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The Nature and Extent of Salt-affected Agricultural Soils in Ho – Keta Plain in the Volta Region of Ghana

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

One of the major environmental issues that have severe adverse effect on sustainable agriculture productivity is soil salinization. A research was conducted at Ho-Keta plain in the Volta Region of Ghana to assess the extent of degradation of salt-affected agricultural soils. Two soil series, Oyebi and Ada in three salt-affected areas within the Lower Volta basin in the Ho-Keta plain were selected from Anyako, Anyenui and Atiehife. Soil sampling was done randomly at the depth of 0-30 cm from the soil sites and transported to the laboratory for analysis and measurement of pH (4.61) Calcium (5.60meq/l), Magnesium (3.17meq/l), Sodium (6.95meq/l), Potassium (1.83meq/l) and Electrical Conductivity (5.13dS/m) respectively. The mean values of Ca, Mg, Na and K were used to estimate Sodium Adsorption Ratio (SAR) and Exchangeable Sodium Percentage (ESP) respectively. The mean values of SAR and ESP in the three selected areas were: 43.89, 52.02, 42.85 and 33.87%, 40.77% and 37.83 5% respectively. The results revealed land degradation in the study area as a result of high levels of SAR and ESP leading to low soil chemical properties. Further investigation to show the extent and the nature of soils in the study area is highly recommended.

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1. INTRODUCTION

Soil degradation, caused by salinization is a major environmental issue that has severe adverse effect on sustainable agricultural productivity in arid and semi-arid climatic regions. This is a phenomenon mainly associated with marine or continental origin [1,2,3]. Soil salinization is an increasingly serious constraint, especially in arid and semi-arid regions where salt accumulation is heavy owing to high evaporation and low precipitation rates [4].

In Ghana, about 318,000ha of land has been degraded as a result of excess sodium on the soil exchange complex and/or soluble salts in the soil profile [5]. Salt-affected soils can be grouped into saline and sodic soils [1]. Saline soil is described as soil with electrical conductivity above 4dS/m and usually contains adequate soluble salts that adversely affect the growth of most crops. The soluble salts are mainly chlorides and sulphates of sodium, calcium and magnesium [6]. Sodic soils are soils with exchangeable sodium percentage above 15, with sodium salts (Na_2CO_3) capable of alkaline hydrolysis [6]. These two main groups of salt-affected soils differ physically, chemically, biologically, and in their geographical, geochemical distribution and, therefore, require different approaches for their reclamation and agricultural utilization. Although these two groups of soils account for very large proportion of salt-affected soils worldwide, there are also transitional groups with intermediate properties (Saline-sodic). Common types under the transitional groups are acid-sulphate and degraded sodic soils [7]. The purpose of the study was to identify the nature and extent of salt-affected soils of the Ho-Keta plain in the Volta region of Ghana.

2. MATERIALS AND METHODS

The study area is located in Ho-Keta plain in the Volta Region of Ghana. The geographical location is between latitudes 5° 44’ 51” and 6° 4’ 47” N and longitudes 0° 29’ 54” and 1° 4’ 47” E (Fig. 1). The general occupations of the inhabitants in the area are fishing and farming, mainly with cassava, maize and pepper as the main crops cultivated [6].

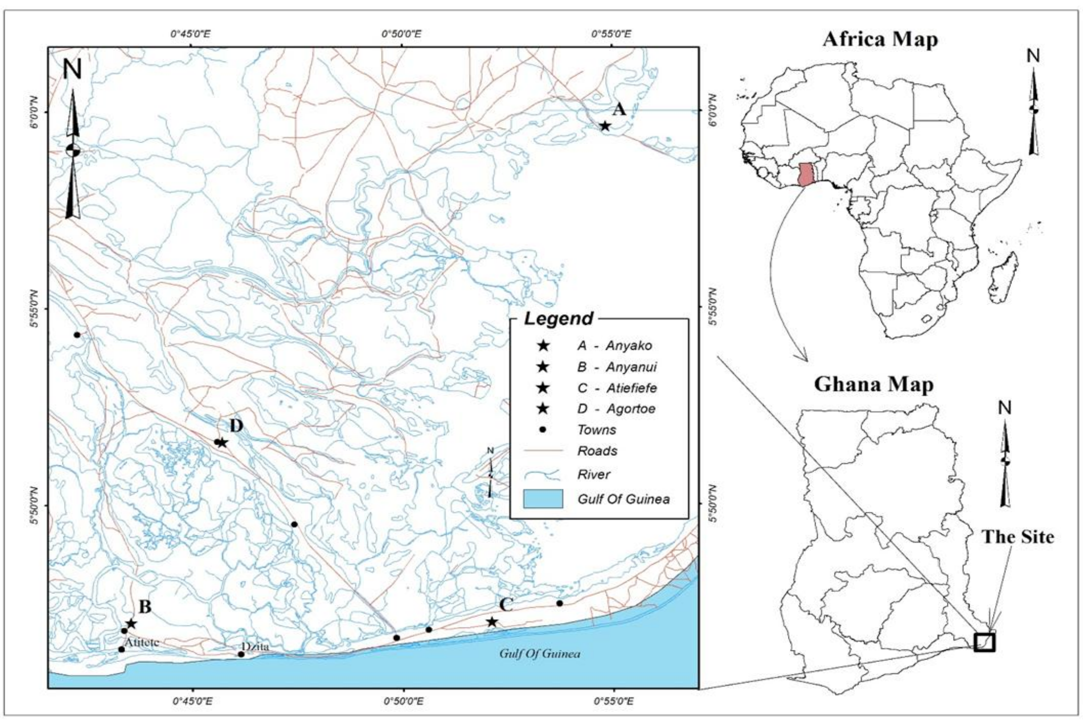

Fig. 1. Location of the study area showing where soils were sampled [17]

The mean annual rainfall for the past 30 years is about 1300 mm, accumulated with the long and short rains [6]. However, significant variations occur from year to year. The study area is bi-modal rainfall pattern with the highest peaks occurring in June and October (Fig. 2).

The mean maximum temperature is 32ºC while the mean minimum is 22ºC (Fig. 3). The mean annual free water evaporation as recorded using Penman-Monteith method is about 1960 mm. As a result of this, the soil is wet throughout the year.

The main geo-morphological unit may be recognized as Dahomeyan rocks, which are believed to be Pre-cambrian in age and form bands of acidic and basic gneiss [6]. According to [8], the Dahomeyan is superimposed by Pleistocene to recent formations of mud, clays and gravel. Clay containing crystals of gypsum and soluble salts are mostly found in lagoon areas.

Vegetation of the study area varies based on soil salinity level and soil moisture. The current climatic conditions only support the growth of tropical grassland. Small and scattered clumps of short trees and shrubs can also be seen at the fringes of lagoons and rivers in the area [7]. These fringes are occupied mainly by mangroves (*Rhizophora racemosa*), isolated patches of grasses (especially, *Paspalum* sp.) and herbs (*Sesuvium portulacastrum*). *Cyperus articulates* and cat-tail (*Typha domin-gensis*) are sedges commonly found in the less brackish parts of the lagoons in the area [6].

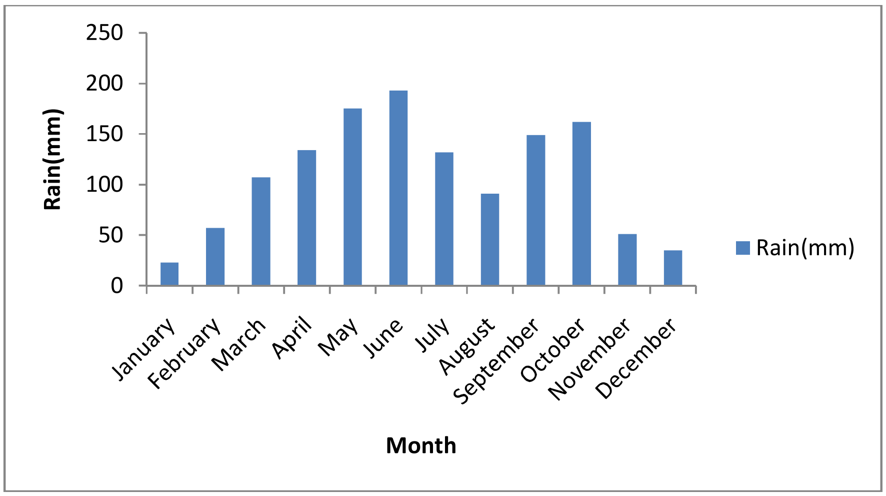

Fig. 2. Rainfall distribution pattern in the study area

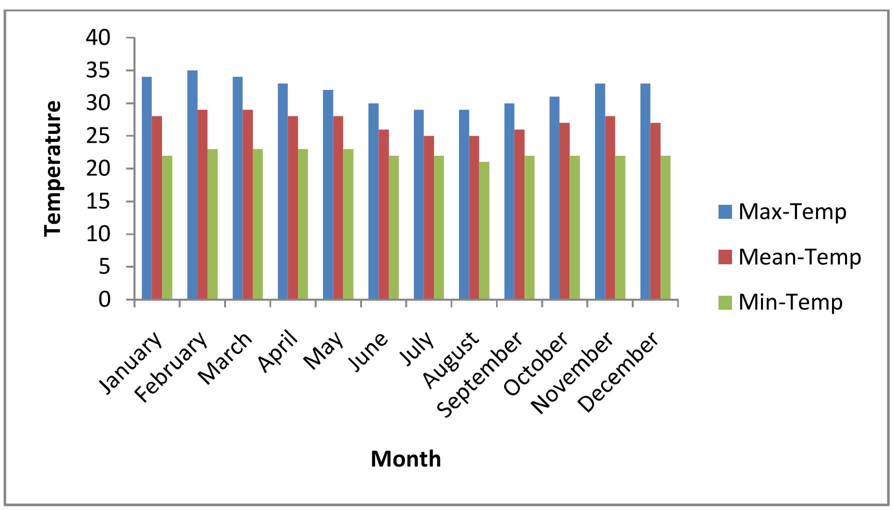

Fig. 3. Temperature distribution of the study area

2.1 Description of the Soils

Two soil series in three salt-affected areas within the Lower Volta basin in the Ho-Keta plain were selected using previous soil survey reports of the area as a guide [9,10]. These series were selected from areas: Anyako, Anyenui and Atiehife. Anyako has a poorly-drained saline-sodic soil which is flooded during the wet season. It occurs on a nearly level land where slope does not exceed 2 percent. The water table drops to about 1.3 m from the surface during the dry season. When seen in sections, it comprises rusty root channels. The second and third horizons contain mottled dark yellowish (10 yr 4/6) clay with weak to moderate medium sub-angular blocky structure which also contains sticky slightly plastic pyrites. The lower horizon is light olive brown (2.5 yr 5/4) and (2.5 yr 5/2) and brownish yellow (10 yr 5/8). It contains sand and has no definite structure. The soil is classified as Oyebi series and Gleyic Solonetz respectively according to the Ghanaian and World Reference Base soil classification system [10,14].

Soils from Anyenui and Atiehife were poorly drained saline-sodic soils developed on alluvial deposits. The salt-affected soil at each area is essentially flat, and ponding of water could occur during period of runoff. The top soil of Anyenui is dark brown (10 yr 5/8), with massive clay texture. It is crumbly with rusty root channels, cracks and deposits of salt crystals on the surface. The second horizon contains mottled olive yellow (2.5 yr 6/8), silty clay and rusty root channels. The third horizon which is from 25 to 50 cm is grayish brown (2.5 yr 5/2) and contains mottles yellow (2.5 yr 8/8) and yellowish brown (10yr 5/8). The water table starts from 50 cm. The soil is classified as Oyebi series and Gleyic Solonetz respectively, according to the Ghanaian and the World Reference Base soil classification system [10,14].

The surface horizon of Atiehife soil was very dark gray (2.5 yr 3/3) to light brown (2.5 yr 5/2). It has moderate to strong fine columnar structure, sticky slightly plastic with many fine roots and no definite structure. The second and third horizons are made of light yellowish brown (2.5 yr 6/3) and (2.5 yr 6/4) with mottles (10 yr 5/8) yellowish brown. The fourth and fifth horizons are also made of mottles (2.5 yr 5/8) with presence of pyrites. The last horizon is dark yellowish brown (10 yr 3/4) with brownish gray mottles (10 yr 6/2). The soil is classified as Ada series and Endogypsi-Gleyic Solonchak respectively, according to the Ghanaian and the World Reference Base soil classification system [10,14].

2.2 Soil Sampling and Analysis

Ten (10) salt-affected soil samples were collected randomly at the depth of 0-30cm from each of the three selected areas. Samples from each soil were put together and a sub-sample taken to represent the entire study area. The soils sampled were packed into labeled polyethylene bags and transported to the laboratory for analysis. Na^+ and K^+ ions were determined by flame photometry and Ca^{2+}, Mg^{2+}, HCO_3^- , CO_3^{2-} and SO_4^{2-} by titration method [11].

Two different criteria are currently recognized in the scientific literature as indices of salinity. These are the Sodium Adsorption Ratio (SAR) with a reported threshold of 12 and the Exchangeable Sodium Percentage (ESP) with a reported threshold of 15%. These indices are defined below:

$$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}}$$

SAR is sodium adsorption ratio, while Na^+, Ca^{2+} and Mg^{2+} are measured soluble cations (meq/l)

$$ESP = \frac{Na^+}{CEC} \times 100$$

ESP represents exchangeable sodium percentage, CEC represents cation exchange capacity and Na^+ represents measured exchangeable Na (meq/l).

3. RESULTS AND DISCUSSION

The results of the classification of salt affected soils and physico-chemical characteristics of the soils in the study area are summarised in Tables 1, 2 and 3.

Table 1. Classification of salt affected soils

Soil types	EC_{soil} (ds/m)	ESP (%)
Non-saline	<4	<15
Saline	>4	<15
Saline-sodic	>4	>15
Sodic	<4	>15

Source: U. S. Salinity Laboratory Staff (1954)

The soil pH ranged from 4.14 to 5.11. Soil pH of salt-affected soil is normally high, due to increased concentration of basic cations and salt in soil solution of arid and semi- arid climatic regions [6]. Saline soils present pH values below 8.5, whilst saline-sodic or sodic soils present pH values of 8.5 and above [9]. The low soil pH levels in the selected soils could be attributed to the high level of sulphate and chloride than carbonates. As pH increases, CO_3^{2-} increases. This was due to the higher solubility of CO_3^{2-} and the greater potential of its hydrolysis (Table 2). However, SO_4^{2-} concentration decreases as the pH increases, because, $CaSO_4$ accumulates somewhat between 7 and 8.5 pH values and it may react against pH rises in the soil by forming H_2SO_4 [12].

Soil electrical conductivity (EC_{soil}) varied from 4.80 to 5.44 dS/m (Table 2). Soils from Ateihifie have high EC_{soil} values than Anyenui and Anyako. Soil electrical conductivity indicates the concentration of soluble salt in soil solution [10]. Soil salinity (EC) produces osmotic effect and often causes physiological drought if it exceeds the critical limit for the crop [11].

The soil organic matter (SOM) varied from 1.33 to 5.01%, and could be described as low (<1.50%) to high (>3.00%) respectively. Low SOM is an indication of low fertility and high fragility of soils. Soil organic carbon contributes to soil productivity, due to its ameliorative effect on nutrient supply, nutrient retention and the improvement in soil structure formation [13]. Soil organic carbon increase rapidly at the same rate as the solubility, decomposition and accessibility of organic matter increase. Carbon input into the soil decrease as plant health is adversely affected by poor soil physical and chemical conditions [14]. In salt- affected soils, increases in salt and sodium result in a decrease in soil carbon [15]. The sparse vegetation cover of the selected sites suggest that plant health was adversely affected by the accumulation of salt and sodium and could possibly be attributed to the low organic carbon content of the soils.

The cation exchange capacity (CEC) also varied from 16.1 to 20.75 meq/l of soil. Exchangeable Na value was higher than Ca, Mg and K contents of the soil. CEC is a measure of the nutrient power of the soil. Management practice like application of gypsum which reduces salinity is recommended [16]. Low pH in these soils could also be attributed to the low levels of calcium within the profile. The high exchangeable Na+ content suggests that more salt was received by the soils due to their proximity to the adjoining small lagoons. The surface horizon of these soils accumulated salt by capillary action, from the salty groundwater of nearby lagoons and wind deposits from the sea [6].

Sodium Adsorption Ratio (SAR) of the study area ranged with a mean value of 42.88 to 52.04 (Table 2). Anyenui soil had the highest SAR value while Atiehife soils had the least. This indicates that the level of sodium in the Anyenui area is high (Table 3). Sodium adsorption ratio (SAR) is often used to assess the potential of excess exchangeable Na^+ to cause soil structure deterioration [17]. High bicarbonate precipitates Ca and Mg in the soil as follows [18]:

$$2HCO_3^- + Ca^{2+} \rightarrow CaCO_3 + H_2O + CO_2 \uparrow$$

Table 2. Chemical properties of the soil in the study area

Soil	Depth	pH(H_2O)	EC_{soil}	HCO_3^-	CO_3^{2-}	SO_4^{2-}	ESP	SAR
			dS/m	----------mg/kg----------------			%	
Anyako	0-30	4.14	4.80	0.17	0.21	6.78	33.87	43.89
Anyenui	0-30	5.11	5.14	0.15	0.19	2.79	40.77	52.04
Ateihifie	0-30	4.59	5.44	0.19	0.25	4.32	37.83	42.88
Mean	0-30	4.61	5.13	0.17	0.22	4.63	37.49	46.27

Table 3. Chemical properties of the soil in the study area

Soil	Depth	Org. M	Ca	Mg	Na	K	CEC
		%	------------------------ meq/l--				
Anyako	0-30	1.33	5.98	3.60	6.30	1.79	18.60
Anyenui	0-30	5.01	6.98	3.60	8.46	2.10	20.75
Ateihifie	0-30	1.65	3.83	2.30	6.09	1.62	16.10
Mean	0-30	2.66	5.60	3.17	6.95	1.83	18.48

This ultimately leaves high proportion of Na in soil. In this content HCO_3^- in the soil was relatively high according to [19] and it was no surprise that the levels of SAR and ESP were high. The soil of the study area could be described as saline-sodic ranging from Anyako to Atiehife (Table 1).

4. CONCLUSION

The study revealed land degradation in the study area as judged by high levels of SAR and ESP leading to low soil chemical properties. From above it can be concluded that the levels of Calcium and Magnesium are low as compared to the level of Sodium in the soil. This indicates that calcium carbonate and magnesium carbonate are precipitated as a result of the presence of bicarbonate in the soil. The fertility level of the soil was very low and requires management practices that promote accumulation of organic matter.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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