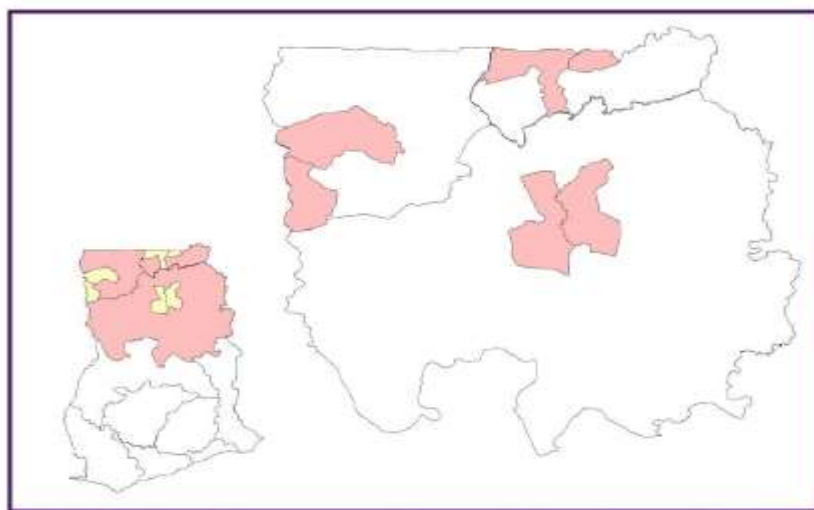




Baseline Survey Report



Soil Resources of Africa RISING Intervention Community in Ghana



Submitted to:

Africa RISING-West Africa Project-Ghana

Produced by

Francis M. Tetteh, Nketia, Kwabena Abrefa, Kwasi Appiah
Eric Asamoah, Anim Bofo (Council for Scientific and Industrial Research, Soil
Research Institute)

November 2013



TABLE OF CONTENTS

1.0 INTRODUCTION	4
1.1 Background	4
1.2 OBJECTIVES	5
2.0 MATERIAL AND METHODOLOGY	6
2.1 ENVIRONMENTAL CONDITIONS OF THE STUDY SITES.....	7
2.2 VEGETATION AND LAND USE.....	9
2.3 GEOLOGY AND RELIEF	10
2.4 SURVEY AND SOILS.....	11
2.4.1 SOIL PHYSICAL PROPERTIES.....	11
3.0 SOIL CHEMICAL PROPERTIES	15
3.1 Soil analytical methods	15
3.2 Soil Fertility Characteristics.....	15
3.3 Soil pH	16
3.4 Soil Organic Matter (SOM)	17
3.5 Total Nitrogen.....	17
3.6 Exchangeable Bases.....	17
3.7 Exchangeable/acidity	18
3.8 Effective CEC	18
3.9 Available P.....	18
4.0 EVALUATION.....	19
4.1 MAIZE.....	19
4.1.1 Climate.....	19
4.1.2 Soil.....	19
4.2 MILLET.....	20
4.2.1 Climate.....	20
4.2.2 Soil.....	20
4.3 SORGHUM.....	20
4.3.1 Climate.....	20
4.3.2 Soils.....	21
4.4 SUITABILITY ASSESSMENT OF THE OBSERVED SITES FOR CEREAL (MAIZE, MILLET AND SORGHUM) PRODUCTION.	21

5.0 CONCLUSIONS & RECOMMENDATIONS	24
6.0 REFERENCE.....	25
7.0 APPENDIX.....	26
7.1 CHEMICAL PROPERTIES OF SOILS IN THE NORTHERN REGIONAL SITES	26
7.2 PHYSICO PROPERTIES OF SOILS IN THE NORTHERN REGIONAL SITES	28
7.3 CHEMICAL PROPERTIES OF SOILS IN THE UPPER WEST REGIONAL SITES.....	31
7.4 CHEMICAL PROPERTIES OF SOILS IN THE UPPER WEST REGIONAL SITES.....	33
7.5 CHEMICAL PROPERTIES OF SOILS IN THE UPPER EAST REGIONAL SITES.....	34
7.6 PHYSICO PROPERTIES OF SOILS IN THE UPPER EAST REGIONAL SITES	36
7.7 SITE COORDINATES.....	37
7.8 MAPS.....	40

LIST OF TABLES

Table 1: Below shows communities where soils were sampled and described.	6
Table 2: A summary of soil depth and coarse-fragment content of the soils.....	12
Table 3: Fertility Ratings for Soil Indicators	16
Table 4: Rated Landscape soil requirement for Maize production	22
Table 5: Rated Landscape soil requirement for Millets production.....	22
Table 6: Rated Landscape soil requirement for Sorghum production	23

LIST OF FIGURES

Figure 1: Ecological Map of Ghana showing Project Districts.....	4
Figure 2: Annual Rainfall distribution in Ghana.....	8
Figure 3: (Figure 3 below shows the types of Vegetation in Ghana	10
Figure 4: Soils of Upper West Regional Sites	40
Figure 5: Soils of Upper East Regional Sites.....	41
Figure 6: Soils of Northern Regional Sites	42

1.0 INTRODUCTION

1.1 Background

The Africa RISING project ‘Sustainable Intensification of Key Farming Systems in the Sudano-Sahelian Zone of West Africa’ is being implemented within the 3 northern regions of Ghana (Upper East, Upper West and Northern Region) which occurs in the Sudan and Interior Savanna ecological zones of Ghana (as shown in Figure 1).

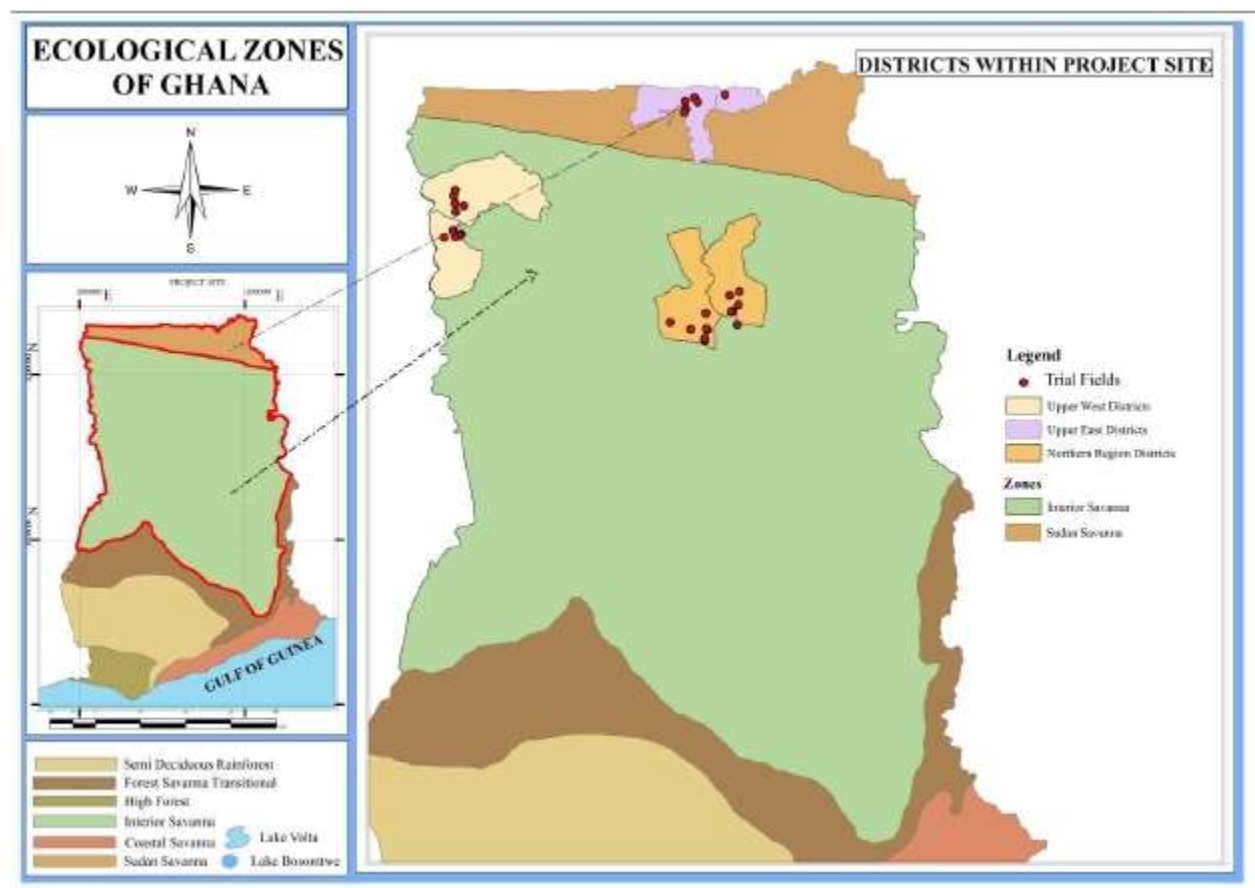


Figure 1: Ecological Map of Ghana Showing Project Districts

Soil characterization and mapping activities were undertaken within Twenty-five (25) communities, (i.e. 10 communities from the Upper West Region, 5 from Upper East Region and 10 from the Northern Region).

This report presents soil survey information that describes the physico-chemical properties of soils observed in each project implementation site for the production of cereal crops. Though soil was the main evaluation characteristic indicator, other physical properties such as climatic, relief, and the like were involved in the evaluation assessment.

1.2 OBJECTIVES

The objectives of the soil evaluation activity is to:

- Examine the major physical characteristics of the soils and their effect on cereal crop production
- Examine the chemical properties and fertility status of the soils
- Make recommendations on appropriate management practices of the soils for cereal production (maize, millet and sorghum).

2.0 MATERIALS AND METHODOLOGY

In the studies, the main activities that were undertaken involved soil identification, characterization, sampling and plotting of observation/sampling points on the GPS device.

Soil examinations were undertaken to a depth of 60cm but samples were collected to a depth of 30cm. Soil properties such as texture, coarse fragments, structure, effective soil depth, consistency and color were assessed. In the field, soil observations were made at every project implementation site in each community within each district.

Bulk samples were taken at randomly selected points at pre-determined depths of 30cm (i.e. 0 – 15 and 15 – 30cm).

All project implementing communities (as indicated in Table 1) were visited and soil assessment was made. Baseline soil information was derived from the detailed reconnaissance soil surveys of Navrongo – Bawku, Lawra-Wa, Yapei-Sawla soil survey regions (Adu, 1969; Adu and Asiamah, 2003a; 2003b).

Table 1: Below Shows Communities Where Soils Were Sampled and Described.

Region	District	Communities
Northern	Tolon	Tibognayili, Gbanjong,
	Kumbungu	Cheyohi, Tingoli, Pkerim
	SaveluguNanton	Jana Kpallung, Tibali, Botingli, Duko
Upper West	Wa West	Nyagli Passe Siriyyiri
	Wa Municipal	Zanko Guo

	Nadowli	Goriyiri Goli Natorduori Papu Gylli
Upper East	KasenaNankani West	Tekuru Bonia Nyangua Gia
	Bongo	Samboligo

2.1 ENVIRONMENTAL CONDITIONS OF THE STUDY SITES

The study sites form part of the Interior Savanna Ecological Zones consisting of the Guinea and Sudan Savannas which covers more than one-third of the land area of the country (as shown in Figure 1).

The climatic conditions of the study sites are characterized by well defined wet, and dry seasons of about equal durations with annual rainfall of between 700 – 1100 mm falling in a unimodal pattern. Monthly rainfalls increase gradually from March until a maximum is reached in August or September. Considerable variations exist between successive rainy seasons in time of onset, duration and amount of precipitation year after year.

Mean monthly temperatures are high throughout the year with mean monthly figures ranging from 25°C for the coolest in December to over 30°C for the hottest in April. The relative humidity recordings show high atmosphere moisture content in the nights and early mornings

during the rainy season. As indicated in Figure 2 below, is the mean monthly rainfall and temperatures' for Ghana.

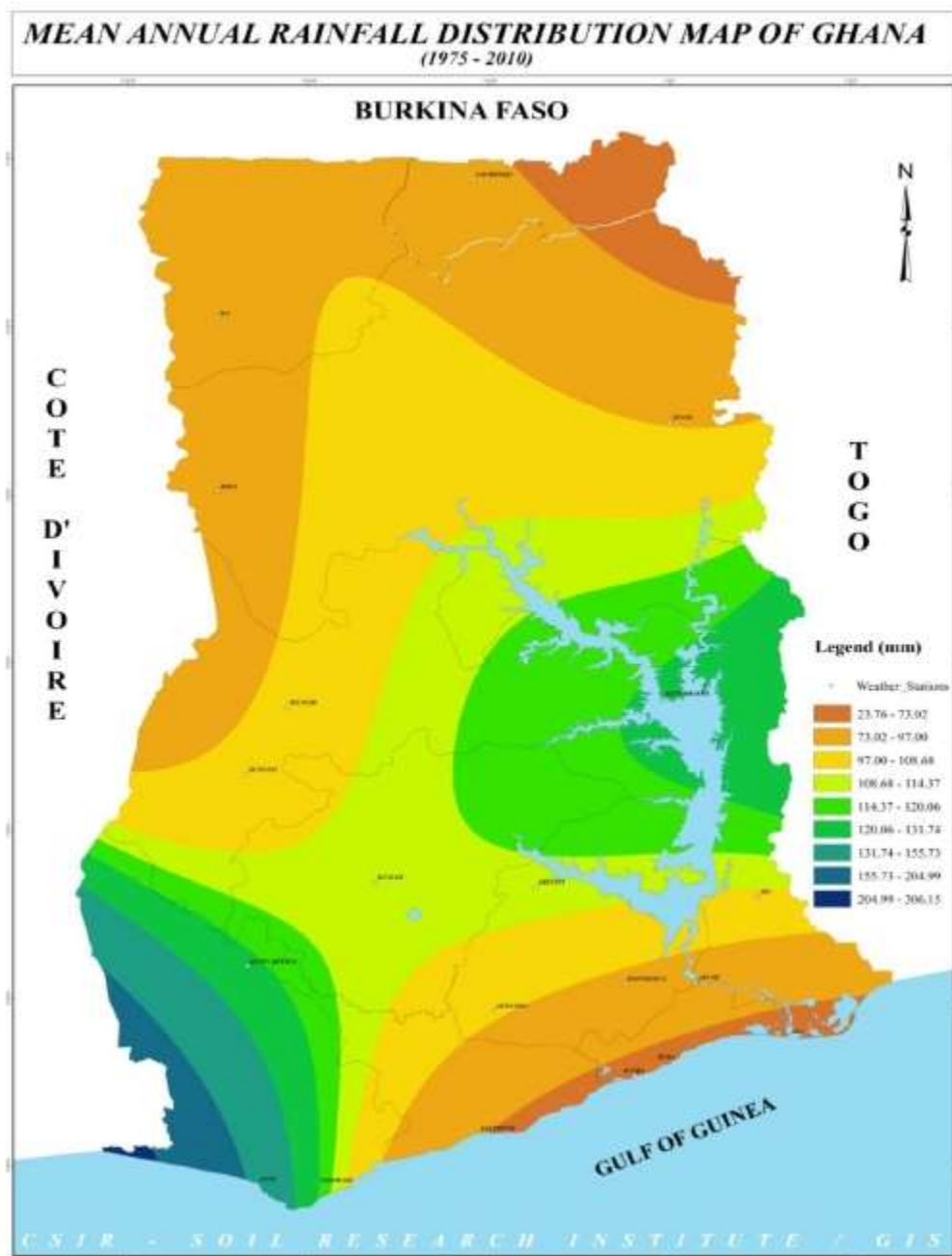


Figure 2: Annual Rainfall Distribution in Ghana

2.2 VEGETATION AND LAND USE

The natural vegetation within the study area is mainly grassland interspersed with short deciduous fire-resistant widely spaced trees. The main tree species are *Anogeissus leiocarpus*, *Butyrospermum parkii*, *Parkia clappertoniana*, *Mitragynainermis*, *Borassus aethiopum*, *Khayasenegalensis*, *Ceibapentandra* and *Adansonia digitata*. Common grasses of the zone includes: *Andropogon gayanus*, *Hyparrhenia spp*, *Tripogon minimum*, *Pennisetum pediccellatum*, *Cymbopogon gigantens*, *Schizachyrumsemiberbe*, *Heteropogon contortus* and *Hyparrheniarufa*. At the time of the study, most of the lands have been prepared waiting for the rains to sow (Figure 3 below shows the types of Vegetations in Ghana)

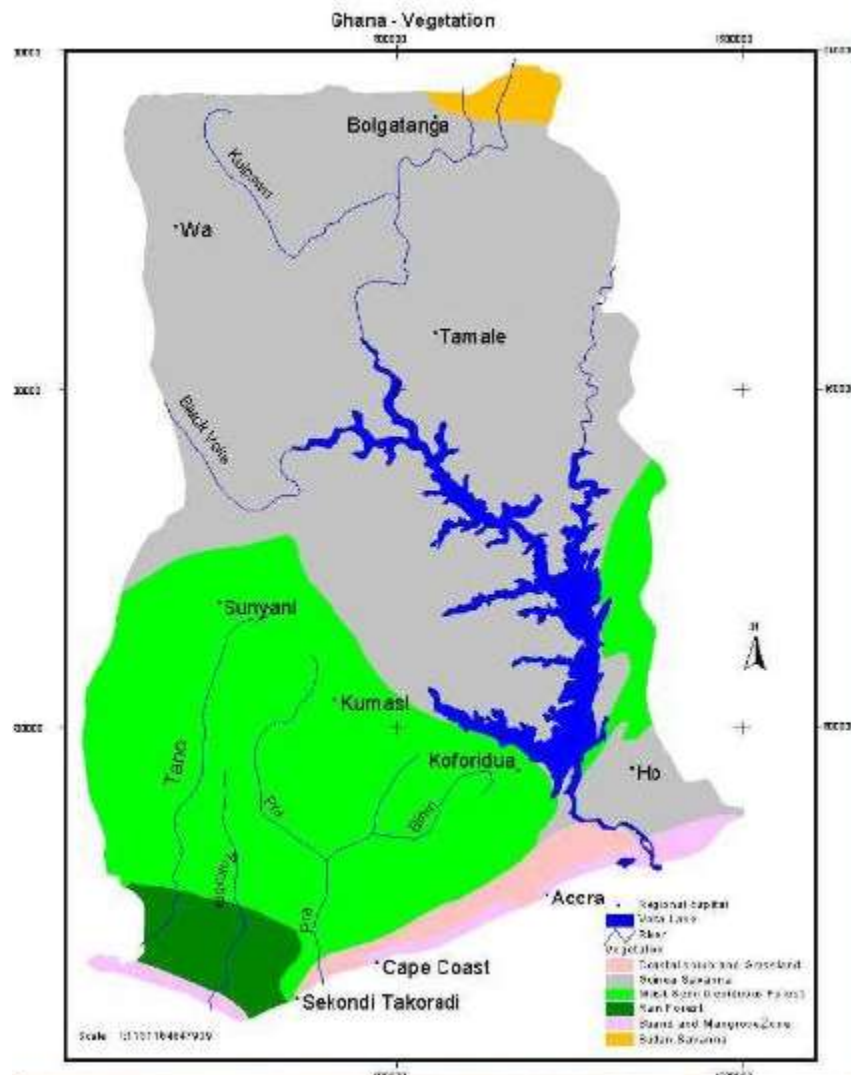


Figure 3: The Types of Vegetation in Ghana

2.3 GEOLOGY AND RELIEF

The underlying geology of the study area consists mainly of shales, mudstones (northern region) and granites (upper west and east). Alluvial deposits also 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 1-2%.

2.4 SURVEY AND SOILS

In the field, soil observation was made at the mother trial site in each project implementing community. Auger bores were made to examine the soil for depth, drainage, texture and coarse fragment content. Composite samples were taken at 3 randomly selected points at pre-determined depths of 0 – 15 and 15– 30cm.

Observations were further made when the existed changes in the topological structure of the landscape of the implementation area. Also, presence of rock outcrops and ironpan boulders were examined. The coordinates of each observed site was recorded by means of Global Positioning System (GPS).

2.4.1 SOIL PHYSICAL PROPERTIES

1. Upper East Region

Granite and the Upper Birimianphyllite are the main geological parent materials from which the observed soils in the region are developed.

However, 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. Major physical characteristics that will influence soil management include depth and texture. Coarse fragment content is not significantly present at the sites visited. However, it should be noted that, there are several soils that are characteristically gravelly and concretionary. Soil depth range from 25 to 60+ cm. Topsoil texture is coarse sandy loam or loamy sand and the subsoil texture is sandy loam. A summary of soil depth and coarse-fragment content of the soils at the project sites is presented in Table 2.

2. Upper West Region

The soils of the upper east and west regions are weathered products of cape coast granite influence by soil forming factors and soil forming processes.

The terrain of the area is generally gentle undulating with slopes of about 3 – 6%. The soils are generally moderately deep to deep with sandy loam textures. They are concretionary, gravelly and stony underlain by an indurated ironpan.

In the assessment of soil quality, coarse fragment and soil depth are the most important aspects considered. Table 2 below shows the coarse fragment content (concretion, gravels, stones and boulders) and soil depth (cm) in the districts visited.

3. *Northern Region*

The soils within the areas visited in the northern region are weathered products of volcanic shale and mudstone.

Morphologically, the soils within the visited districts in the northern region are grouped based on their effective depth. The depth of the soils are as very shallow (<15 cm), shallow (15 – 30 cm), slightly deep (30 – 60 cm), moderately deep (60 – 100 cm), deep (100 – 150 cm) and very deep (>150cm). The soils at the visited districts (Savelugu, Tolon and Kunbungu) of the northern region possess these characteristics;

- They are shallow (15 -30cm) to very shallow (<15cm) underlain by ironpan.
- They are medium to light textured (loam – loamy sand)
- They are concretionary, gravelly and contains ironpan boulders
- The terrain is flat with gentle slopes (1 – 3%)

Table 2: A Summary of Soil Depth and Coarse-Fragment Content of the Soils

Region	District	Community	Soil Depth(cm)	Coarse Fragment	% Coarse Fragment	Remarks
		Nyagli	45	few	3	Underlain by

Upper West	Wa West					indurated ironpan
		Pase	60	few	3	Underlain by indurated ironpan
		Siriyiri	30	few	3	Underlain by indurated ironpan
		Zanko	35	few	5	Underlain by indurated ironpan
		Guo	80	nil	10	(Moderately deep) Underlain by indurated ironpan
	Nadoli	Goriyiri	65	Common	15	Underlain by indurated ironpan
		Goli,	80+	Few	5	Moderately Deep
		Natorduori	75+	Nil		Moderately Deep
		Papu	30	Nil		Underlain by indurated ironpan
		Grill	45	common	8	Underlain by indurated ironpan
Upper East	KassinaNankana	Bonia	35	many	15	Underlain by indurated ironpan
		Tekuro	80+	few	3	Moderately deep
		Nyangua	100	few	3	Deep
		Gia	75	Common	10	Moderately Deep

	Bongo	Sambobigo	50	few	3	Underlain by indurated ironpan
Northern	Savulugu	Jana,	55	few	4	Underlain by indurated ironpan
		Duko	45	few	4	Underlain by indurated ironpan
		Botingli	40	common	10	Underlain by indurated ironpan
		Tibali	75	few	5	Underlain by indurated ironpan
		Kpallung	25	Common	10	Underlain by indurated ironpan
	Tolon	Tibognayili,	30	Many	20	Underlain by indurated ironpan
		Tingoli,	45	Common	15	Underlain by indurated ironpan
		Gbanjong	50	Common	15	Underlain by indurated ironpan
	Kumbungu	Cheyohi,	55	Common	10	Underlain by indurated ironpan
		Pkerim	60	few	5	Underlain by indurated ironpan

3.5 SOIL CHEMICAL PROPERTIES

3.5.1 Soil analytical methods

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

- ◆ *Soil texture* – determined on particles < 2 mm in diameter by the hydrometer method (Bouyoucous, 1962)
- ◆ *Soil reaction (pH)* – measured in a soil:water ratio of 1:1 using a glass electrode pH meter
- ◆ *Organic matter (OM)* – determined using the modified method of Walkley and Black (Nelson and Summers, 1982)
- ◆ *Total nitrogen (N)* – determined by Kjeldahl digestion and distillation (Reeuwijk, 1986)
- ◆ *Available phosphorus* – determined colorimetrically after extraction with Bray's P1 solution
- ◆ *Available potassium* – obtained by flame photometry after extraction with Bray's P1 solution
- ◆ *Exchangeable bases (Ca, Mg, K & Na)* – determined in neutral ammonium leachate. Ca & Mg in the leachate were determined by EDTA titration while K & Na, by flame photometry
- ◆ *Exchangeable acidity* – determined by titration in 1.0N potassium chloride (KCl) extract

Effective cation exchange capacity (ECEC) – obtained by the summation of exchange acidity and exchangeable bases

3.5.2 Soil Fertility Characteristics

Soil fertility characteristics show that nutrient levels are generally low to moderate with some communities showing higher values for some parameters than others.

Table 3: Fertility Ratings for Soil Indicators

<i>Parameter</i>	<i>Range</i>	<i>Mean</i>	<i>Fertility Rating</i>
pH	4.97 - 7.59	6.21	Good
Soil Organic Matter (%)	0.28 – 3.93	1.09	Low
Available P (mg/kg)	1.04 – 67.77	7.23	Low
Exchangeable K (cmolc/kg)	0.04 – 0.57	0.14	Low
ECEC (cmolc/kg)	2.15 – 13.54	4.74	Low

3.5.3 Soil pH

At Savelugu (SV), soil pH values ranged from slightly acidic 6.0 to slightly alkaline 7.6) with most of the sample pH values near neutral.

At Kumbugu (KB) sample pH values ranged from moderately acidic to slightly acidic. The pH values are good for the cultivation of most crops.

Samples collected at Tolon were of pH values ranging from moderately to slightly acidic.

The best soil pH values for crop production range from 5.5 to 7.0 i.e. from moderately acidic to neutral. The soil pH values gathered from all the sites fall within this range and therefore desirable and will require no lime application (Table 1).

3.5.4 Soil Organic Matter (SOM)

Soil organic matter levels were low in the whole of the following sites: WW, ND, T, KN, BO, KB (except at one point where organic matter was moderate), and SV (except at one point where SOM was high i.e. > 3.0% and two other points with moderate values).

3.5.5 Total Nitrogen

Total N levels ranged from low to moderate with a greater proportion of the samples with low levels across all sites, i.e. less than 0.1% (Table 1). Generally, Total N levels follow the same trend as soil organic matter.

3.5.6 Exchangeable Bases

Calcium

Calcium levels were low except at a few points where exch. Ca levels were above 5.0 cmolc/kg.

Magnesium

Exchangeable Mg levels ranged from low to moderate.

Potassium

Exchangeable K levels were very low (<0.15). In soils at WW and T, all the samples were low in K content. At ND, two out of the four sampled areas had moderate K levels. At KB one of the sites was adequate in K and the other two sites were moderate in K content.

Sodium

Exchangeable Na levels were low and desirable at all sites within acceptable limits. Exchangeable Na formed less than 5% of ECEC of soils at all sites.

3.5.7 Exchangeable/acidicity

Exchangeable acidity levels ranged from 0.05 to 0.76 cmolc/kg with almost all samples having values < 0.50 cmol/kg soil

3.5.8 Effective CEC

The effective CEC values were low across all sites i.e, <10.00 cmol/kg. It was only one point in Savelugu that had 13.54 cmolc/kg. Management practices that can improve CEC (application of organic manure, compost, and soil conservation practices) are recommended.

3.5.9 Available P

Available phosphorus levels were generally low (<10.00 ppm P) and declined in concentration from top- to sub-soils. In Savelugu, however, 4 out of the 6 sites had from moderate to high P levels. Application of phosphate fertilizers (TSP, SSP, or rockphosphate) is recommended.

4.0 EVALUATION

SOIL AND ENVIRONMENTAL REQUIREMENT FOR CEREALS (MAIZE, MILLET AND SORGHUM)

4.1 MAIZE

4.1.1 Climate

Maize grows in the temperature range of 14°C – 40°C. The growth of the crop is optimal at temperature range of 18°C – 32°C with evenly distributed rainfall of 500 mm – 1500 mm in the growing cycle.

Maize is very sensitive to moisture stress from the beginning of flowering until grain formation (50 – 100 days from the day of planting).

4.1.2 Soil

Maize grows on many types of soils. Well drained, well aerated, deep loam and silty loam soils with adequate organic matter is best for the crop. Soils with water logging must be avoided. Soil pH must be in the range 5.8 – 7.8 for optimal growth but can tolerate 5.2 – 8.5 of pH.

4.2 MILLET

4.2.1 Climate

Millet grows and matures under conditions of low rainfall and soil fertility, with little attention. The temperature range for growth is 16⁰C – 32 ⁰C. The distribution of rainfall throughout the growing season is more important than the total precipitation in that period. Millet grows in a region that can secure a precipitation of 150 – 1350 mm/growing cycle. Optimum growth is achieved in regions with 300 – 600 mm/growing cycle. Millet is drought resistant but water is required at flowering. A heavy rain flowering however interferes with fertilization and causes reduce yield.

4.2.2 Soil

Millet does well with loamy to clay soils. Soils with at least 50 cm depth can be tolerated but optimum depth of 200 cm is needed. Well drained, aerated with pH range of 5.2 – 8.2 but optimum pH is 5.6 – 7.6.

4.3 SORGHUM

4.3.1 Climate

Sorghum grows in areas with at least 150 mm rainfall in the growing cycle but precipitation of 400 – 900 mm is best for optimum yield. A temperature range of 21 – 32 °C guaranties an optimum yield but a night temperature of below 15°C for 5 nights completely hinders anthesis. Sorghum is able to withstand areas of water logging as compared to the other cereals in the tropics other than rice.

4.3.2 Soils

The crop prefers many soil types but the optimum is obtained on heavier textured soils. Soils with vertic (cracking and swelling) properties are mostly recommended. The depth of the soils should be at least 50cm with a pH range of 5.5 – 8.2.

4.4 SUITABILITY ASSESSMENT OF THE OBSERVED SITES FOR CEREAL (MAIZE, MILLET AND SORGHUM) PRODUCTION.

Suitability ratings of the soils are evaluated in reference to; (1) Climate (Temperature, Rainfall and Humidity), (2) Landscape features (Slope, Relief and stoniness) and (3) Soil features affecting suitability (Soil texture, soil depth, and coarse fragment content). In this assessment of suitability, information considered in rating these soils for cereal production are ;

- Soil Texture
- Soil Depth
- Soil Drainage
- Coarse Fragment content and
- Topography

Some landscape and soil requirement for cereal production have been rated according to Sys *et al* (1993) and presented in the Table 3-5 below;

Table 4: Rated Landscape Soil Requirement for Maize Production

Land Characteristics	RATING			
	Highly Suitable	Moderately Suitable	Marginally Suitable	Not Suitable
Topography (t) Slope (%)	0-4	4 – 8	8 - 16	>16
Drainage (w)	Well to mod. well	Somewhat poor	Poor	Poor to not drainable
Texture	SiC, SiCL, SC, SCL, L	C, SL, LfS, LS	fS, S, LcS	
Coarse fragment (vol %)	0 - 15	15 – 35	35 -55	>55
Soil depth (cm)	>100 - 75	75 -50	50 – 20	<20

Table 5: Rated Landscape Soil Requirement for Millets Production

Land Characteristics	RATING			
	Highly Suitable	Moderately Suitable	Marginally Suitable	Not Suitable
Topography (t) Slope (%)	0-4	4 – 8	8 - 16	>16
Drainage (w)	Well to mod. well	Somewhat poor	Poor	Poor to not drainable
Texture	SiC, SiCL, SC, SCL, L	C, SL, LfS, LS	fS, S, LcS	
Coarse fragment (vol %)	0 - 15	15 – 35	35 -55	>55
Soil depth (cm)	>90 - 50	50 - 20	20 - 10	<10

Table 6: Rated Landscape Soil Requirement for Sorghum Production

Land Characteristics	RATING			
	Highly Suitable	Moderately Suitable	Marginally Suitable	Not Suitable
Topography (t) Slope (%)	0-4	4 – 8	8 - 16	>16
Drainage (w)	Well to mod. well	Somewhat poor	Poor	Poor to not drainable
Texture	SiC, SiCL, SC, SCL, L	C, SL, LfS, LS	fS, S, LcS	
Coarse fragment (vol %)	0 - 15	15 – 35	35 -55	>55
Soil depth (cm)	>100 - 75	75 -50	50 – 20	<20

5.0 CONCLUSIONS & RECOMMENDATIONS

- The soils are shallow (15 – 30cm) to moderately deep (60 – 100cm)
- They are gravelly and concretionary
- They are susceptible to erosion because of the light to medium textures of the topsoil.
- The topsoil tends to be droughty while the subsoil has moderate to poor moisture holding capacity because of the many (15 – 25%) gravels and concretions.
- The presence of indurated ironpan and ironpan boulders restrict root movement.

Hence, it is recommended that;

- The research interventions should adopt soil fertility improvement and management
- Erosion control measures should be encouraged to reduce loss of top soils and if possibly, limit the use of tractors for ploughing and encourage animal ploughing and ridging.

6.0 REFERENCE

- Adu, S. V. 1969. Soils of the Navrongo-Bawku Area, Upper Region, Ghana. Memoir No. 5. Soil Research Institute, Kumasi
- Adu, S. V. and Asiamah, R. D. 2003a. Soils of the Yapei – Sawla Road area, Northern Region, Ghana. Memoir No. 16, Soil Research Institute, Kumasi
- Adu, S. V. and Asiamah, R. D. 2003b. Soils of the Lawra – Wa Region, Upper West Region, Ghana. Memoir No. 18, soil Research Institute, Kumasi
- Bray, R. H. and L. T. Kurtz 1945. Determination of total organic and available forms of phosphorus in soil. *Soil Science* , 599: 39-45
- Bouyoucos, G. J. 1962. Hydrometer method improved for making particle size analysis of soils. *Agron. Jour.* 54: 464-465
- Nelson, D. W. and Sommers, L. W. 1982 Total carbon, organic carbon and organic matter. *In*: Page, A. L., R. H. Miller and D. R. Keeney (eds.). *Methods of soil analysis*. 2. Chemical and Microbiological Properties. *Agronomy* 9: 301 – 312
- Sys, C., Van Ranst, E., Debaveye, J. and Beernaert, F. 1993. LAND EVALUATION PART III. CROP REQUIREMENTS. International Training Centre for Post Graduate Soil Scientists, University of Ghent. Agricultural Publications No. 7, General Administration for Development Co-operation, Brussels,

APPENDIX

CHEMICAL PROPERTIES OF SOILS IN THE NORTHERN REGIONAL SITES

	pH 1:1				EXCHANGEABLE CATION me/100g					Exch. A	E.C.E.C	% Base	A BR.
Districts/ Communities	H2O	% ORG. C	% TOTAL N.	% ORG. M	Ca	Mg	K	Na	T.E.B	(Al + H)	Me/100g	Sat	PPn
olon/Tibognayili 0-15	6.25	0.81	0.08	1.40	5.07	1.60	0.12	0.09	6.88	0.13	7.01	98.14	4.31
olon/Tibognayili 5-30	6.89	0.69	0.05	1.19	6.94	2.40	0.07	0.04	9.46	0.10	9.56	98.95	3.75
olon/Gbanjong 0- 5	6.62	0.53	0.13	0.91	2.14	0.27	0.08	0.04	2.53	0.10	2.63	96.20	5.02
olon/Gbanjong 15- 30	5.84	0.44	0.09	0.76	2.67	0.53	0.07	0.04	3.31	0.22	3.53	93.77	1.67
olon/Tingoli 0-15	5.99	0.59	0.12	1.02	2.94	1.07	0.08	0.04	4.13	0.20	4.33	95.38	3.59
olon/Tingoli 5-30	6.43	0.50	0.09	0.86	2.40	1.60	0.07	0.04	4.11	0.13	4.24	96.94	2.71
olon/Farm 2 0-15	6.05	0.56	0.06	0.97	3.20	1.07	0.07	0.04	4.38	0.13	4.51	97.12	6.70

olon/Farm 2 15-30	5.67	0.41	0.03	0.71	3.47	1.07	0.06	0.04	4.64	0.24	4.88	95.08	1.28
umbugu/Cheyohi2 15	5.61	0.72	0.09	1.24	1.87	1.07	0.16	0.09	3.19	0.25	3.44	92.73	9.17
umbugu/Cheyohi2 5-30	5.72	0.69	0.05	1.19	3.47	1.07	0.07	0.04	4.65	0.20	4.85	95.88	7.18
umbugu/Cheyohi2- 0-15	6.35	0.81	0.10	1.40	2.94	2.14	0.24	0.16	5.48	0.11	5.59	97.98	9.01
umbugu/Cheyohi2- 15-30	6.76	0.44	0.07	0.76	3.74	2.14	0.19	0.09	6.16	0.12	6.28	98.09	1.36
umbugu/Pkerim 0- 5	6.67	0.99	0.09	1.71	4.54	2.40	0.57	0.30	7.82	0.13	7.95	98.36	3.75
umbugu/Pkerim 5-30	6.32	0.81	0.07	1.40	4.27	2.67	0.22	0.13	7.29	0.13	7.42	98.25	2.35
avelugu/TB 0-15	6.11	0.96	0.09	1.66	5.34	1.07	0.16	0.13	6.70	0.13	6.83	98.10	67.7
avelugu/TB 15-30	6.20	0.75	0.06	1.29	5.34	1.34	0.13	0.09	6.90	0.12	7.02	98.29	2.35
avelugu/Kpalung 15	7.59	2.28	0.09	3.93	9.88	3.47	0.09	0.05	13.49	0.05	13.54	99.63	13.1
avelugu/Kpalung 5-30	7.19	1.81	0.07	3.12	6.68	1.60	0.09	0.05	8.42	0.05	8.47	99.41	3.55

avelugu/Botingli 0-5	7.09	0.81	0.11	1.40	5.61	0.80	0.19	0.13	6.73	0.05	6.78	99.26	8.03
avelugu/Botingli 5-30	6.82	0.60	0.08	1.03	5.34	1.07	0.13	0.09	6.63	0.10	6.73	98.51	4.13
avelugu/Duko 0-15	6.34	0.99	0.13	1.71	2.67	0.80	0.12	0.09	3.68	0.10	3.78	97.36	5.02
avelugu/Duko 15-30	6.06	0.81	0.09	1.40	3.47	2.14	0.12	0.06	5.79	0.13	5.92	97.81	1.20
avelugu/Duko2 0-5	6.37	0.81	0.11	1.40	3.20	0.53	0.19	0.13	4.05	0.11	4.16	97.36	18.3
avelugu/Duko2 15-30	6.10	0.75	0.08	1.29	2.40	0.27	0.13	0.09	2.89	0.13	3.02	95.69	2.95
avelugu/Jana 0-5	6.64	1.11	0.05	1.91	5.87	2.67	0.16	0.13	8.83	0.11	8.94	98.77	22.2
avelugu/Jana 5-30	6.98	0.84	0.03	1.45	5.87	1.87	0.13	0.09	7.96	0.10	8.06	98.76	7.18

PHYSICO PROPERTIES OF SOILS IN THE NORTHERN REGIONAL SITES

Sample	Districts/ Communities	MECHANICAL ANALYSIS			TEXTURE
		% SAND	% CLAY	% SILT	
	Tolon/Tibognayili 0-15	54.30	10.00	35.70	sandy loam
	Tolon/Tibognayili 15-30	52.78	12.00	35.22	sandy loam
	Tolon/Gbanjong 0-15	57.38	8.00	34.62	sandy loam
	Tolon/Gbanjong 15-30	54.88	5.00	40.12	sandy loam
	Tolon/Tingoli 0-15	68.56	11.00	20.44	sandy loam
	Tolon/Tingoli 15-30	75.80	7.00	17.20	sandy loam
	Tolon/Farm 2 0-15	66.42	7.00	26.58	sandy loam
	Tolon/Farm 2 15-30	58.32	12.00	29.68	sandy loam
	Kumbugu/Cheyohi2 0-15	49.90	9.00	41.10	loam
	Kumbugu/Cheyohi2 15-30	42.18	10.00	47.82	loam
	Kumbugu/Cheyohi 2-1 0-15	50.04	6.00	43.96	sandy loam
	Kumbugu/Cheyohi 2-1 15-30	49.16	8.00	42.84	sandy loam

	Kumbugu/Pkerim 0-15	67.46	8.40	24.14	sandy loam
	Kumbugu/Pkerim 15-30	49.16	8.00	42.84	loam
	Savelugu/TB 0-15	44.48	11.00	44.52	loam
	Savelugu/TB 15-30	41.74	14.00	44.26	loam
	Savelugu/Kpalung 0-15	48.58	10.40	41.02	loam
	Savelugu/Kpalung 15-30	48.96	10.00	41.04	loam
	Savelugu/Botingli 0-15	76.22	10.00	13.78	sandy loam
	Savelugu/Botingli 15-30	77.00	11.00	12.00	sandy loam
	Savelugu/Duko 0-15	52.74	12.00	35.26	sandy loam
	Savelugu/Duko 15-30	47.42	16.00	36.58	loam
	Savelugu/Duko 2 0-15	50.24	10.40	39.36	loam
	Savelugu/Duko 2 15-30	46.44	12.00	41.56	loam

	Savelugu/Jana 0-15	52.88	12.00	35.12	sandy loam
	Savelugu/Jana 15-30	54.48	12.00	33.52	sandy loam

CHEMICAL PROPERTIES OF SOILS IN THE UPPER WEST REGIONAL SITES

	pH 1:1				EXCHANGEABLE CATION me/100g					Exch. A	E.C.E.C	% Base	AV BRA
Districts/ Communities	H ₂ O	% ORG. C	% TOTAL N.	% ORG. M	Ca	Mg	K	Na	T.E.B	(Al + H)	Me/100g	Sat	PPm
Wa West/Zanko 0-15	6.70	0.38	0.15	0.66	1.87	1.07	0.12	0.09	3.15	0.10	3.25	96.92	23.92
Wa West/Zanko 15-30	6.08	0.32	0.12	0.55	2.00	0.67	0.12	0.09	2.88	0.13	3.01	95.68	1.12
Wa West/Guo 0-15	6.73	0.57	0.08	0.98	2.14	1.07	0.12	0.09	3.42	0.10	3.52	97.16	3.83
Wa West/GUO 15-30	6.77	0.48	0.06	0.83	2.14	1.34	0.12	0.04	3.64	0.10	3.74	97.33	22.32
Wa West/Nyagli 0-15	5.78	0.54	0.06	0.93	3.20	1.60	0.04	0.04	4.89	0.13	5.02	97.41	4.38
Wa West/Nyagli 15-30	6.32	0.32	0.03	0.55	2.14	1.60	0.05	0.04	3.83	0.13	3.96	96.72	4.15
Wa West/Pase 0-15	6.45	0.64	0.13	1.10	3.20	2.40	0.08	0.04	5.72	0.13	5.85	97.78	10.12

Pa West/Pase 5-30	6.73	0.60	0.09	1.03	5.34	1.87	0.12	0.09	7.42	0.10	7.52	98.67	3.83
Pa West/Siriyiri 5-15	6.06	0.86	0.12	1.48	4.01	1.07	0.09	0.04	5.21	0.13	5.34	97.57	8.29
Pa West/Siriyiri 5-30	6.45	0.57	0.08	0.98	4.54	1.87	0.09	0.04	6.55	0.13	6.68	98.05	5.34
adowli/Goriyiri 0- 5	6.64	0.44	0.12	0.76	2.14	0.53	0.21	0.17	3.06	0.13	3.19	95.92	2.63
adowli/Goriyiri 5-30	5.35	0.37	0.06	0.64	1.87	0.27	0.19	0.13	2.46	0.53	2.99	82.26	1.75
adowli/Papu 5-15	6.25	0.32	0.08	0.55	1.07	0.80	0.11	0.04	2.03	0.13	2.16	93.97	4.70
adowli/Papu 15- 0	5.75	0.28	0.05	0.48	1.34	1.07	0.12	0.09	2.62	0.28	2.90	90.33	7.97
adowli/Gyilli 0- 5	6.26	0.38	0.08	0.66	1.60	0.27	0.11	0.04	2.02	0.13	2.15	93.95	6.30
adowli/Gyilli 15- 0	5.96	0.22	0.05	0.38	1.87	0.27	0.13	0.09	2.36	0.21	2.57	91.82	2.79
adowli/Natorduori 5-15	6.35	0.69	0.07	1.19	2.40	1.34	0.21	0.17	4.13	0.13	4.26	96.95	15.3
adowli/Natorduori 5-30	6.91	0.44	0.04	0.76	2.14	0.27	0.09	0.04	2.55	0.11	2.66	95.86	2.47
adowli/Goli 5-15	6.20	0.32	0.10	0.55	1.34	0.80	0.14	0.09	2.37	0.13	2.50	94.80	10.2
adowli/Goli 5-30	6.06	0.16	0.06	0.28	1.34	0.80	0.11	0.09	2.33	0.14	2.47	94.34	1.83

CHEMICAL PROPERTIES OF SOILS IN THE UPPER WEST REGIONAL SITES

Sample	Districts/ Communities	MECHANICAL ANALYSIS			TEXTURE
		% SAND	% CLAY	% SILT	
	Wa West/Zanko 0-15	68.50	8.00	23.50	sandy loam
	Wa West/Zanko 15-30	64.10	11.00	24.90	sandy loam
	Wa West/Guo 0-15	62.04	6.40	31.56	sandy loam
	Wa West/GUO 15-30	55.58	14.00	30.42	sandy loam
	Wa West/Nyagli 0-15	56.66	12.00	31.34	sandy loam
	Wa West/Nyagli 15-30	50.50	14.00	35.50	loam
	Wa West/Pase 0-15	64.92	8.00	27.08	sandy loam
	Wa West/Pase 15-30	53.80	11.00	35.20	sandy loam
	Wa West/Siriyiri 0-15	44.68	13.00	42.32	loam
	Wa West/Siriyiri 15-30	41.82	15.60	42.58	loam

	Nadowli/Goriyiri 0-15	74.66	9.00	16.34	sandy loam
	Nadowli/Goriyiri 15-30	83.30	4.00	12.70	loamy sand
	Nadowli/Papu 0-15	82.22	9.00	8.78	loamy sand
	Nadowli/Papu 15-30	68.76	18.00	13.24	sandy loam
	Nadowli/Gyilli 0-15	85.04	6.00	8.96	loamy sand
	Nadowli/Gyilli 15-30	79.72	8.00	12.28	loamy sand
	Nadowli/Natorduori 0-15	75.80	7.00	17.20	sandy loam
	Nadowli/Natorduori 15- 30	72.34	7.00	20.66	sandy loam
	Nadowli/Goli 0-15	85.20	6.00	8.80	loamy sand
	Nadowli/Goli 15-30	84.38	6.00	9.62	loamy sand

CHEMICAL PROPERTIES OF SOILS IN THE UPPER EAST REGIONAL SITES

	pH 1:1				EXCHANGEABLE CATION		Exch. A	E.C.E.C	% Base
--	--------	--	--	--	---------------------	--	---------	---------	--------

Page					me/100g							
Districts/ Communities	H2O	% ORG. C	% TOTAL N.	% ORG. M	Ca	Mg	K	Na	T.E.B	(Al + H)	Me/100g	Sat
asenaNankana/Bonia 0-5	5.59	0.66	0.03	1.14	1.87	0.80	0.14	0.13	2.94	0.22	3.16	93.05
asenaNankana/Bonia 15-20	5.69	0.45	0.02	0.78	2.40	0.80	0.11	0.07	3.38	0.21	3.59	94.14
asenaNankana/Nyangua 0-15	5.67	0.75	0.03	1.29	1.74	0.40	0.19	0.13	2.46	0.21	2.67	92.14
asenaNankana/Nyangua 15-30	5.56	0.48	0.02	0.83	1.87	0.53	0.17	0.09	2.65	0.22	2.87	92.35
asenaNankana/Tekuru 0-5	5.30	0.57	0.04	0.98	1.60	0.80	0.14	0.08	2.62	0.54	3.16	82.89
asenaNankana/Tekuru 15-20	5.81	0.54	0.02	0.93	3.47	1.07	0.12	0.09	4.75	0.43	5.18	91.69
asenaNankana/Gia 0-5	5.28	0.63	0.04	1.09	1.87	0.53	0.16	0.09	2.65	0.50	3.15	84.11
asenaNankana/Gia 15-20	4.97	0.51	0.03	0.88	1.87	0.53	0.14	0.09	2.63	0.76	3.39	77.56
asenaNankana/Farm 0-5	5.59	0.54	0.05	0.93	2.68	0.80	0.27	0.15	3.90	0.42	4.32	90.29

5												
KasenaNankana/Farm 15-30	5.41	0.36	0.03	0.62	1.60	0.27	0.09	0.04	2.00	0.45	2.45	81.64
ongongo/Sambobigo 0-15	6.41	0.41	0.04	0.71	1.87	1.07	0.17	0.13	3.24	0.13	3.37	96.14
ongongo/Sambobigo 15-30	6.31	0.31	0.03	0.53	1.34	1.07	0.07	0.04	2.52	0.13	2.65	95.10

PHYSICO PROPERTIES OF SOILS IN THE UPPER EAST REGIONAL SITES

Sample	Districts/ Communities	MECHANICAL ANALYSIS			TEXTURE
		% SAND	% CLAY	% SILT	
	KasenaNankana/Bonia 0-15	77.36	8.00	14.64	sandy loam
	KasenaNankana/Bonia 15-30	74.00	6.00	20.00	sandy loam
	KasenaNankana/Nyangua 0-15	78.14	6.00	15.86	loamy sand
	KasenaNankana/Nyangua 15-30	72.20	7.00	20.80	sandy loam
	KasenaNankana/Tekuru	81.74	8.00	10.26	loamy sand

	0-15				
	KasenaNankana/Tekuru 15-30	76.94	6.00	17.06	loamy sand
	KasenaNankana/Gia 0-15	81.72	6.00	12.28	loamy sand
	KasenaNankana/Gia 15-30	76.94	6.00	17.06	loamy sand
	KasenaNankana/Farm 0-15	84.22	6.00	9.78	loamy sand
	KasenaNankana/Farm 15- 30	82.98	6.00	11.02	loamy sand
	Bongo/Sambobigo 0-15	82.58	6.40	11.02	loamy sand
	Bongo/Sambobigo 15-30	72.26	10.00	17.74	sandy loam

SITE COORDINATES

Community	LATITUDE			LONGITUDE		
	D	M	S	D	M	S
Zanko	10	3	20	2	35	23.848
Guo	10	2	53	2	35	59.444
Nyagli	10	4	44	2	38	31.81

Passe	10	2	4	2	41	59.834
Siriyiri	10	2	15	2	37	39.982
Papu	10	14	17	2	34	24.613
Gyilli	10	11	57	2	37	37.57
Natorduori	10	15	10	2	37	53.068
Goli	10	18	7	2	38	14.941
Goriyiri	10	20	25	2	37	49.555
Bonia	10	51	59	1	7	54.286
Nyangua	10	56	26	1	4	32.392
Tekuru	10	54	43	1	3	12.451
Gia	10	54	59	1	8	6.779
	10	50	38	1	8	25.919
Samboligo	10	57	31	0	52	30.503
Tibognayili	9	29	33	1	13	54.199
Gbanjong	9	26	50	1	5	51.451
Tingoli	9	22	42	1	0	22.536
	9	23	13	1	0	27.573
Cheyohi 2	9	26	37	0	59	29.88
Cheyohi 2-1	9	27	2	0	59	44.463
Pkerim	9	33	6	0	59	58.289
Tibali	9	39	58	0	50	49.738
Kpallung	9	41	31	0	47	0.301

Botingli	9	36	25	0	47	25.145
Duko 1	9	33	54	0	49	28.534
Duko 2	9	33	39	0	50	13.047
Jana	9	28	39	0	47	53.865

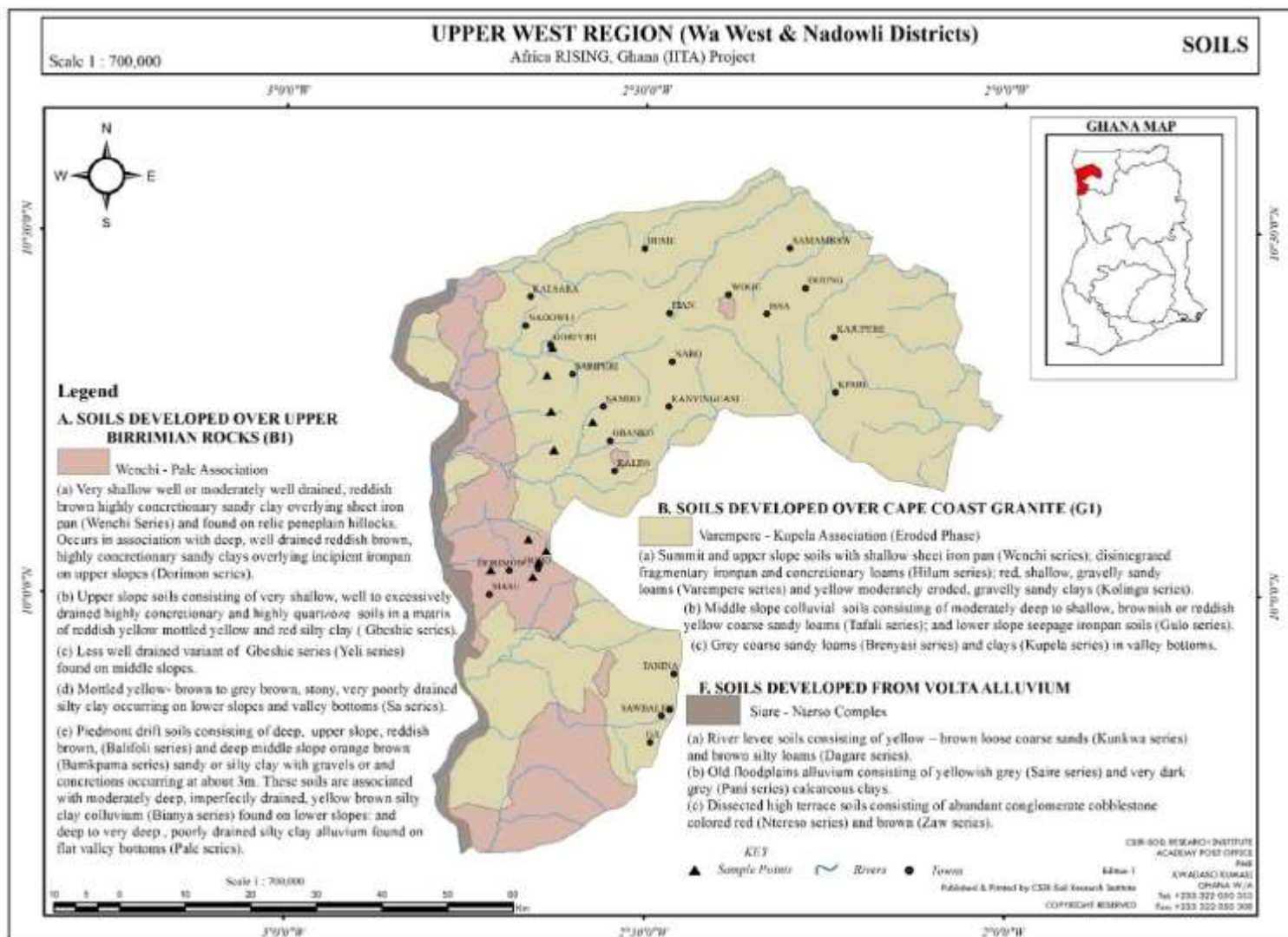


Figure 4: Soils of Upper West Regional Sites

UPPER EAST REGION (Kassina Nankana, Bongo Districts)

Africa RISING, Ghana (IITA) Project

SOILS

SCALE 1 : 300,000

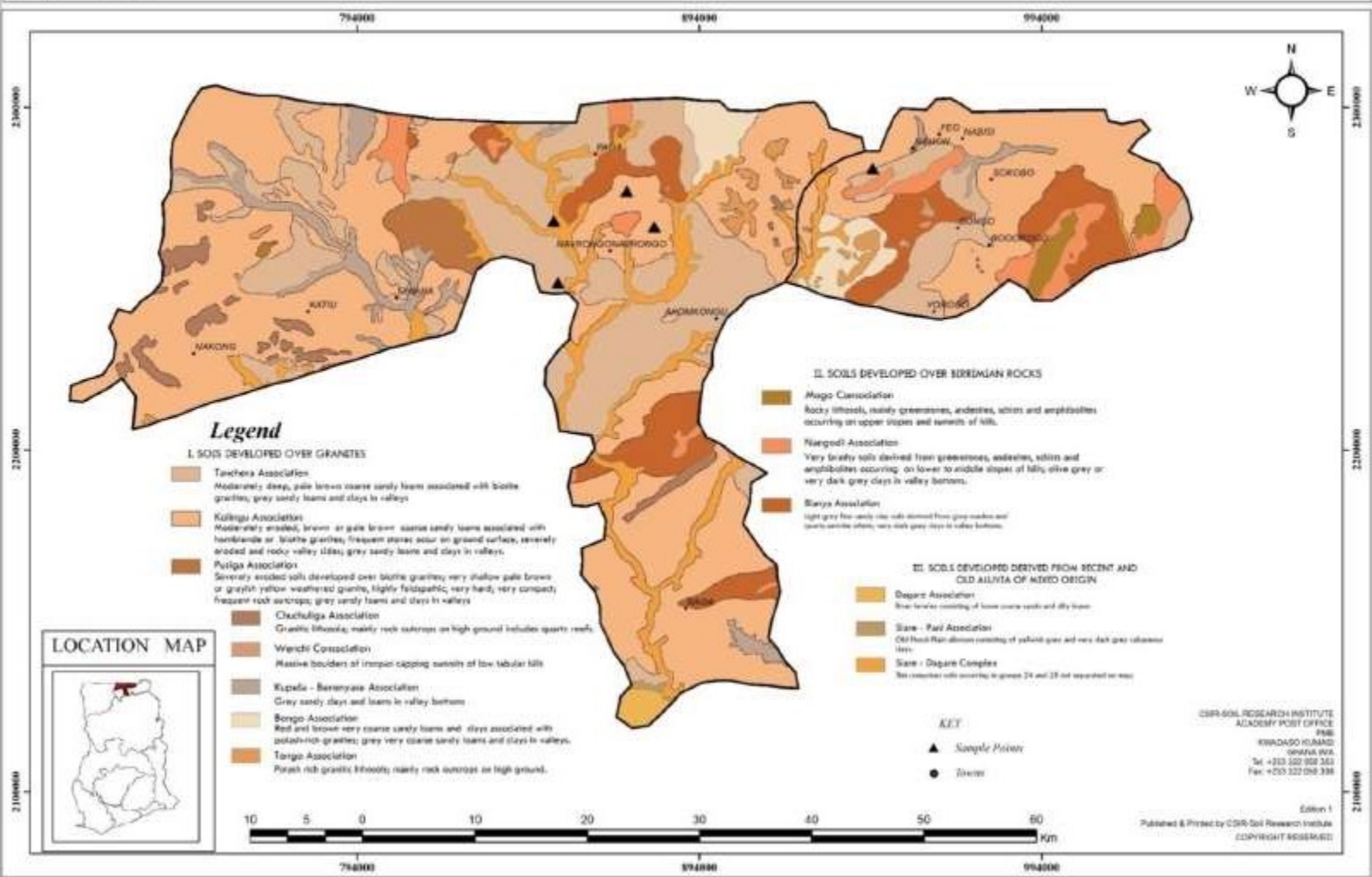


Figure 5: Soils of Upper East Regional Sites

NORTHERN REGION (Savelugu, Tolon, Kumbungu Districts)

SOILS

SCALE 1 : 1,550,000

Africa RISING, Ghana (IITA) Project

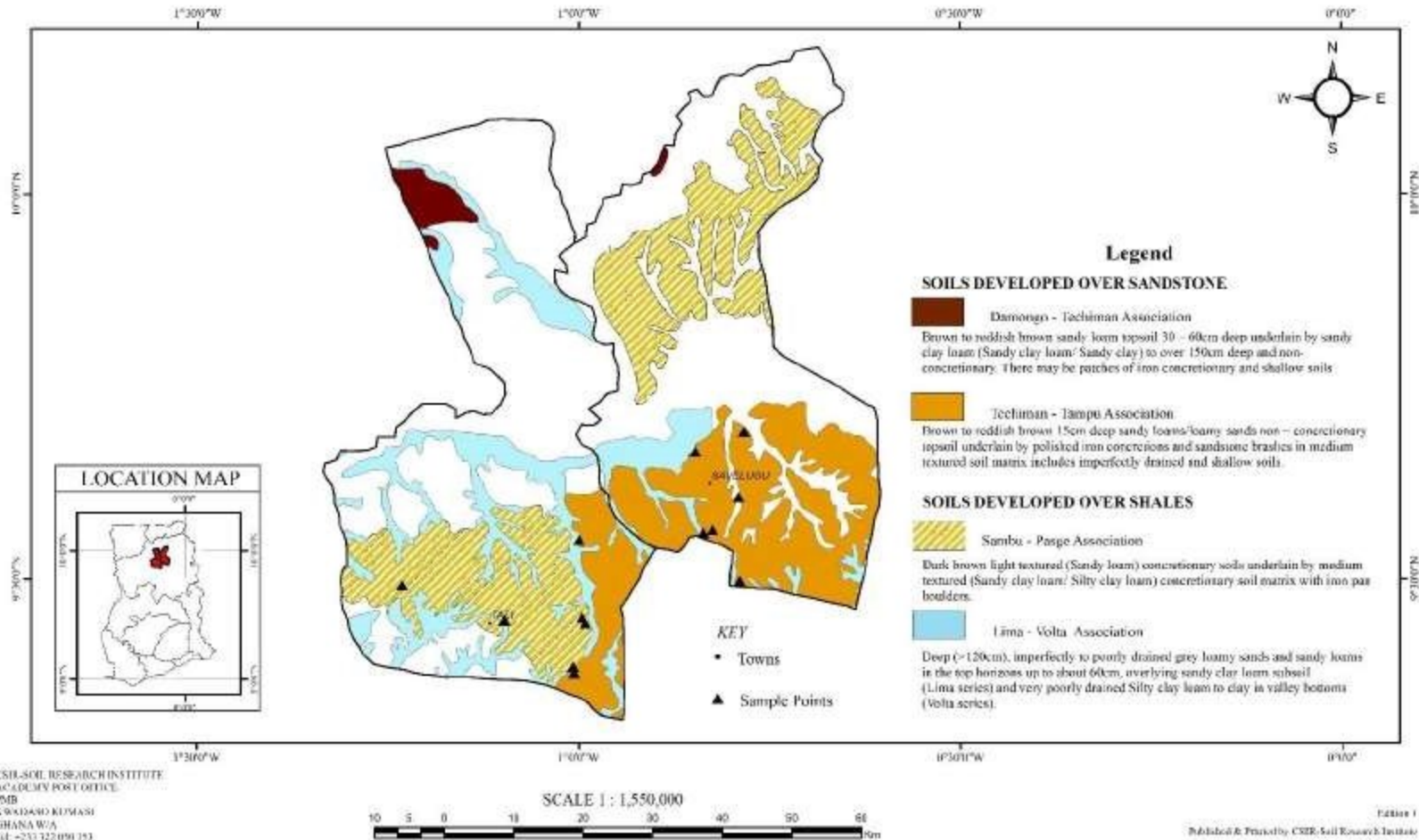


Figure 6: Soils of Northern Regional Sites