Soil Properties of a Toposequence in the Moist Semi-Deciduous Forest Zone of Ghana

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Abstract

In 1997 a semi-deciduous forest area at the University of Ghana Agricultural Research Station, Kade, was selected as a research area for ecological studies. The area is gently sloping forming a toposequence. Several activities have been initiated, e.g. six soil profiles have been described, sampled and analysed; suction cells have been installed for analysing soil solution chemistry; the water balance is determined from soil water data and climatological measurements; and for benchmark soil studies the clay mineralogy has been examined. This paper describes the basic physical and chemical status of the six soil profiles. The soil profiles were sited on the Bekwai, Nzima (upper slope), Kokofu, Kakum (middle slope), Temang and Oda (bottom slope) series. All soils are derived from Pre-Cambrian phyllite and are dominated by low activity kaolinitic clays. The toposequence shows longitudinal gradients in textures, iron content and drainage conditions and marked vertical gradient in carbon, nitrogen and phosphorous contents, soil reaction and base saturation with highest values in the topsoil due to the ion-pump effect of the natural vegetation. Upper slope soils are clayey and show distinct enrichment of clay in the subsoils. They are well drained, rich in iron oxides, strongly leached with low EC values, base saturation, and pH(CaCl₂) (3.7-4.4) in the subsoil, but the ion-pump maintains relatively high pH(CaCl₂) (5.4-5.9) and base saturation in the topsoil. Drainage becomes poorer towards the valley bottom, where soils generally show loamy textures and redoximorphic features, but only Oda shows high base saturation and pH(CaCl₂) (5.8-5.9) throughout the profile.

Key words: Catena, soil series, pedology, forest, soil

Introduction

The semi-deciduous forest zone of Ghana contains some of the most productive soils of the country (Ahn, 1970; Adu, 1992). The zone, which covers some 48,000 km², has adequate rainfall for the cultivation of large scale plantation crops, such as cocoa [Theobroma cacao], oil palm (Elaeis guineensis) and lemon (Citrus spp.) as well as annual crops such as maize (Zea mays), cassava (Manihot utilissima) and plantain (Musa sapientum).

The soils of the forest zone are generally developed from rocks of the Birrimian system (middle Pre-Cambrian) (Adu, 1992), which consists mainly of argillaceous sediments metamorphosed into phyllite. The well-drained upland soils belong to the Forest Ochrosol Great Soil Group of the Ghanaian soil classification system (Bramner, 1962) and are generally accommodated as Acrisols in the FAO-unesco Revised Legend (FAO, 1988) and as Ultisols in Soil Taxonomy (Soil Survey Staff, 1998).

Despite their agricultural importance and the general belief that their fertility is depleting and, hence, diminishing yields (MOFA, 1998), only cursory and rather old data are available on these soils (Bramner, 1962; Adu, 1992). Detailed physical, chemi-
 Chemical and mineralogical data are needed to properly classify the soils and to develop improved management strategies for them.

The methodological approach for studying soils on a toposquence is well established, particularly in the tropics (Milne 1935; Moorman, 1981; Ogunkunle, 1993), although this has often resulted in stereotypic views of the tropical soil environment as, for example, the red soil-black soil toposquence.

The main aims of this work were to characterise the morphological, physical and chemical properties of the major soils on one of the most typical toposquences in the semi-deciduous forest zone of Ghana and to classify the soils according to Soil Taxonomy [Soil Survey Staff, 1998], FAO Soil Map of the World, Revised Legend (FAO, 1988) and the newly launched World Reference Base for Soil Resources (ISSS/ISRIC/FAO, 1998).

**Materials and methods**

The study site is at the University of Ghana Agricultural Research Station, Kade (6° 05' N; 0° 05' W) in the moist semi-deciduous forest zone (*Antiaris Chlorolophora association*) of Ghana, approximately 175 km NE of Accra, and 150 m above sea level (Fig. 1). The vegetational zoning in Ghana reflects the climate, particularly total rainfall and its distribution over the year.

The climate of the area is humid tropical. Average annual temperature is 28°C, with the maximum temperature in March and the minimum temperature in August. The monthly average temperature varies less than 5°C during the year. The rainfall pattern is bimodal and the average annual rainfall during the period 1978-98 amounted to 1179 mm with about 80 per cent falling from March to mid-July and from September to November. Annual potential evapotranspiration is about 1400 mm. The soil moisture regime is udic and the soil temperature regime isohyperthermic (Van Wambeke, 

![Fig 1. Location of study site (the catena experiment) at the University of Ghana Agricultural Research Station, Kade, Ghana](image-url)
Fig 2. A toposequence of soils at the University of Ghana Agricultural Research Station, Kade, Ghana.

1982).

The study site is located in a gently rolling part of the Birim basin with soil parent materials being almost exclusively Pre-Cambrian (Lower Birrimian) rocks, predominantly phyllites, greywackes, schists and gneisses (Adu, 1992). A tributary of the Kadewa, a small seasonal stream drains the site. Drainage is generally good on the uplands but becomes poor down-slope towards the streambed.

Field work
Sites for six soil profiles were selected in a patch of relatively undisturbed forest on a gentle slope. The forest shows no well-marked structural or floristic zonation along the slope. The soil profiles comprise the Bekwai, Nzima, Kokofu, Kakum, Temang and Oda series, which belong to the Bekwai-Nzima/Oda compound association (Adu, 1992). These soils occur extensively in the zone, occupying more than 55 per cent of the area. The constituent soils of the association occur in a definite topographical se-

quence. The soil profiles were described (Table 1) according to the FAO guidelines (FAO, 1990), and bulk samples for laboratory analyses were taken from the major genetic horizons. The length and slope of the toposequence were determined using an Abney Level instrument with readings taken at 20 m intervals.

Laboratory analyses
The soil samples were air dried and passed through a 2-mm sieve. Particle size distribution (clay < 2 μm, silt 2-50 μm, sand 50-2000 μm) was determined by sieve and Sedigraph 5100 (Micrometrics Instrument Corporation). Soil pH was determined potentiometrically in water (pH H₂O) and in 0.01 M CaCl₂ (pH CaCl₂) at a soil-solution ratio of 1:2.5. Electrical conductivity (EC) was determined in a 1:5 soil solution ratio. Exchangeable cations were extracted with 1 M NH₄OAc at pH 7. Calcium (Ca) and
<table>
<thead>
<tr>
<th>Soil horizon</th>
<th>Depth (cm)</th>
<th>Crust color</th>
<th>Crust thickness</th>
<th>Consistence</th>
<th>Roots</th>
<th>Boundary</th>
<th>Notes</th>
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</thead>
<tbody>
<tr>
<td>A</td>
<td>0-7</td>
<td>10 YR 2/4</td>
<td>Clay loam</td>
<td>Weak fine crumb</td>
<td>Friable</td>
<td>Common very fine roots</td>
<td>Clear smooth</td>
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<tr>
<td>Bt</td>
<td>34-57</td>
<td>7.5 YR 2/4</td>
<td>Clay loam</td>
<td>Moderate medium subangular blocky</td>
<td>Fditile</td>
<td>Few very fine roots</td>
<td>Abrupt broken</td>
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<tr>
<td>Bt1</td>
<td>78-119</td>
<td>7.5 YR 2/4</td>
<td>Clay loam</td>
<td>Moderate medium subangular blocky</td>
<td>Firm</td>
<td>Very few very fine roots</td>
<td>Gradual smooth</td>
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<tr>
<td>Bt2</td>
<td>90-133</td>
<td>7.5 YR 2/4</td>
<td>Clay loam</td>
<td>Moderate medium subangular blocky</td>
<td>Firm</td>
<td>Very few very fine roots</td>
<td>Gradual smooth</td>
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<td>A</td>
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<td>Clay loam</td>
<td>Weak fine crumb</td>
<td>Fritile</td>
<td>Common very fine roots</td>
<td>Clear smooth</td>
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<td>Bt</td>
<td>22-45</td>
<td>10 YR 2/4</td>
<td>Clay loam</td>
<td>Moderate medium subangular blocky</td>
<td>Fritile</td>
<td>Few very fine roots</td>
<td>Abrupt broken</td>
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<tr>
<td>Bt1</td>
<td>48-74</td>
<td>7.5 YR 2/4</td>
<td>Clay loam</td>
<td>Moderate medium subangular blocky</td>
<td>Firm</td>
<td>Very few medium and few very fine roots</td>
<td>Abrupt very</td>
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<tr>
<td>Bt2</td>
<td>60-119</td>
<td>7.5 YR 2/4</td>
<td>Clay loam</td>
<td>Moderate to strong medium subangular blocky</td>
<td>Firm</td>
<td>Very few fine and very fine roots</td>
<td>Gradual smooth</td>
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<tr>
<td>CR</td>
<td>103-133</td>
<td>7.5 YR 2/4</td>
<td>Clay loam</td>
<td>Moderate to strong medium subangular blocky</td>
<td>Very firm</td>
<td>Very few very fine roots</td>
<td>-</td>
</tr>
<tr>
<td>E</td>
<td>0-7</td>
<td>10 YR 2/4</td>
<td>Clay loam</td>
<td>Weak fine crumb</td>
<td>Very firm</td>
<td>Few medium common very fine and very fine roots</td>
<td>Clear smooth</td>
</tr>
<tr>
<td>Bt</td>
<td>22-45</td>
<td>10 YR 2/4</td>
<td>Clay loam</td>
<td>Moderate fine subangular blocky</td>
<td>Firm</td>
<td>Very few fine, common very fine few roots</td>
<td>Diffuse smooth</td>
</tr>
<tr>
<td>Bt1</td>
<td>35-42</td>
<td>7.5 YR 2/4</td>
<td>Clay loam</td>
<td>Strong coarse angular blocky</td>
<td>Firm</td>
<td>Very few fine few very fine roots</td>
<td>Diffuse smooth</td>
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<tr>
<td>Bt2</td>
<td>53-120</td>
<td>7.5 YR 2/4</td>
<td>Clay loam</td>
<td>Strong medium subangular blocky</td>
<td>Firm</td>
<td>Few fine and very fine roots</td>
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<tr>
<td>A</td>
<td>0-10</td>
<td>10 YR 2/4</td>
<td>Loam</td>
<td>Weak fine crumb</td>
<td>Very friable</td>
<td>Very few fine-medium and few medium – coarse roots</td>
<td>Clear smooth</td>
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<tr>
<td>Eg</td>
<td>10-50</td>
<td>7.5 YR 2/4</td>
<td>Loam</td>
<td>Weak fine and medium angular and subangular</td>
<td>Fritile</td>
<td>Very few fine medium and few fine roots</td>
<td>Gradual smooth</td>
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<tr>
<td>Bw</td>
<td>44-85</td>
<td>7.5 YR 2/4</td>
<td>Loam</td>
<td>Moderate fine and medium angular and subangular</td>
<td>Firm</td>
<td>Very few fine roots</td>
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<td>Tswg</td>
<td>0-6</td>
<td>10 YR 2/4</td>
<td>Loam</td>
<td>Weak fine crumb</td>
<td>Fritile non sticky(wet) and non plastic(wet)</td>
<td>Many fine roots</td>
<td>Clear smooth</td>
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<tr>
<td>Bw</td>
<td>8-13</td>
<td>10 YR 2/4</td>
<td>Loam</td>
<td>Weak fine and medium subangular blocky</td>
<td>Slightly sticky and plastic(wet)</td>
<td>Many medium and few coarse roots</td>
<td>Gradual smooth</td>
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<td>Cgl</td>
<td>12-50</td>
<td>7.5 YR 2/4</td>
<td>Clay loam</td>
<td>Moderated medium subangular blocky</td>
<td>Slightly sticky non plastic(wet)</td>
<td>Few fine and very few very fine roots</td>
<td>Abrupt smooth</td>
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<td>Cg2</td>
<td>22-60</td>
<td>7.5 YR 2/4</td>
<td>Clay loam</td>
<td>Moderate medium subangular blocky</td>
<td>Non sticky(wet) non plastic(wet)</td>
<td>Very few fine and very fine roots</td>
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<td>Olt</td>
<td>0-4</td>
<td>10 YR 2/4</td>
<td>Loam</td>
<td>Weak fine crumb</td>
<td>Fritile non sticky(wet) and non plastic(wet)</td>
<td>Many fine medium and few very fine roots</td>
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<td>Cgl</td>
<td>8-22</td>
<td>7.5 YR 2/4</td>
<td>Clay loam</td>
<td>Weak fine subangular blocky</td>
<td>Slightly sticky non plastic(wet)</td>
<td>Very fine and very fine roots</td>
<td>Gradual smooth</td>
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<tr>
<td>Cg2</td>
<td>22-69</td>
<td>7.5 YR 2/4</td>
<td>Clay loam</td>
<td>Weak fine and medium subangular blocky</td>
<td>Slightly sticky non plastic(wet)</td>
<td>Very few very fine roots</td>
<td>Abrupt and wavy</td>
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<td>Cg3</td>
<td>69-96</td>
<td>7.5 YR 2/4</td>
<td>Clay loam</td>
<td>Strong medium subangular blocky</td>
<td>Very firm</td>
<td>Very few very fine roots</td>
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magnesium (Mg) were determined by atomic absorption spectrophotometry while potassium (K) and sodium (Na) were determined by flame photometry. Exchangeable acidity (H⁺ and Al³⁺) was extracted with 1 M KCl and determined by titration with NaOH before and after addition of NaF (Sims, 1996). The cation exchange capacity CEC at pH 7 was determined by the NH₄OAc method. The effective cation exchange capacity (ECEC) was determined as the sum of exchangeable cations and exchangeable acidity. Total carbon (C) was determined by measuring the carbon dioxide evolved by igniting the soil in an induction - operating like the LECO furnace (Tabatabei & Bremner, 1970). Total nitrogen (N) was determined by the Kjeldahl method. Total phosphorus (P) was determined spectrophotometrically by the molybdenum blue method using ascorbic acid as a reductant after heating the soil to 550 °C and extraction with 6M sulphuric acid. Free iron (Fe₃⁺) and aluminium (Al₄⁺) were determined by the dithionite-citrate-bicarbonate method of Mehra & Jackson (1960).

Results and discussions

General soil properties
The six profiles (Fig. 2) were developed in situ by intensive chemical weathering under humid and warm conditions. The upper slope soils (Bekwai and Nzima), middle slope (Kokofu and Kakum) and the bottom slope (Temang and Oda) vary from clay loams to sandy clay loams. The bottom slope soils are temporarily submerged during the rainy season and their sand content may be due to mixing with alluvial sediments. The soils are highly weathered and leached (EC<0.05 dS m⁻¹) (Table 2), gradually merging into soft saprolite or hard rock at depths varying from 150 to 200 cm. Clay mineralogical analyses show that kaolinite is predominantly clay mineral in all the soils (Owusu-Bennoah, in prep). Substantial amounts of iron oxides (goethite and hematite) occur in soils on the upper slope Bekwai series in accordance with the profile descriptions (Table 1). Each profile shows a systematic increase in clay content with depth, presumably as a result of clay migration, while the sand content decreases with depth. Very little variation in the silt content is observed with depth in all the profiles. All topsoil structures are weak granular while subsoil structures are moderate to strong subangular blocky, which is typical for mature stable landscapes (Okusami et al., 1997).

Topsoil colours are predominantly dark brown (10 YR 3/4 moist) to black (10 YR 2/1 moist) at all slope positions (Table 1). Subsoil colours range from uniformly red (2.5 YR 5/6 moist) in the well-drained upper slope soils to light brownish grey (2.5 Y 6/2 moist) with red mottling on the middle slope and to uniformly light brownish grey (2.5 Y 6/2 moist) in the valley bottom, where drainage is poor. Almost all the horizons or higher landscape positions show low colour values and high chromas whereas the opposite is observed for the soils at the valley bottom. The main variation in Fe₃⁺ values is along the toposequence, showing a decrease of values towards the poorly drained bottom gradients. The rather high content of Fe₃⁺ in the upper slope soils is in agreement with the occurrence of substantial amounts of goethite and hematite as shown by x-ray diffractions of Bekwai samples. In contrast, Al₄⁺ is low indicating low Al for Fe substitution in the iron oxides (Owusu-Bennoah et al., 1997).

While drainage and colours show a clear gradient along the toposequence, most other soil variables are strongly influenced by forest vegetation bio-cycling and show well-

Table 2. Physical and chemical properties of the soils along the toposequence.

<table>
<thead>
<tr>
<th>Soil series</th>
<th>Horizon</th>
<th>Depth (cm)</th>
<th>Particle size fractions (%)</th>
<th>C (%)</th>
<th>N (%)</th>
<th>CN ratio</th>
<th>Total P ppm</th>
<th>Fe₂O₃ ppm</th>
<th>Al₂O₃ ppm</th>
<th>pH</th>
<th>pH EC 1:5</th>
<th>CEC (mg kg⁻¹)</th>
<th>Exchangeable cations</th>
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<th>Soil series</th>
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* auger samples, approximate depth; nd = not determined


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marked vertical gradients. Generally, the topsoil of all the profiles show high organic-
C, P and N contents as compared with the horizons below (Table 2). This contrast is
particularly expressed in the well-drained upper slope soils where, for example, topsoil
C contents are about 4 per cent and decrease to about 0.5 per cent in the subsoil. A ma-
jor role of soil organic matter is it serves as a store and slow release source of nitrogen
(N), phosphorus (P), and sulphur (S) and potassium (K). The C:N ratio of the surface
soils is on the average 10:1, which is within the range of 10-12 suggested by Nye &
Stephens (1958) for tropical forest soils, and shows that mineralisation of organic residues
is advanced.

Except for the low-lying Oda soil, all the soils show strongly acidic subsoil pH (CaCl₂)
values, which range from 3.6 to 4.4. The relatively high pH 5.9 observed in the surface of
the Oda soil may be due to accumulation of bases leached from the soil located at the
upper slope and also to release of OH⁻ from iron reduction processes (Hoyt & Turner,
1975; Hue, 1992). Due to the bio-cycling of base cations, surface soil pH (both methods)
is markedly higher than that in the subsoil of all the soils except Oda. With the excep-
tion of the Oda series, variation in pH values along the slope is not marked. Ex-
changeable acidity (H⁺ and Al³⁺) follows the same pattern as pH; Al³⁺ is very low in the
topsoil of all the profiles but tends to increase with depth. This trend is particularly marked
in the profiles located at the upper slope. Exchangeable acidity of the Oda series at the
bottom slope is almost zero. A similar pattern is observed for aluminium saturation or
percent base saturation (BS), of the soils.

As shown in Table 2, base saturation of the surface horizons is more than 100 per
cent. This may be attributed to the high and sustained bio-cycling power of the forest
vegetation, resulting in an excess of exchangeable base cations over the CEC at the
beginning of the rainy season, when litter, accumulated during the dry season, decom-
poses and large amounts of base cations are released. Later in the rainy season base satu-
ration is expected to be lower due to plant uptake of exchangeable bases and some
leaching. It is possible that base saturation of surface horizons could drastically decline
under continuous cultivation of short rooted crops that are not efficient in intercepting
leached nutrients and also not capable of recycling nutrients from lower horizons. The
exceptionally high base saturation in the bottom horizons of the Oda series could be
attributed to the presence of a soft rock, which solubilizes to release base cations
when treated with NH₄OAc.

The effective cation exchange capacity (ECEC) of the topsoils ranges between 4.96
and 19.80 cmol (+) kg⁻¹ with an average of 11.86 cmol (+) kg⁻¹. The values decrease
sharply in the horizons below the topsoil in all the soil profiles and decline down the
slope from the upper (Nzima series) to the middle slope (Kakum series). The ECEC
values increase with depth in the soils of the bottom slope as shown by both Temang
and Oda series. The main contributor to the increasing ECEC is the content of exchange-
able Mg in the C-horizons of these profiles. Calcium and Mg constitute the dominant
base cations in the soils. Except for Bekwai series all the soils contain small to very small
amounts of exchangeable K, especially in the subsoils. Apart from the Oda series, the
amounts of Ca, Mg and K decrease with depth. From a depth of about 60 cm and
below, all the soils tend to contain more Mg than Ca.

The amounts of Na are almost constant
with depth, except for Temang and Oda series in which exchangeable Na increases in the bottom horizons. These distributions show that Ca, Mg, and K are nutrients, which are taken up by tree roots and re-circulated to the surface via plant residues and subsequently released when organic matter is mineralized. The calcium/magnesium ratios are > 1 in the upper 60 cm of the soils, whereas these ratios are < 1 below this depth, suggesting that the parent material is rich in Mg. Even though rainfall is heavy and leaching is intense in the study area, it appears that the forest vegetation is a major buffer in nutrient cycling. The vegetation builds up a store of nutrients (N, P, Ca, Mg, K and probably other nutrients) in the organic materials that accumulate on top of the soils and bases are recycled after decomposition. Thus, it is likely that cultivation of the soils, which will lead to removal of topsoil litter, may reduce the nutrient cycling capabilities of the soils.

**Soil management considerations**

Soil management practices to be considered for the study area should provide for minimum physical and chemical degrada-tional processes. The traditional slash and burn agriculture practised in the area would accelerate the decline of organic matter in the topsoil and expose the soils to heavy rainfall, which may lead to soil degradation. Although Al vulnerability shows high variability between different crops, almost all of the soils may not need liming to be productive. Liming is, however, necessary in Bekwai and Kakum series, which show more than 40 per cent Al saturation in their subsoil horizons.

Juo (1977) concluded from a study of some Ultisols from agro-ecological zones similar to the ones in this study that relatively low levels of exchangeable Al would suggest that nutrient deficiencies are probably more critical limiting factors than Al toxicity for crop growth. Total P is high in all the A horizons and in the soils at the upper slope (Bekwai and Nzima), but its availability for plants is unknown. Medium to high P availability was, however, found in the A horizons of other strongly leached Ghanaian soils with total P contents comparable to those in the Kade soils (Owusu-Bennoah et al. 1997). Nevertheless, Duah-Yentumi et al (1997) concluded that microbial growth was limited mainly by P in a cocoa stand at Kade.

**Soil classification**

Table 3 shows how the locally established soil series names correlate with the international soil classification systems Soil Taxonomy (Soil Survey Staff, 1998), FAO Soil Map of the World, Revised Legend (FAO, 1988) and World Reference Base for Soil Resources (WRB)(ISSS/ISRIC/FAO, 1998). According to Soil Taxonomy, Bekwai series is allocated as a Typic Paleudult as a result of the < 35 % BS argillie horizon in which the clay content does not decrease relative to the maximum with more than 20 per cent. The argillie horizon of the Nzima series shows BS > 35 % and the lack of decreasing clay content of the argillie horizon, which shows an apparent CEC of < 24 cmol (+) kg⁻¹ clay, allocates it as Kandic Paleudalf. Both Kokofu and Kakum series show kandic horizons. However, the BS criteria (35 %) of Soil Taxonomy separate them as Udric Kandiudalf and Aquic Kandiudults, respectively. The valley bottom soils (Temang and Oda) show no distinct soil development and the redoximorphic features place them both as Aerio Endoaquents.

According to FAO the Bekwai, Nzima and Kokofu series show argillic horizons with CEC
### Table 3.
Classification of soils on a toposequence at Kade, Ghana

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>Upper slope</td>
<td>Bekwai</td>
<td>Typic Paleudult</td>
<td>Ferric Acrisol</td>
<td>Aluminic Acrisol</td>
</tr>
<tr>
<td>Upper slope</td>
<td>Nzima</td>
<td>Kandic Paleudalf</td>
<td>Haplic Acrisol</td>
<td>Chromic Acrisol</td>
</tr>
<tr>
<td>Middle slope</td>
<td>Kokofu</td>
<td>Udic Kandiudalf</td>
<td>Haplic Lixisol</td>
<td>Haplic Lixisol</td>
</tr>
<tr>
<td>Middle slope</td>
<td>Kakum</td>
<td>Aquic Kandiudult</td>
<td>Gleyic Acrisol</td>
<td>Gleyic Acrisol</td>
</tr>
<tr>
<td>Bottom slope</td>
<td>Temang</td>
<td>Aeric Endoaquent</td>
<td>Eutric Gleysol</td>
<td>Eutric Gleysol</td>
</tr>
<tr>
<td>Bottom slope</td>
<td>Oda</td>
<td>Aeric Endoaquent</td>
<td>Eutric Gleysol</td>
<td>Eutric Gleysol</td>
</tr>
</tbody>
</table>

values < 24 cmol (+) kg⁻¹ clay at pH 7. Bekwai series shows ferric properties and keys out as Ferric Acrisol. Nzima series keys out as Haplic Acrisol, while 50 per cent of Kokofu places it as a Haplic Lixisol. Kakum series shows gleyic properties within 50 cm and the presence of an argic horizon accommodates it as a Gleyic Acrisol. Temang and Oda series both show gleyic properties within 50 cm and high base saturation and key out as Eutric Gleysols.

In the newly launched WRB system, Bekwai series keys out as Aluminic Acrisol due to Al saturation in excess of 50%. Nzima series keys out as Chromic Acrisol, whereas Kokofu series keys out as Haplic Lixisol. The Kakum series is a Gleyic Acrisol, while the Temang and Oda series are Eutric Gleysol.

During the fieldwork the depth to the saprolite was examined by augering at various places on the toposequence. This revealed that the depth varies from 140 to 175 cm, which might affect the classification of the soils, particularly in Soil Taxonomy. Therefore, to validate and extrapolate the classification of the soil series in the study area the Ghanaian soil database should be consulted in order to analyse variability ranges of these series.

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**References**


