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VISUAL ASSESSMENT AND CLASSIFICATION OF SURFACE SOIL TYPES IN DRYLAND AND FADAMA AREAS OF KEBBI STATE, NIGERIA

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ABSTRACT

The need for background information outlining the basic characteristics of surface soil types in the savannah areas is essential for environmental soil management. Visual assessment and classification of surface soil condition is a key to environmental soil management and development. In this study, Visual Soil Assessment (VSA) was used to assess and classify the surface soil condition of dryland and fadama sites of Kebbi State, Nigeria. The results show that the most common soil types, which have dominated great part of fadama and dryland agricultural sites in Kebbi State, are Alfisols, Aridisols, Calcisols, Histosols, Inceptisols, Mollisols and Vertisols. The study highlighted some of the basic characteristics of these soil types. The findings of the study provide an improved understanding of the basic meaning of surface soil condition for proper sustainable soil management of dryland and fadama soils in Kebbi State, Nigeria.

INTRODUCTION

Throughout the world history, many people have assessed and classified the soil environment according to the purposes of its suitability for agricultural production, forest development, water management, livestock production or government developmental activities (e.g. Soil Survey Staff, 1999). Similarly, in the Kebbi State Nigeria, farmers have classified soil according to the agricultural land use, given local names that are suitable to a particular area or crop or soil-colour. Some of these names include Kasar-shinkafa (rice soil), Kasar-gero (millet soil), Farar-kasa (white soil), Bakar-kasa (black soil), Jar-kasa (red soil), Rafi (valley area), Fadama (flood-plain areas), Tudu (dryland area), Laka (clay soil) and Yashi (sandy soil) (Usman and Basiru, 2013). However, because of the limitation of its uses in soil management (Usman, 2007), this farmer's classification of soils in Kebbi State must be improved by scientific classification. The scientific classification will help to establish hierarchies of environmental soil classes and permit the understanding of the relationship among the major components of agricultural soil environment, and the factors responsible for environmental soils behaviour and environmental soils changes (Soil Survey Staff, 2010). In line with this, the objective of the present study was to assess and classify the soils based on scientific system of classification according to the current status of dryland and fadama areas of Kebbi State. This would lead to proper and sustainable soil management in dryland and fadama areas of Kebbi State Nigeria.

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MATERIALS AND METHODS

Study area

The assessment was carried out in the dryland and fadama savannah areas of Kebbi State Nigeria around Arewa, Argungu, Augie, Birnin Kebbi and Dandi local governments. These areas lies within latitude 11° and 13°N and longitudes 4° and 15°E, bordering the nations of Niger republic to the west and Benin republic to the southwest (Figure 1). The vegetation cover is characterised by few annual grasses, shrubs and trees. The sites are largely owned by rural farmers through inheritance and land tenure system. These rural farmers are tribes of Hausa and nomadic Fulani ethnic groups, whose sources of income depend greatly on farming systems.

Visual Soil Assessment

Although, several soil assessment methods have been developed over the past decades (see Mueller *et al.,* 2010), the

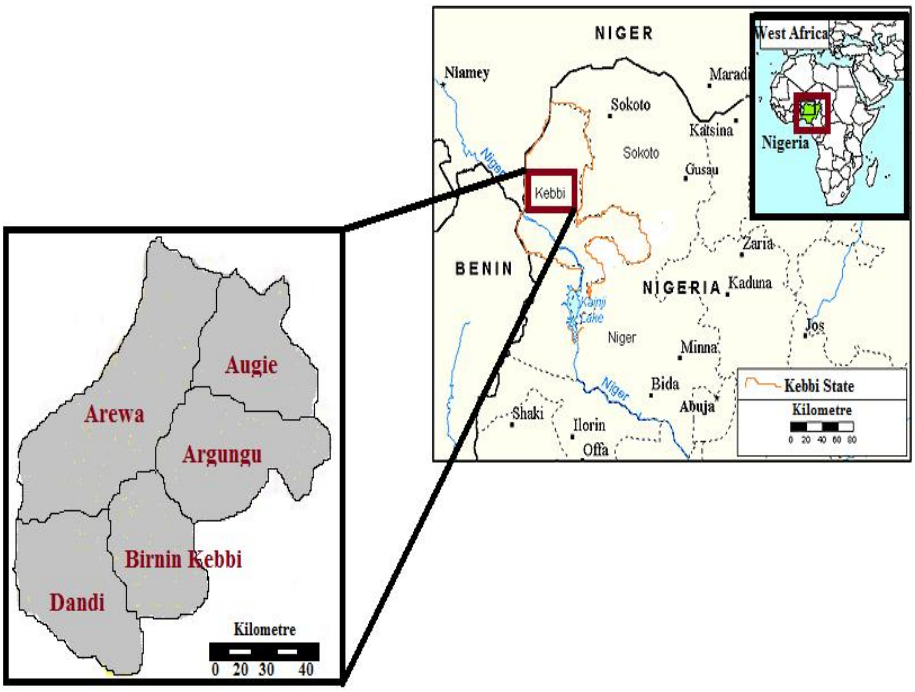

Figure 1. Map of the study area located in Nigeria from West Africa. Source: available at: http://www.joshuaproject.net/people-profile.php?peo3=11634&rog3=NI

Visual Soil Assessment (VSA) method was noted to have clear advantages for its reliable assessments over others (e.g. Ball *et al.,* 2007; Shepherd, 2009; Usman *et al.,* 2012). The European Commission (EU, 2010) defined VSA as a direct evaluation of those soil properties, which are visible by the naked eye and which can be evaluated directly in the field. The method was found profitable in assessing the key soil 'states', which are dynamic indicators capable of changing under different management regimes and land-use pressure (FAO, 2008). It is useful in establishing hierarchies of soil classes and will provides an improved understanding of the relationship among the surface soil factors as they can be seen in the field (Soil Survey Staff, 1999). Soil types were classified according to guidelines provided by FAO and USDA (Soil Survey Staff, 1999; FAO, 2006). Sites were assessed and classified by direct observation according to VSA over a given pedon's area (2 m^2 site within a given field site).

The following definitions correspond to contextualised soil orders defined by Soil Survey Staff and FAO (Table 1) used as a complete guidelines in the field:

Table 1. Soil type's classification systems used

Soil group	Classification system	Reference
Alfisols	USDA classification	Soil Survey Staff (1999)
Anthrosols	FAO classification	FAO (2006)
Aridisols	USDA classification	Soil Survey Staff (1999)
Calcisols	FAO classification	FAO (2006)
Entisols	USDA	Soil Survey Staff (1999)
Histosols	FAO-USDA classifications	Soil Survey Staff (1999), FOA (2006)
Inceptisols	USDA classification	Soil Survey Staff (1999)
Mollisols	USDA classification	Soil Survey Staff (1999)
Oxisols	USDA classification	Soil Survey Staff (1999)
Vetisols	FAO-USDA classifications	Soil Survey Staff (1999), FAO (2006)

Alfisols (AL: USDA classification system) represents the surface soils that possessed the properties of moderately weathered condition of well-decomposed organic material, and because of the surface formation condition, the soil may become saturated for up to 5 to 30 days. The textural parent materials are coarse-loamy, loamy, or finer particle-size class (based on VSA). In the presence study, the term Alfisols is used to classify the surface soil condition with well-decomposed organic materials that physically saturated with water during the rainy season for period of 5 to 7 consecutive days (field observation).

Anthrosols (AN: FAO classification system) is a soil term that can be used to classify the surface soil profoundly modified by human activities such as addition of mineral fertilizer, organic/household waste materials or anthropogenic agricultural activities such as irrigation. The parent materials are almost any soil material, modified through farming or by addition of organic or inorganic materials. In the presence study, the term Anthrosols was used to classify the surface soil condition attributed with addition of inorganic fertilizer and household waste materials.

Aridisols (AR: USDA classification system) is a soil term used to describe soils characterised by arid condition, low concentration of organic matter, dryness and limited moisture condition (water is not available to plants for long periods). Generally, during most of the time when the soils are warm enough for plants to grow, soil water is held at potentials less than the permanent wilting point. In the presence study, the term aridity or dryness and low moist condition were used to classify Aridisols in dryland of the study area.

Calcisols (CL: FAO Classification system) represent the surface soils characterised by high accumulation of lime and calcium carbonate. Calcisols are common in calcareous parent materials and widespread in arid and semi-arid surface soil environments. Parent materials are developed as alluvial, colluvial and aeolian deposits of weathering processes (physical and thermal). In the presence study, the surface soil physically characterised by substantial accumulation of lime

Table 2. Major surface soil types in dryland and fadama areas of Kebbi State

Study area	Site	Surface soil dynamic condition: VSA – Field based	Soil type: FAO-USDA[1]
Arewa	Dryland	Surface and subsurface soils are affected by mineral fertilizers (0–13 cm depth).	Anthrosols
Argungu, Augie, Birnin Kebbi	Dryland	15-35 cm depth is mixed up thoroughly with organic manure of which large are animal and plant debris.	Alfisols
All the five study areas	Dryland	High sand particle and very dryness, poor structure and susceptible to erosion.	Aridisols
Arewa, Argungu, Augie, Dandi,	Dryland	Cream-white coloured with hardened structure 'calcareous'.	Calcisols
Argungu	Fadama	New clay deposited particles (50–65% content)	Entisols
Argungu, Augie, Birnin Kebbi	Dryland Fadama	10 – 30 cm depth from the top surface mixed-up by decomposed organic matter.	Histosols
Argungu, Augie, Birnin Kebbi	Fadama	30–50% (field observation) clay content with very moderate drainage surface condition.	Inceptisols
Argungu, Augie, Birnin Kebbi	Fadama	10–17 cm depth (field observation) is mixed thoroughly with clay particles and well-decomposed organic materials	Mollisols
Arewa, Birnin Kebbi	Dryland	Low fertile soil and poor structure on gently slope areas (9 – 37 m slope distance).	Oxisols
Argungu, Augie, Birnin Kebbi	Fadama	Surface cracks of various sizes and shapes (5.2-10.3 cm depth: field observation).	Vertisols

[1]Soil type names according FAO-USDA classification systems: the general information and the overall assessment observations are discussed under each soil type.

and calcium carbonate was used to classify Calcisols in the dryland of the study area.

Entisols (EN: USDA classification system) is used for immature soils on steep, actively eroding slopes, and flood plains that receive new deposits of alluvium at frequent intervals, which have little or no evidence of the development of pedogenic horizons. However, on many surface soil landscapes the soil material is not in place long time ago but brought into existence by human activities or climate factor such as rainfall. In the present study, the term Entisols was sued for soil characterised by newly alluvial clay deposit soil particles brought in place in fadama floodplain areas by human activities of modifying land for irrigation purposes in the study area.

Histosols (HI: FAO-USDA classification system): Histosols is soils that formed in organic soil materials with half or more of the upper 80 cm is organic (field observation); the parent material are incompletely decomposed plant remains, with or without combination of sand, silt or clay. In the presence study, the term Histosols was used to classify the surface soil condition characterised by addition of only organic materials (plant or animal form).

Inceptisols (IN: USDA classification systems) is term that can be used only on soils of cool to very warm, humid and sub-humid regions low moisture range from very poorly drained to excessively drained, through alteration of parent materials. Generally, the definition of Inceptisols is automatically complicated; however, in the presence study, two major surface soil characteristics i.e. very poorly drained and excessively drained were used in fadama of the study area to classify the term 'Inceptisols'.

Mollisols (MO: USDA classification system) is use to define soil with very dark coloured, base-rich, mineral soils of the steppes developed under grassland cover. This soil order has deep, high organic matter surface soil typically between 60 cm to 80 cm depth (field observation). In the presence study, surface soil characterised by grassland cover, deep with high organic matter was used to classify Mollisols in fadama of the study area.

Oxisols (OX: USDA Soil classification system) is weathered soils that are low in fertility common on the gentle slopes of geologically old surfaces in tropical and subtropical regions appear structure-less and have the feel of a loamy texture upon first examination. In the presence study, surface soils characterised by low fertile condition on the gentle slopes are used to classify Oxisols in the dryland areas of the study area.

Vertisols (VE: FAO-USDA classification system) is soil term that can be used for clayey soils that have deep, wide cracks for some time during the year and have slicken-sides within 100 cm of the mineral soil surfaces that shrink when dry and swell when moistened. In the present study, surface soil attributed with cracks during the dry season and high clay particles was used to classify Vertisols in the fadama areas of the study area.

RESULTS AND DISCUSSION

The results of field survey identified 10 surface soil types in dryland and fadama areas of the study area in Kebbi State (Table 2). In dryland areas, the major soil types are Alfisols, Aridsols, Calcisols and Histosols (Table 2). Alfisols and Histosols are common in Argungu, Augie and Birnin Kebbi whereas Calcisols is common in Arewa, Argungu, Augie and Dandi areas. Aridisols is found to be the most common soil type in all the five areas of Kebbi State, although more common around Arewa and Dandi. Anthrosols and Oxisols are not common in most of the sites visited but are found in four sites around Arewa and Birnin Kebbi, respectively. These soil types of dryland areas in Kebbi State tallied very-well with the study of FAO-SWALIM (2007) in some selected areas of Somaliland. Similarly, they have also fall under the World Reference based for soil types, reported by Deckers *et al.* (1998). However, one of the main geophysical conditions of the sites where these soil types are classified is poor vegetation cover. This has been observed as a key factor contributing to surface soil modification of most Aridisols and Calcisols in African sub-Saharan regions (Bridges (1997; Bationo *et al.* (2006). In fadama site, the common soil types are Inceptisols, Mollisols and Vertisols (Table 2). These three soil types are found in Argungu, Augie and Birnin Kebbi areas. Entisols is not common soil types in fadama areas, and is only observed in two sites around Argungu areas. One of the physical features of these soil types is good surface condition, appeared

to be of high clay particles compare with Anthrosols, Aridisols and Histosols. Shrinkage, swelling and surface cracks are described as the most common characteristics of Vertisols in fadama areas (e.g. Ojanuga, 1987; Usman and Basiru, 2013).

Alfisols: Alfisosls are found only in few areas of dryland and fadama of Kebbi State. They are soils of high humus due to accumulation of organic matter on the top surface soils. The surface colour is darker, texture is loamy-sand/clay and structure is granular with high decomposed organic materials (e.g. Figure 2). The surface climate condition is ustic (implying dryness) during the rainy season and aridic (dry-hot) in dry season; topography is levelled to gently slope; and parent materials are colluvials deposited particles of different organic materials which are mixed with sands, thoroughly.

Figure 2. Typical example of Alfisols in Dryland of Kebbi State. (Photograph: Suleiman Usman, 2010)

Anthrosols: Anthrosols are very recent modified surface soils of dryland areas of Kebbi State. They are mineral soils which have occurred as a result of regular applications of inorganic mineral fertilizers (e.g. Figure 3). They are very-well drained with poor surface structure that is largely grains. Surface climate is torric (hot-dry) with very poor vegetation cover and flat to gently surface topography. Parent materials are week originated from consolidated soil particles with very low organic matter, fine-grained textured and very loose surface consistency.

Figure 3. Typical example of Anthrosols in Dryland of Kebbi State. (Photograph: Suleiman Usman, 2008)

Aridisols: In Kebbi State, Aridisols is the major surface soil types in most of dryland areas. The surface soil characteristics are low moisture content, low organic matter, high infiltration rate, poor resistance to erosion and runoff, poor vegetation cover, and presence of sheet and rill erosions. The actual surface climate and moisture regime is aridic (e.g. Figure 4); soil temperature is hot to extremely hot; and topography is flat, levelled, gently slope to up-and-down undulating. Geologically, the surface parent materials are consolidated and unconsolidated fluvial, alluvial, lacustrine, estuarine, and colluvial sand and sand-loam particles formed 100 to 10000 years ago (Holocene natural). The soil texture is fine sand, coarse sand, loamy coarse sand, loamy-sand, loam and silt loam. Single-grains and massive-sand are two common soil structures; these two types of soil structure, have different surface coloured that ranged from light, reddish and brownish.

Figure 4. Typical example of Aridisols in Dryland of Kebbi State. (Photograph: Suleiman Usman, 2008)

Calcisols: Calcisols are soils of few dryland areas of Kebbi State, commonly developed from unconsolidated sediments of fluvial calcium carbonate (CaCO3) 100 to 10000 years ago (Holocene natural). Most of these surface soils are whitish-reddish or and brownish coloured (e.g. Figure 5). The surface texture is extremely hard forming flate-like structure and very sticky consistency at moist condition (after heavy rainfall). Surface climate is semi-aridic. The topography is flat to up-and-down undulating, largely covered with deposited calcareous sand, clay, limestone and rocky particles of alluvial and fluvial parent materials.

Figure 5. Typical example of Calcisols in Dryland of Kebbi State. (Photograph: Suleiman Usman, 2010)

Entisols: These are new surface soils environment in few areas of Kebbi State's fadama. They are alluvial deposited particles of largely clay. The parent materials are commonly originated from old consolidated metamorphic rocks under floodplains condition (e.g. Figure 6).

Figure 6. Typical example of Entisols in Fadama of Kebbi State. (Photograph: Suleiman Usman, 2011)

The topography is ridges and surface climate condition is ustic. Characteristically, soil texture is clay-loam; soil structure is angular, sub-angular, or platy-wedge-rounded; soil consistency is rigid-blocks; and colour is brownish mixed with light, white, and black mottling.

Histosols: Histosols are few surface soils of dryland areas in Kebbi State. They have similar climate, topography, parent materials and physical properties with Aridisols. However, physically, the organic matter content of Histosols is high than that of Aridisols but lower compare with Alfisols. The surface thickness of organic materials is one of the most important characteristic used to assess Histosols in the State. As typically measured in the field, the thickness of organic matter is between 55 cm to 72 cm in the upper surface soil layer (e.g. Figure 7). Also, when water was added in a sample collected from the field, the soil remained saturated for up to 27 minutes and up to 1 day 2 hrs after heavy rains in July (25-26/7/2008) in dryland site of Argungu.

Figure 7. Typical example of Histosols in Dryland of Kebbi State. (Photograph: Suleiman Usman, 2008)

Inceptisols: These are among the major fadama surface soils of Kebbi State after Vertisols. The properties of Inceptisols are characterised as ustic-cool to warm surface climate condition, flat to levelled topography, alluvial consolidated metamorphic parent materials, and are very well-drain surface condition (e.g. Figure 8). The soil texture is clay-loam, soil structure is plate-like, consistency is sticky and plastic, and colour is light-black to greyish.

Figure 8. Typical example of Inceptisols in Fadama of Kebbi State. (Photograph: Suleiman Usman, 2010)

Mollisols: In Kebbi State, Mollisols are found in few fadama areas where soil biota and their biological activities are physically high. The surface climate is udic (humid moist) and colour is black to dark, developed under green carpeted grassed or other plants and animals organic materials (e.g. Figure 9). The moisture is available throughout the year, but reduces only during the dry season to 11.8 cm depth as measured in the field. Physically, the parent materials were originated from old Holocene natural of alluvial clay metamorphic rocks 100 to 10000 years ago. The surface topography is flat characterised by shrinking and swelling conditions. The surface drainage and moisture are good due to high organic matter. Soil texture is highly clay-loam having granular structure and cemented consistency.

Figure 9. Typical example of Mollisols in Fadama of Kebbi State. (Photograph: Suleiman Usman, 2010)

Oxisols: Oxisols are dominant soils of mostly gently slopes areas of dryland in Kebbi State. They have very low organic matter and poor surface soil condition. The surface climate and moisture are aridics with coarser sandy and sandy-loam textural classes of fluvial and lacustrine metamorphic parent materials. Oxisols have massive soil structure, which are brownish, reddish in coloured and are used for building and road side constructions in the State (e.g. Figure 10). Sheet and rill erosions are common in most of the Oxisols sites assessed.

Figure 10. Typical example of Oxisols in Dryland of Kebbi State. (Photograph: Suleiman Usman, 2008)

Figure 11. Typical examples of Vertisols in Fadama of Kebbi State. (Photograph: Suleiman Usman, 2010)

Vertisols: Vertisols occur primarily in fadama areas of Kebbi State. They are characterised by high clay mineral content and

fine texture; sticky and plasticity consistency; blocky and prismatic structure; shrinkage and swelling; and black, light, and brownish surface coloured. They form very deep, wide surface cracks of different shapes and size that can be separated from the main soil body as blocky, prismatic, angular and sub-angular shapes (e.g. Figure 11). Most of the surface cracks in Vertisols are 6 mm wide as measured in the field. Parent materials are mostly of consolidated clay sediments formed under flat-levelled topography aged 100 to 10000 years ago (Holocene natural). The surface climate condition is ustic, udic and perudic (extremely wet) to aquic (water saturated) conditions.

Conclusion

The present study observed and explained the basic meaning of some key soil terms based on visual assessment in dryland and fadama of five local government areas in Kebbi State, Nigeria. The information may be considered as pre-requisites for the achievement of the basic requirement and objective of soil science under surface soil assessment and classification in the field. Although, it is not intended to go into the detail analysis of the soil types in the study area, however, it is understood that the current status of surface soil condition in dryland and fadama sites of Arewa, Argungu, Augie, Birnin Kebbi and Dandi local governments areas of Kebbi falls under the following FAO-USDA soil terms: Anthrosols, Alfisols, Aridisols, Calcisols, Entisols, Histosols, Inceptisols, Mollisols, Oxisols and Vertisols. The physical, chemical and hydrological analyses would provide detail information of dryland and fadama soils in the study area. These analyses should be carried out on regular basis for proper and sustainable soil management for agricultural development in the region.

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