least 50 cm depth needed; optimum is 200 cm.	5.2–8.2	5.6–7.6
Sorghum 		21–32	At least 150 mm	400–900	Night temperature of <15 °C for 5+ nights hinders anthesis. Withstands areas of waterlogging better than other cereals in the tropics (other than rice).	Grows on many soil types but optimum obtained on heavier textured soils. Soils with vertic (cracking and swelling) properties are mostly recommended. At least 50 cm depth needed.	5.5–8.2	5.6–7.6

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Appendices

Appendix 1: Soil depths and characteristics

Region	District	Communities	Coarse-fragment content in soil	Soil depth (cm)[a]	Description
Upper West	Wa East	Loggu	Nil	60+	
		Bulenga	Many	30	Underlain by ironpan
		Kpalinye	Nil	40	Shallow to granitic rock; presence of rock outcrops
		Zinye	Nil	50	Shallow to granitic rock; presence of rock outcrops
		Naaha	Nil	60+	Rock outcrops common
	Nadowli	Daffiama	Nil	80+	
		Tabiesi	Nil	60+	
		Goriyiri	Nil	50+	Shallow to rock, underlain by ironpan
		Kalsegra	Nil	60	Underlain by ironpan
		Ombo	Nil	60+	
		Goli	Few	80+	Moderately deep
		Natorduori	Nil	75+	Moderately deep
		Papu	Nil	30	Underlain by ironpan
		Gyill	Common	45	Underlain by ironpan
	Wa West	Nyagli	Few	45	Underlain by ironpan
		Pase	Few	60	Underlain by ironpan
		Siriyiri	Few	30	Underlain by ironpan
	Wa Municipal	Zanko	Few	35	Underlain by ironpan
		Guo	Nil	80	Moderately deep, underlain by ironpan
	Lawra	Naapal	Many (30%)	30	Underlain by ironpan
		Nandom	Abundant (30%)	20	Underlain by ironpan

		Tanchara			
		Furo	Nil	60+	
		Tuopari	Nil	60+	
		Dazuri	Nil	60+	
	Sissala West	Sorbelle	Nil	60+	Patches of shallow ironpan soil
		silbelle	Nil	60+	
		Pulima	Nil	50	Underlain by ironpan
		Jawia	Nil	50	Underlain by ironpan
		Bullu	Nil	60+	
Upper East	Bongo	Dua	Nil	60+	
		Yindongo	Moderate	60+	Quartz gravel/stones and ironstone concretions
		Namoo	Moderate	30	Quartz gravel
		Beo	Nil	40	
		Gowrie	Nil	30	Shallow to rock (granite); rock outcrops are common
		Sambobigo	Few	50	Underlain by ironpan
	Bawku West	Binaba	Nil	60+	
		Tilli	Nil	40	Shallow to rock (granite)
		Tanga	Nil	60+	
		Gongo	Moderate	30	Underlain by ironpan
		Yaringu	Moderate	25	Underlain by ironpan
	Kassena-Nankana	Bonia	Many	35	Underlain by ironpan
		Tekuru	Few	80+	Moderately deep
		Nyangua	Few	100	Deep
		Gia	Common	75	Moderately deep
Northern	Tolon-Kumbungu	Kpachi	Moderate	50	Underlain by ironpan
		Tolon	Nil	80+	Deep
		Tingoli	Moderate/ Common	45	Underlain by ironpan
		Zugu	Many	20	Ironpan boulders on surface

		Dundo	Moderate	25	Underlain by ironpan
		Tibognayili	Many	30	Underlain by ironpan
		Gbanjong	Common	50	Underlain by ironpan
	Yendi	Zakoli	Moderate	50	Underlain by ironpan
		Malzeri	few	40	Underlain by ironpan
		Piong	Moderate	50	Underlain by ironpan
		Zang	Moderate	30	Underlain by ironpan
		Adibo	Moderate	40	Underlain by ironpan
	West Gonja	Busunu	Nil	80+	
		Sori No. 1	Moderate	50	Underlain by ironpan
		Damongo Zongo	Nil	80+	
		Joanokponto	Nil	60	Underlain by ironpan
		Frafra No. 4 Busunu	Nil	80+	
	Savelugu-Nanton	Duko	Few	45+	Underlain by ironpan
		Libga	Nil	80+	
		Kansheigu	Nil	60	Underlain by ironpan
		Jana	Moderate/few	50+	Underlain by ironpan
		Manguli	Moderate	30	Underlain by ironpan
		Botingli	Common	40	Underlain by ironpan
		Tibali	Few	75	Underlain by ironpan
		Kpallung	common	25	Underlain by ironpan
	Kumbungu	Cheyohi	Common	55	Underlain by ironpan
		Pkerim	Few	60	Underlain by ironpan

*Soil depth groupings:

very shallow <15 cm,
shallow 15–30 cm,
slightly deep 30–60 cm,
moderately deep 60–100 cm,
deep 100–150 cm, very deep >150 cm.

Appendix 2: Methods

Study sites and sampling

Across the two studies, 50 (Senayah et al. 2012) and 25 (Tetteh et al. 2013) communities were surveyed. Four sites were recorded by both studies (Goriyiri in the Upper West Region; Jana, Duko, and Tingoli in the Northern Region).

Soils were examined for depth, drainage, texture, and coarse fragment content. Bulk samples were taken at three randomly selected points at predetermined depths of 0–20 and 20–40 cm (Senayah et al. 2012); or 0–15 and 15–30 cm (Tetteh et al. 2013). Soil examinations were undertaken to a depth of 60 cm in both studies. Observations were also made on slope and surface features such as rock outcrops and ironpan boulders. The coordinates of each site were recorded using a global positioning system.

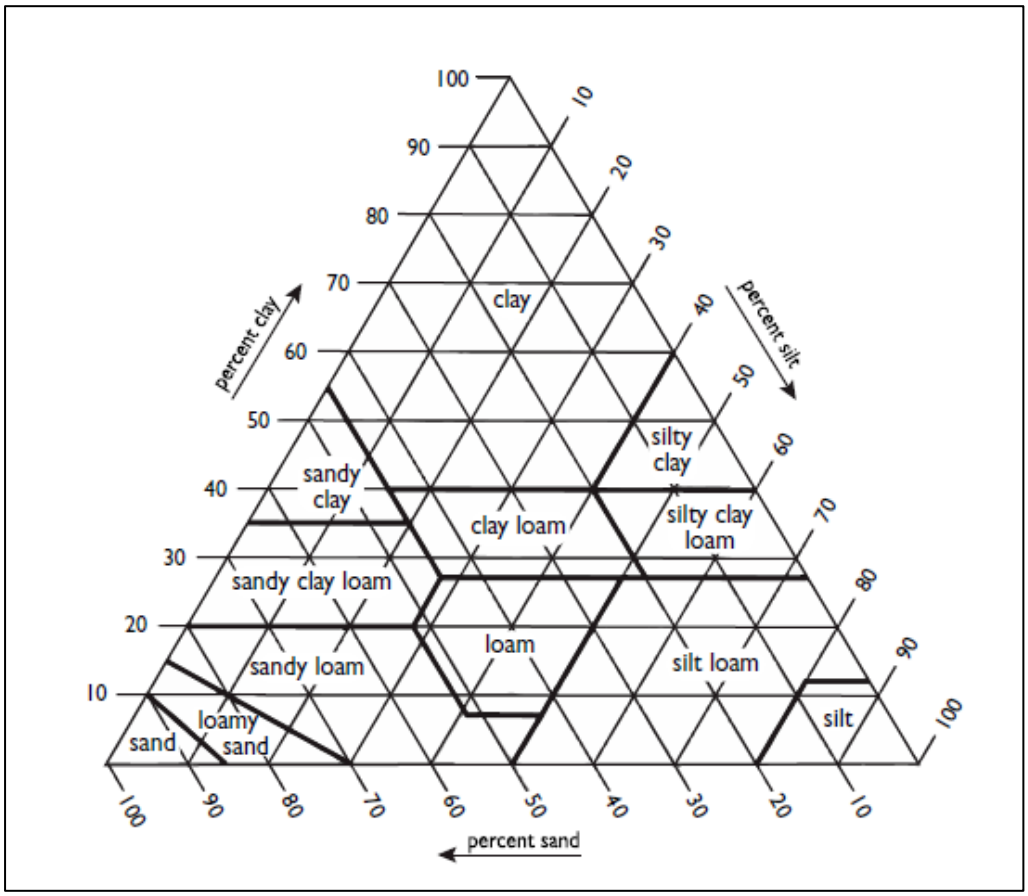
Secondary soil information was derived from existing detailed reconnaissance soil surveys of Navrongo-Bawku, Lawra-Wa, and Yapei-Sawla districts (Adu 1969; Adu and Asiamah 2003a,b).

Soil analysis

The following laboratory analyses were carried out on the soil samples.

- Soil texture (sand, silt, and clay) was determined on particles <2 mm diameter by the hydrometer method (Bouyoucous, 1962).
- Soil pH was determined in a 1:1 suspension of soil and water using an HI 9017 microprocessor glass electrode pH meter.
- Organic matter was determined by a modified Walkley and Black procedure as described by Nelson and Sommers (1982).
- Total nitrogen was determined by the Kjeldahl digestion and distillation procedure as described by KIT (1984). Available phosphorus was determined by the Bray-1 method as described by Bray and Kurtz (1945). Particle size distribution was determined by the hydrometer method.
- Exchangeable bases (calcium, magnesium, potassium, and sodium) in the soil were determined in 1.0 M ammonium acetate (NH4OAc) extract (Black, 1986). Calcium and magnesium in the leachate were determined by ethylenediaminetetraacetic acid (EDTA) titration; potassium and sodium were determined by flame photometry.
- Exchangeable acidity (hydrogen and aluminum) was determined by titration in 1.0 M potassium chloride extract as described by Page et al. (1982).
- Effective CEC was determined by the sum of exchangeable bases (calcium, magnesium, sodium, and potassium) and exchangeable acidity (aluminum and hydrogen).

Appendix 3: Soil texture classification



Source: Soil Survey Staff (1993), Figure 3-16. Natural Resources Conservation Service, US Department of Agriculture.
www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/ref/?cid=nrcs142p2_054253

Appendix 4: Chemical and physical analysis of soil samples

Location	Depth	Site	pH	OC[a] (g/kg)	TN[b] (g/kg)	OM[c] (g/kg)	Bray's available		Exchangeable cations (cmol(+)/kg)							Base sat. (%)	Particle size analysis			Texture
							P (mg/kg)	K (mg/kg)	Ca	Mg	K	Na	TEB	Exch. Acidity	ECEC		Sand (%)	Silt (%)	Clay (%)	
Northern Region																				
West Gonja	0–20	Busunu	6.42	45	4	78	6.46	31.79	6.4	0.53	0.2	0.08	7.21	0.1	7.31	98.6	77.1	20.6	2.3	L. sand
		Sori No. 1	6.05	60	5	103	6.38	65.94	1.34	0.8	0.07	0.05	2.26	0.18	2.44	92.6	74.6	23.4	2.1	L. sand
		Damongo Z.	5.97	45	4	78	17.06	79.81	1.6	0.4	0.14	0.07	2.21	0.25	2.46	89.8	74.4	23.6	2	L. sand
		Joanokponto	6.7	67	6	116	9.41	65.6	1.34	1.07	0.23	0.09	2.73	0.08	2.81	97.2	78.0	19.9	2.1	L. sand
		Frafra No. 4	6.58	71	6	122	25.91	92.66	1.34	0.53	0.27	0.09	2.23	0.1	2.33	95.7	75.0	20.9	4.1	L. sand
	20–40	Busunu	6.08	34	3	59	7.26	23.33	2.14	0.8	0.13	0.06	3.13	0.18	3.31	94.6	76.3	21.7	2	L. sand
		Sori No. 1	6.39	34	3	59	3.59	42.27	1.6	0.53	0.22	0.09	2.44	0.12	2.56	95.3	75.4	22.0	2.6	L. sand
		Damongo Z.	5.68	38	3	66	7.73	66.96	0.93	0.4	0.29	0.09	1.71	0.6	2.31	74.0	76.6	21.1	2.3	L. sand
		Joanokponto	6.68	42	4	72	5.58	37.2	2.67	0.8	0.44	0.14	4.05	0.08	4.13	98.1	81.0	17.0	2	L. sand
		Frafra No. 4	6.92	57	5	98	12.68	74.05	1.34	0.4	0.21	0.09	2.04	0.08	2.12	96.2	74.3	21.7	4	L. sand
Tolon-Kumbung	0–20	Kpachi	5.58	34	3	59	30.62	65.6	3.2	0.93	0.35	0.13	4.61	0.65	5.26	87.6	65.2	32.8	2.05	S. loam
		Tolon	6.21	42	4	72	4.36	42.61	1.6	0.8	0.16	0.09	2.65	0.18	2.83	93.6	65.0	32.9	2.05	S. loam
		Tingoli	5.91	55	5	95	7.81	63.91	4.54	0.27	0.18	0.08	5.07	0.25	5.32	95.3	64.3	29.5	6.2	S. loam
		Zugu	6.7	45	4	78	6.06	6.96	2.4	1.07	0.19	0.09	3.75	0.08	3.83	97.9	70.3	25.6	4.1	S. loam
		Dundo	6.05	71	6	122	5.02	54.74	2.54	0.93	0.14	0.09	3.7	0.2	3.9	94.9	68.2	27.5	4.3	S. loam
	20–40	Kpachi	7.09	34	3	59	4.46	44.64	2.94	1.07	0.48	0.19	4.68	0.05	4.73	98.9	56.0	39.7	4.3	S. loam
		Tolon	6.31	45	4	78	3.99	30.77	1.07	0.27	0.17	0.08	1.59	0.15	1.74	91.4	27.9	48.1	24	Loam
		Tingoli	6.49	47	4	81	5.9	18.6	3.87	0.13	0.22	0.11	4.33	0.08	4.41	98.2	61.3	30.7	8.05	S. loam
		Zugu	6.3	34	3	59	2.47	53.09	1.34	0.53	0.09	0.08	2.04	0.15	2.19	93.2	57.2	36.8	6	S. loam
		Dundo	6.72	64	5	110	3.51	66.47	1.87	0.53	0.17	0.08	2.65	0.08	2.73	97.1	54.1	39.7	6.2	S. loam
	0–15	Tibognayili	6.25	81	8	140	4.31	92.66	5.07	1.6	0.12	0.09	6.88	0.13	7.01	98.1	54.3	35.7	10	S. loam
		Gbanjong	6.62	53	13	91	5.02	76.76	2.14	0.27	0.08	0.04	2.53	0.1	2.63	96.2	57.4	34.6	8	S. loam
		Cheyohi	5.61	72	9	124	9.17	51.74	1.87	1.07	0.16	0.09	3.19	0.25	3.44	92.7	49.9	41.1	9	Loam
		Pkerim	6.67	99	9	171	3.75	69.66	4.54	2.4	0.57	0.3	7.82	0.13	7.95	98.4	67.5	24.1	8.4	S. loam
	15–30	Tibognayili	6.89	69	5	119	3.75	54.11	6.94	2.4	0.07	0.04	9.46	0.1	9.56	99.0	52.8	35.2	12	S. loam
		Gbanjong	5.84	44	9	76	1.67	55.46	2.67	0.53	0.07	0.04	3.31	0.22	3.53	93.8	54.9	40.1	5	S. loam
		Cheyohi	5.72	69	5	119	7.18	58.84	3.47	1.07	0.07	0.04	4.65	0.2	4.85	95.9	42.2	47.8	10	Loam
		Pkerim	6.32	81	7	140	2.39	48.36	4.27	2.67	0.22	0.13	7.29	0.13	7.42	98.25	49.2	42.8	8	Loam

Location	Depth	Site	pH	OC[a] (g/kg)	TN[b] (g/kg)	OM[c] (g/kg)	Bray's available		Exchangeable cations (cmol(+)/kg)							Base sat. (%)	Particle size analysis			Texture
							P (mg/kg)	K (mg/kg)	Ca	Mg	K	Na	TEB	Exch. Acidity	ECEC		Sand (%)	Silt (%)	Clay (%)	
Yendi	0–20	Zakoli	6.54	108	10	186	5.74	68.31	2.14	1.34	0.31	0.09	3.88	0.08	3.96	98.0	47.7	50.2	4.1	Si loam
		Malzeri	6.98	67	6	116	9.97	113.29	2.94	1.07	0.26	0.08	4.35	0.07	4.42	98.4	41.4	56.5	2.1	Si loam
		Piong	6.33	71	6	122	6.7	47	2.94	0.8	0.18	0.08	4	0.1	4.1	97.6	45.6	52.4	2	Si loam
		Zang	6.59	82	7	141	3.35	53.77	2.4	0.8	0.26	0.08	3.54	0.08	3.62	97.8	50.7	47.2	2.1	S. loam
		Adibo	5.91	60	5	103	4.86	56.13	2.27	2.14	0.19	0.06	4.66	0.25	4.91	94.9	25.3	70.5	4.2	Si loam
	20–40	Zakoli	6.6	67	6	116	3.67	40.92	3.74	1.07	0.29	0.09	5.19	0.08	5.27	98.5	44.8	51.1	4.05	Si loam
		Malzeri	6.59	49	4	84	5.02	36.52	4.01	0.53	0.21	0.07	4.82	0.08	4.9	98.4	29.6	66.1	4.3	Si loam
		Piong	6.27	49	4	84	4.15	36.52	2.67	1.47	0.18	0.08	4.4	0.12	4.52	97.3	48.6	49.1	2.3	Si loam
		Zang	6.2	75	6	129	1.83	43.62	2.94	1.87	0.2	0.11	5.12	0.12	5.24	97.7	47.1	48.8	4.05	S. loam
		Adibo	5.94	38	3	65	1.75	25.02	1.87	1.34	0.53	0.16	3.9	0.2	4.1	95.1	29.6	68.4	2	Si loam
Savelugu-Nanton	0–20	Duko	6.34	97	8	167	11	109.57	4.54	4.01	0.13	0.06	8.74	0.12	8.86	98.6	56.3	41.5	2.2	S. loam
		Libga	5.5	38	3	66	7.89	41.93	2.67	0.53	0.36	0.12	3.68	0.7	4.38	84.0	53.7	42.0	4.3	S. loam
		Kansheigu	6.37	79	7	136	8.85	95.7	2.27	1.2	0.14	0.08	3.69	0.12	3.81	96.9	47.0	50.9	2.1	Si loam
		Jana	6.18	71	6	122	8.13	52.08	4.27	1.09	0.17	0.07	5.6	0.15	5.75	97.4	31.4	62.6	6	Si loam
		Manguli	5.94	75	6	129	3.99	38.21	2.94	2.14	0.18	0.06	5.32	0.2	5.52	96.4	35.9	58.0	6.1	Si loam
	20–40	Duko	6.59	67	6	116	5.02	68.65	4.81	0.27	0.3	0.12	5.5	0.08	5.58	98.6	52.6	45.3	2.1	S. loam
		Libga	5.75	34	3	59	2.87	26.38	1.34	0.53	0.08	0.04	1.99	0.6	2.59	76.8	71.4	22.6	6	S. loam
		Kansheigu	6.2	53	4	91	3.27	50.05	1.6	0.53	0.22	0.08	2.43	0.15	2.58	94.2	56.6	41.4	2.03	S. loam
		Jana	5.93	60	5	103	3.03	40.24	1.76	1.71	0.17	0.08	3.72	0.25	3.97	93.7	28.4	63.6	8.05	Si loam
		Manguli	5.87	71	2	122	3.11	40.92	2.67	2.14	0.17	0.08	5.06	0.35	5.41	93.5	35.7	54.3	10	Si loam
	0–15	Kpallung	7.59	228	9	393	13.15	88.6	9.88	3.47	0.09	0.05	13.49	0.05	13.54	99.6	48.6	41.0	10.4	Loam
		Tibali	6.11	96	9	166	67.77	61.21	5.34	1.07	0.16	0.13	6.7	0.13	6.83	98.1	44.5	44.5	11	Loam
		Botingli	7.09	81	11	140	8.05	89.28	5.61	0.8	0.19	0.13	6.73	0.05	6.78	99.3	76.2	13.8	10	S. loam
	15–30	Kpallung	7.19	181	7	312	3.59	58.84	6.68	1.6	0.09	0.05	8.42	0.05	8.47	99.4	49.0	41.0	10	Loam
		Tibali	6.2	75	6	129	2.39	46.67	5.34	1.34	0.13	0.09	6.9	0.12	7.02	98.3	41.7	44.3	14	Loam
		Botingli	6.82	60	8	103	4.15	55.46	5.34	1.07	0.13	0.09	6.63	0.1	6.73	98.5	77.0	12.0	11	S. loam

Location	Depth	Site	pH	OC[a] (g/kg)	TN[b] (g/kg)	OM[c] (g/kg)	Bray's available		Exchangeable cations (cmol(+)/kg)							Base sat. (%)	Particle size analysis			Texture
							P (mg/kg)	K (mg/kg)	Ca	Mg	K	Na	TEB	Exch. Acidity	ECEC		Sand (%)	Silt (%)	Clay (%)	
Upper West Region																				
Lawra	0–20	Naapal	6.36	92	1	159	4.54	55.8	2.81	0.67	0.09	0.05	3.62	0.1	3.72	97.3	61.3	34.4	4.3	S. loam
		N. Tanchara	6.42	112	10	193	16.42	129.52	6.94	0.53	0.45	0.19	8.11	0.1	8.21	98.8	56.8	38.2	4.4	S. loam
		Furo	5.66	50	4	86	1.83	87.92	3.61	2.4	0.14	0.07	6.22	0.6	6.82	91.2	55.4	28.3	16.3	S. loam
		Tuopari	5.51	46	4	79	2.07	50.72	3.61	0.53	0.09	0.06	4.29	0.65	4.94	86.8	71.8	24.1	4.1	S. loam
		Dazuri	5.62	46	4	79	2.55	70	1.6	1.07	0.11	0.09	2.87	0.6	3.47	82.7	75.2	22.4	2.4	L. sand
	20–40	Naapal	5.79	43	4	74	3.51	44.98	3.21	0.13	0.07	0.04	3.45	0.5	3.95	87.3	52.4	37.6	10.5	S. loam
		N. Tanchara		0	0	0														
		Furo	5.81	43	3	74	0.72	59.86	6.02	4.81	0.17	0.08	11.08	0.4	11.48	96.5	31.7	44.3	24.16	Loam
		Tuopari	5.56	43	3	74	1.6	55.12	3.61	0.53	0.12	0.1	4.36	0.65	5.01	87.0	66.0	32.0	2	S. loam
		Dazuri	5.93	43	3	74	1.51	61.88	2.01	0.8	0.17	0.13	3.11	0.2	3.31	94.0	69.2	28.4	2.4	S. loam
Nadowli	0–20	Dafiama	5.13	29	3	50	4.78	65.94	2.01	1.6	0.11	0.11	3.83	0.85	4.68	81.8	75.6	22.0	2.4	L. sand
		Tabiesi	5.72	67	6	116	24.63	109.57	2.41	1.07	0.26	0.13	3.87	0.45	4.32	89.6	71.5	24.2	4.28	S. loam
		Goriyiri	6.58	98	9	169	17.38	178.21	1.6	0.27	0.39	0.16	2.42	0.08	2.5	96.8	65.7	30.2	4.1	S. loam
		Kalsegra	5.66	50	4	86	4.7	84.87	3.61	4.81	0.12	0.05	8.59	0.6	9.19	93.5	71.2	24.3	4	S. loam
		Ombo	7.26	98	9	169	20.01	177.2	5.61	4.81	0.39	0.16	10.97	0.05	11.02	99.6	75.2	22.5	2.3	L. sand
	20–40	Dafiama	5.13	15	2	26	2.79	52.75	2.41	1.01	0.09	0.08	3.59	0.85	4.44	80.9	73.3	24.4	2.34	L. sand
		Tabiesi	5.66	53	5	91	13.31	61.21	2.14	2.4	0.17	0.12	4.83	0.6	5.43	89.0	68.4	25.3	6.3	S. loam
		Goriyiri	6.9	46	4	79	5.9	154.2	2.01	2.14	0.29	0.14	4.58	0.08	4.66	98.3	67.5	24.5	8	S. loam
		Kalsegra	5.42	32	2	55	3.99	73.04	2.81	2.14	0.09	0.04	5.08	0.7	5.78	87.9	67.8	26.2	6.1	S. loam
		Ombo	7.02	78	7	134	4.31	134.25	4.41	2.14	0.22	0.1	6.87	0.05	6.92	99.3	77.4	20.3	2.3	L. sand
	0–15	Goli	6.2	32	10	55	10.28	47	1.34	0.8	0.14	0.09	2.37	0.13	2.5	94.8	85.2	8.8	6	L. sand
		Natorduori	6.35	69	7	119	15.31	74.4	2.4	1.34	0.21	0.17	4.13	0.13	4.26	97.0	75.8	17.2	7	S. loam
		Papu	6.25	32	8	55	4.7	25.7	1.07	0.8	0.11	0.04	2.03	0.13	2.16	94.0	82.2	8.8	9	L. sand
		Gyilli	6.26	38	8	66	6.3	87.58	1.6	0.27	0.11	0.04	2.02	0.13	2.15	94.0	85.0	9.0	6	L. sand
	15–30	Goli	6.06	16	6	28	1.83	36.52	1.34	0.8	0.11	0.09	2.33	0.14	2.47	94.3	84.4	9.6	6	L. sand
		Natorduori	6.91	44	4	76	2.47	50.39	2.14	0.27	0.09	0.04	2.55	0.11	2.66	95.9	72.3	20.7	7	S. loam
		Papu	5.75	28	5	48	7.97	25.36	1.34	1.07	0.12	0.09	2.62	0.28	2.9	90.3	68.8	13.2	18	S. loam
		Gyilli	5.96	22	5	38	2.79	26.04	1.87	0.27	0.13	0.09	2.36	0.21	2.57	91.8	79.7	12.3	8	L. sand

Location	Depth	Site	pH	OC[a] (g/kg)	TN[b] (g/kg)	OM[c] (g/kg)	Bray's available		Exchangeable cations (cmol(+)/kg)							Base sat. (%)	Particle size analysis			Texture
							P (mg/kg)	K (mg/kg)	Ca	Mg	K	Na	TEB	Exch. Acidity	ECEC		Sand (%)	Silt (%)	Clay (%)	
Wa East	0–20	Loggu	6.95	50	4	86	4.31	103.14	3.61	1.07	0.17	0.08	4.93	0.05	4.98	99.0	76.9	21.1	2	L. sand
		Bulenga	6.78	102	9	176	34.2	137.29	2.67	2.27	0.24	0.09	5.27	0.08	5.35	98.5	65.5	30.3	4.25	S. loam
		Kpalinye	7.21	88	7	152	8.37	126.81	4.54	2	0.31	0.1	6.95	0.05	7	99.3	69.1	26.4	4.5	S. loam
		Zinye	6.58	60	5	103	8.61	97.73	3.2	0.53	0.3	0.08	4.11	0.08	4.19	98.1	79.4	18.4	2.2	L. sand
		Naaha	6.54	60	5	103	1.36	93.38	2.94	1.34	0.58	0.16	5.02	0.09	5.11	98.2	82.6	13.2	4.22	L. sand
	20–40	Loggu	6.62	36	3	62	1.51	64.25	2.4	0.8	0.11	0.04	3.35	0.07	3.42	98.0	76.3	21.4	2.3	L. sand
		Bulenga	6.81	95	8	164	1.28	96.04	3.74	1.6	0.21	0.07	5.62	0.08	5.7	98.6	64.4	29.4	6	S. loam
		Kpalinye	6.82	67	6	116	2.39	92.66	3.74	2.4	0.27	0.08	6.49	0.08	6.57	98.8	56.4	35.3	8.3	S. loam
		Zinye	6.71	53	4	91	7.57	61.88	2.67	0.53	0.54	0.15	3.89	0.08	3.97	98.0	75.3	22.3	2.4	L. sand
		Naaha	6.49	32	3	55	1.04	63.24	3.74	1.34	0.34	0.1	5.52	0.1	5.62	98.2	55.4	34.6	10	S. loam
Sissala West	0–20	Sorbelle	6.32	53	5	91	0.88	30.77	1.34	0.8	0.34	0.07	2.55	0.12	2.67	95.5	69.4	28.4	2.16	S. loam
		Silbelle	6.68	43	3	74	3.91	59.86	1.6	0.27	2.17	0.6	4.64	0.08	4.72	98.3	71.8	26.1	2.1	L. sand
		Pulima	5.97	43	3	74	1.12	30.77	0.8	0.27	–	1.74	8.81	0.2	9.01	97.8	72.7	25.2	2.12	L. sand
		Jawia	5.91	50	4	86	2.47	38.89	1.07	0.8	0.28	0.06	2.21	0.25	2.46	89.8	71.4	26.3	2.3	S. loam
		Bullu	6.31	39	3	67	1.67	19.61	1.34	0.27	0.25	0.05	1.91	0.12	2.03	94.1	76.0	22.0	2	L. sand
	20–40	Sorbelle	6.39	39	3	67	0.96	25.36	1.07	0.53	0.18	0.03	1.81	0.12	1.93	93.8	77.9	20.8	2	L. sand
		Silbelle	6.59	39	3	67	3.99	49.71	1.34	1.07	0.45	0.1	2.96	0.08	3.04	97.4	71.1	24.5	4.4	S. loam
		Pulima	5.9	36	3	62	8.93	23.67	0.8	0.27	0.24	0.05	1.36	0.25	1.61	84.5	72.8	25.2	2	L. sand
		Jawia	5.95	36	3	62	3.11	26.04	1.34	0.27	0.48	0.11	2.2	0.25	2.45	89.8	64.2	33.4	4.4	S. loam
		Bullu	6.65	32	2	55	1.28	29.76	1.2	0.13	0.26	0.06	1.65	0.08	1.73	95.4	72.0	26.0	2.02	S. loam
Wa West	0–15	Nyagli	5.78	54	6	93	4.38	38.21	3.2	1.6	0.04	0.04	4.89	0.13	5.02	97.4	56.7	31.3	12	S. loam
		Pase	6.45	64	13	110	10.13	53.09	3.2	2.4	0.08	0.04	5.72	0.13	5.85	97.8	64.9	27.1	8	S. loam
		Siriyiri	6.06	86	12	148	8.29	57.83	4.01	1.07	0.09	0.04	5.21	0.13	5.34	97.6	44.7	42.3	13	Loam
	15–30	Nyagli	6.32	32	3	55	4.15	33.82	2.14	1.6	0.05	0.04	3.83	0.13	3.96	96.7	50.5	35.5	14	Loam
		Pase	6.73	60	9	103	3.83	48.7	5.34	1.87	0.12	0.09	7.42	0.1	7.52	98.7	53.8	35.2	11	S. loam
		Siriyiri	6.45	57	8	98	5.34	37.2	4.54	1.87	0.09	0.04	6.55	0.13	6.68	98.1	41.8	42.6	15.6	Loam
Wa Municipal	0–15	Zanko	6.7	38	15	66	23.92	35.17	1.87	1.07	0.12	0.09	3.15	0.1	3.25	96.9	68.5	23.5	8	S. loam
		Guo	6.73	57	8	98	3.83	54.11	2.14	1.07	0.12	0.09	3.42	0.1	3.52	97.2	62.0	31.6	6.4	S. loam
	15–30	Zanko	6.08	32	12	55	1.12	54.11	2	0.67	0.12	0.09	2.88	0.13	3.01	95.7	64.1	24.9	11	S. loam
		Guo	6.77	48	6	83	22.32	36.52	2.14	1.34	0.12	0.04	3.64	0.1	3.74	97.3	55.6	30.4	14	S. loam

Location	Depth	Site	pH	OC[a] (g/kg)	TN[b] (g/kg)	OM[c] (g/kg)	Bray's available		Exchangeable cations (cmol(+)/kg)							Base sat. (%)	Particle size analysis			Texture
							P (mg/kg)	K (mg/kg)	Ca	Mg	K	Na	TEB	Exch. Acidity	ECEC		Sand (%)	Silt (%)	Clay (%)	
Upper East Region																				
Bawku West	0–20	Binaba	6.44	30	3	52	11.4	43.96	1.34	0.8	0.07	0.06	2.27	0.1	2.37	95.8	80.7	15.1	4.2	L. sand
		Tilli	5.56	60	5	103	10.61	46.67	2.4	0.27	0.01	0.07	2.85	0.75	3.6	79.2	71.4	22.4	6.2	S. loam
		Tanga	5.73	31	2	53	5.1	36.52	0.93	0.53	0.08	0.05	1.59	0.4	1.99	79.9	80.3	16.7	3	L. sand
		Googo	5.82	46	4	79	10.61	52.08	1.34	0.4	0.1	0.05	1.89	0.4	2.29	82.5	70.6	27.0	2.4	S. loam
		Yarigu	5.91	42	3	72	10.68	47.68	1.74	0.94	0.09	0.06	2.83	0.25	3.08	91.9	71.0	27.4	1.6	S. loam
	20–40	Binaba	6.12	23	2	40	6.62	32.8	1.34	1.07	0.06	0.03	2.5	0.2	2.7	92.6	74.2	19.4	6.4	S. loam
		Tilli	6.03	27	2	47	1.36	26.38	2.14	0.8	0.06	0.06	2.34	0.2	2.54	92.1	69.1	73.2	4.1	S. loam
		Tanga	6.02	27	2	47	0.08	17.25	0.8	0.27	0.04	0.04	1.15	0.2	1.35	85.2	49.3	52.9	3.6	S. loam
		Googo	6.01	42	3	72	8.45	48.02	1.64	0.4	0.14	0.07	2.25	0.2	2.45	91.8	73.8	21.8	4.4	L. sand
		Yarigu	6.13	38	3	67	1.75	22.66	0.94	0.27	0.09	0.04	1.34	0.2	1.54	87.0	66.2	26.8	7	S. loam
Bongo	0–20	Dua	5.98	38	3	67	7.33	34.83	2.14	1.6	0.06	0.04	3.84	0.2	4.04	95.0	61.3	65.7	4.4	S. loam
		Yindongo	6.94	62	5	107	14.91	45.99	4.27	3.34	0.16	0.09	7.86	0.08	7.94	99.0	59.2	28.6	12.2	S. loam
		Namoo	6.67	42	4	72	8.69	36.86	5.47	2.8	0.11	0.09	8.47	0.1	8.57	98.8	71.4	21.6	7	S. loam
		Beo	5.38	30	3	52	12.2	39.57	4.01	3.47	0.14	0.08	7.7	0.75	8.45	91.1	80.4	18.4	1.2	L. sand
		Gowrie	5.52	27	2	47	2.55	33.48	0.8	0.53	0.07	0.06	1.46	0.7	2.16	67.6	68.3	30.7	1	S. loam
	20–40	Dua	6.33	30	2	52	3.19	29.08	2.14	1.34	0.11	0.07	3.66	0.12	3.78	96.8	38.6	53.0	14.4	Loam
		Yindongo	7.01	50	4	86	3.03	24.01	6.94	3.74	0.11	0.08	10.87	0.08	10.95	99.3	55.7	27.3	17	S. loam
		Namoo	6.8	54	4	93	2.79	19.61	4.81	0.8	0.08	0.1	5.79	0.08	5.87	98.6	62.1	31.7	6.2	S. loam
		Beo	5.58	23	2	40	4.86	34.83	1.07	0.53	0.07	0.06	1.73	0.6	2.33	74.2	69.7	26.1	4.2	S. loam
		Gowrie	5.93	20	2	34	6.62	30.1	1.07	0.27	0.07	0.08	1.49	0.25	1.74	85.6	65.7	29.7	4.6	S. loam
	0–15	Samboligo	6.41	41	4	71	1.75	62.56	1.87	1.07	0.17	0.13	3.24	0.13	3.37	96.1	82.6	11.0	6.4	L. sand
	15–30	Samboligo	6.31	31	3	53	2.63	55.46	1.34	1.07	0.07	0.04	2.52	0.13	2.65	95.1	72.3	17.7	10	S. loam

Kasena Nankana	0–15	Tekuru	5.3	57	4	98	6.7	52.75	1.6	0.8	0.14	0.08	2.62	0.54	3.16	82.9	81.7	10.3	8	L. sand
		Bonia	5.59	66	3	114	9.65	59.18	1.87	0.8	0.14	0.13	2.94	0.22	3.16	93.1	77.4	14.6	8	S. loam
		Nyangua	5.67	75	3	129	3.91	54.44	1.74	0.4	0.19	0.13	2.46	0.21	2.67	92.1	78.1	15.9	6	L. sand
		Gia	5.28	63	4	109	8.85	52.75	1.87	0.53	0.16	0.09	2.65	0.5	3.15	84.1	81.7	12.3	6	L. sand
	15–30	Tekuru	5.81	54	2	93	2.23	43.62	3.47	1.07	0.12	0.09	4.75	0.43	5.18	91.7	76.9	17.1	6	L. sand
		Bonia	5.69	45	2	78	5.82	39.9	2.4	0.8	0.11	0.07	3.38	0.21	3.59	94.1	74.0	20.0	6	S. loam
		Nyangua	5.56	48	2	83	1.04	42.61	1.87	0.53	0.17	0.09	2.65	0.22	2.87	92.4	72.2	20.8	7	S. loam
		Gia	4.97	51	3	88	2.63	39.23	1.87	0.53	0.14	0.09	2.63	0.76	3.39	77.6	76.9	17.1	6	L. sand

a OC = organic carbon
b OM = organic matter
c TN = total nitrogen