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New method of soil classification in defining the dynamic condition of agricultural surface soils

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Abstract: *Lack of qualitative information under dynamic surface soil condition has affected the development and proper sustainable management of most agricultural soils globally. Although several methods of soil classifications have been shown to record important soil data in defining soil for multiple benefits, the specific dynamic surface soil condition under specific soil groups (Alfisols, Anthrosols, Aridisols, Calsisols, Entisols, Histosols, Inceptisols, Molisols, Oxisol, Vertisols) is poorly understood in the Sudan Savannah zone of Kebbi State Nigeria. For this reason, a new method of soil classification in defining the capacity and quality of surface soils for multiple benefits has been introduced. This method is called Combined Soil Type Equation (CSTE). CSTE was used to classify and define the surface soil conditions of two or more different soil groups (appeared to be formed under the same surface soil environment) into one new soil group name. Results showed that fourteen different new soil group names were classified: Alanhisols, Alhioxalsols, Aralhisols, Araloxhisols, Aralsols, Aransols, Arhioxalsols, Arhisols, Enmoinarsols, Hicaoxalsols, Inalmosols, Inmoalsols, Vehisols, and Vemohisols.*

Keywords: *Surface soil, Soil group and Combine Soil Type Equation*

I. Introduction

Globally, physical nature and properties of most agricultural surface soil environments are dynamically changed. The results of this change is partly due to climate changes (IPCC, 2007), inappropriate agricultural activities (Usman, 2011), poor environmental government policy and lack of awareness particularly in Africa. As such, our global agricultural surface soil environments need new hierarchical classification system. It is one of the important challenges of today in soil science, the need for new methods of soil classification involving the overall physical surface dynamic nature of agricultural soils. Great numbers of theoretical and technical soil classification methods were introduced. The most recent updated ones among the others are: FAO Guidelines for Soil Descriptions (FAO, 2006), Key to Soil Taxonomy (Soil Survey Staff, 2010), Somalia Field Survey Manual (SWALIM, 2007a), and Visual Soil Assessment Field Guides (FAO, 2008; EU, 2010). These manual guides have been in used for the development of soil science studies, but because of global environmental crises, which have caused surface soils changes, a new method of surface soil classification is required. By definition (Atkinson, 1993), classification of soil is a scheme for separating soils into broad groups, each with broadly similar behaviour.

It is one of the main concerned of soil survey under soil classification (e.g. Cline, 1963), mapping the real surface bodies of soil, as well as classification that strictly related to these surface bodies. The purpose of this mapping/classification (Soil Survey Staff, 2010) is to establish hierarchies of classes that permit soil scientists to understand, as fully as possible, the relationship among the surface soil groups and between the surfaces soil groups as well. Therefore, surface soils must be classified by their own physical appearance as they can be seen in the field; given names and descriptions that are strictly belonging to each soil. In this regard, there are many possibilities of defining and assessing the dynamic physical surface conditions of agricultural soils; namely, switching to an integrated ideas under Combine Soil Type Equation (CSTE). The aim of this paper was to report the practical application of Combine Soil Type Equation as a new method of soil classification. This is hoped to determine the new soil groups under dynamic agricultural surface soil conditions of Sudan Savannah zone of Kebbi State Nigeria.

II. Materials And Methods

2.1 Surface Soil Conditions of the Study Area

The surface soil condition of the study area is divided into two important agricultural lands: dryland and fadama, located in the Sudan Savannah zone of Kebbi State Nigeria. The name dryland was derived from the word arid which implies prolonged dryness, used only with respect of climate itself (Squires and Tow, 1991; Creswell and Martin, 1998). Dryland farming has been defined as an agricultural technique for cultivating land which received little rainfall (Farage *et al.,* 2007). According to field survey carried out from 2008 to 2011 under this present study, dryland farming in the Sudan Savannah may be classify into mono-cropping where only millet is growing; intercropping where millet, sorghum and cowpea are grown; and crop rotation where millet-sorghum-cowpea are grown. On the other hand, the name fadama is a local name given to seasonally flooded areas by Hausa tribes in northern Nigeria. Fadama lands are areas with flat-floored valleys which may flood in the wet season only, and recede during the dry season to leave a coating of alluvial soil (Iloeje, 2001). Rice, wheat and wide range of horticultural crops are grown annually under irrigation and seasonal rainy cultivations in fadama areas of the Sudan Savannah. Table 1 provides the overview of the physical surface soil conditions of dryland and fadama at that very time of field assessment.

Table 1: Visual Soil Assessment of the surface soils in dryland and fadama of the study area

Site description[1]	**Surface condition**[1]	**Physical surface appearance**[1]
1. Organic soils of dryland:	Decomposed organic material.	10 -30 cm depth from surface layer
2. Mineral soils of dryland:	Mineral fertilizer soils	Surface-sub-surface affected (0-13 cm).
3. Clayed soils of fadama:	High clayed particles.	Cracks of various sizes are common.
4. Limestone soils of dryland:	High calcium carbonated particles.	Cream-white coloured, hard consistency.
5. Dry soils of dryland:	Sandy and sandy-loam	Limited soil moisture content, >70% sand
6. Low-fertile soils of dryland:	Gently slope areas.	Poor structure, low-resistance to erosion.
7. High humus soils of fadama:	Decomposed organic materials.	10 – 17 cm depths are mixed with well-decomposed organic materials.

[1]Classifications and descriptions according to Visual Soil Assessment by naked eye

According to FAO-USDA classification systems (FAO, 2006; Soil Survey Staff, 2010), the surface soils of the study area fall into ten broad soil groups as physically assessed during the preliminary field survey in the field. Six of these soil groups belong to dryland: Alfisols, Anthrosols, Aridisols, Calsisols, Histosols and Oxisol; whereas four of them belong to fadama: Entisols, Inceptisols, Molisols, and Vertisols. The Visual Soil Assessment by naked eye according to FAO guidelines (FAO, 2006) revealed that there are varieties of colluvial, alluvial, transported, deposited, residual, and sand dunes parent materials, which might have been changed as a result of agricultural intensification system, climate change, and other environmental factors. The topographical surface soil condition on which these soil parent materials have been changed are back-slope, bendy, concave, contour, convex, deeply, flatly, linear-flats, shallow, and straight under aquic (high moisture), aridic (dryness), perudic (wetted condition), torric (hot and dry), ustic (moderate moisture), udic (sufficient moisture), and moisture surface characteristics (Atkinson, 1993; FAO, 2006). Thus, the surface soil conditions of the ten soil groups listed were considered as theoretical background materials. The following equation corresponds to contextualised terminologies of these soil groups:

$$\text{Soil-}_{E}\ (D + F) = \text{Al-}_{ks}/\text{An-}_{ks}/\text{Ar-}_{ks}/\text{Ca-}_{ks}/\text{En-}_{ks}/\text{Hi-}_{ks}/\text{In-}_{ks}/\text{Mo-}_{ks}/\text{Ox-}_{ks}/\text{Ve-}_{ks}$$

This equation infers that the changes that can be seen in the surface "Soil-$_E$ ($_E$-environment)" situated in dryland (D) and fadama (F) of Kebbi Sudan-Savannah (ks) are formed by combination of different soil parent materials. In this concept, Alfisols (Al-$_{ks}$) represents the surface soil environment that possessed the properties of high humus. Anthrosols (An-$_{ks}$) represents the surface soils characterised by high inorganic fertilizer. Aridisols (Ar-$_{ks}$) represents very low moisture surface soils of high sand particles. Calsisols (Cl-$_{ks}$) represents the surface soils characterised by high accumulation of lime and calcium carbonate. Entisols (En-$_{ks}$) represents all newly formed surface soil particles of flood plain areas. Histosols (Hi-$_{ks}$) represents the surface soils formed as a result of regular application of organic materials. Inceptisols (In-$_{ks}$) represents a very poorly drained surface soil under flood plain areas. Molisols (Mo-$_{ks}$) represents a very dark coloured surface soil developed under decomposed grass/plant materials. Oxisols (Ox-$_{ks}$) represents the surface soils of low fertility on gentle slope areas. And Vertisols (Ve-$_{ks}$) represents the surface soils of very high clay content indicating cracks.

2.2 Combine Soil Type Equation (CSTE): Theoretical Background

Combine Soil Type Equation (CSTE) was developed following the general rule of contextualised soil groups terminologies defined in FAO/USDA guidelines (FAO, 2006; Soil Survey Staff, 2010). CSTE was used to classify a set of two or more different soil groups, which have been formed under the same surface soil into one new soil group name. This new soil group name is the representative of the surface soil environment in the assessment site at that time of the assessment. The equation comprises a combination of field data information system (FDIS), international soil group definition (ISGD) and digital images of the assessment sites.

The FDIS consists of visual assessments of the surface soil parent materials and colour appearances as well as measurement of the surface soil area using measuring tape in metre (m). The overall aim of ISGD is to aid as a guide to classification of surface soil group in the field. The digital images was used in Computer Graphic Paint Design (CGPD) software to show the boundary lines of each soil group including the scale of the area that has been covered under each of the respected soil group in the field. The information provided on each image comported very well with the FDIS and ISGD data information, as appeared physically in the field.

By manner of the present classification model, the various surface soil scales, which have been measured infers that any surface soil group with highest scale, formed the dominant soil parent materials and surface soil colour appearance. Considering the specific mentioned factors, a suffix code was formalised to represent each soil group in a given measured surface soil site. The suffix codes used are: Al, An, Ar, Ca, En, Hi, In, Mo, Ox, and Ve for Alfisols, Anthrosols, Aridisols, Calsisols, Entisols, Histosols, Inceptisols, Molisols, Oxisols, and Vertisols respectively. Combinations of two of more suffix codes give the new name of soil group according to CSTE. This CSTE equation is as follows:

$$\mathrm{CSTE} = 1\,x\ \frac{Al}{1!} x \frac{Al^2}{1!}\ or\ + \frac{An}{1!} x \frac{An^2}{1!}\ or + \frac{Ar}{1!} x \frac{Ar^2}{1!}\ or +\ \frac{En}{1!} x \frac{En^2}{1!}\ or\ + or\ \frac{Hi}{1!} x \frac{Hi^2}{1!}\ or$$
$$+\ \frac{In}{1!} x \frac{In^2}{1!}\ or + \frac{Mo}{1!} x \frac{Mo^2}{1!}\ or\ + \frac{Ox}{1!} x \frac{Ox^2}{1!}\ or\ +\ \frac{Ve}{1!} x \frac{Ve^2}{1!}$$

As defined earlier, each of these symbols represent a particular soil group in the contextual theory of soil group terminologies defined by FAO/USDA. However, the symbol '1!' means under the same surface area. Thus, on this fact, the equation was practical in the field by considering the concept of soil pedon (Soil Survey Staff, 2010). For example, in a short/long distances (pedon/poly-pedon), a new surface soil group has been classified under the same surface soil condition characterised by combination of different set of parent materials, attributed by the same physical colour appearance as accurately conformed very well with one of the definition given by FAO/USDA on a particular soil group. In a practical definition of the CSTE, a combined soil type name is possible using two or more of the following suffix codes: Al, An, Ar, Ca, En, Hi, In, Mo, Ox and Ve, as appeared in the mathematical context of the equation given above. This concept and believe was used as complete guideline idea in defining and classifying the surface soil condition of the Sudan Savannah, Kebbi State Nigeria. The images and formula of the results outputs were given in Appendix attached in this paper.

III. Results

Fourteen new soil groups were classified in dryland and fadama areas of the Sudan Savannah zone of Kebbi State Nigeria. Eight of these soil groups belong to dryland and six to fadama (Table 2). The very surfaces areas are shown in Figure 1 and 2. As a prerequisite of naming the physical surface condition of these new soil groups, each name has provided with specific surface area code indicating where each site has been located. Also, the scale and major surface textural parent materials of each site were given (Table 3 and 4). The specific area code FL means fadama whereas DL means dryland.

Table 2: Fourteen new surface soil groups in fadama and drland areas of Sudan Savannah

Surface area Code[2]	**FAO-USDA 'soil group'**	**CSTE 'new soil group'**
FL-13	Alfisols	Alanhisols
DL-07	Alfisols	Alhioxsols
DL-05	Aridisols	Aralhisols
DL-04	Aridisols	Araloxhisols
DL-03	Aridisols	Aralsols
DL-02	Aridisols	Aransols
DL-06	Aridisols	Arhioxalsols
DL-01	Aridisols	Arhisols
FL-11	Entisols	Enmoinarsols
DL-08	Histosols	Hicaoxalsols
FL-14	Inceptisols	Inalmosols
FL-09	Inceptisols	Inmoalsols
FL-10	Vertisols	Vehisols
FL-12	Vertisols	Vemohisols

[1]Surface area codes are site codes given to each study site.

The term Alanhisols and Alhioxsols are two new soil group names, which have more properties of Alfisols. Beside, Alanhisols has additional properties of Anthrosols and Histosol, whereas Alhioxsols has additional properties of Histosols, Oxisols and Alfisols. The individual grains can be physically seen, although, thoroughly mixed with decomposed organic materials, which are largely from plants. The important physical characteristics of Alanhisols are: well drained, enough silt content, black in colour, moderate clay content and can be feel grassy. Alhioxsols on the other hand, are grassier when felt than Alanhisols. These two soil groups have almost the same soil structure, soil consistency and moisture characteristics. Also, Aralhisols, Araloxhisols, Aralsols, Aransols, Arhioxalsols and Arhisols are six new soil groups classified under the surfaces areas of Aridisols. As the names implies (i.e. Ar-), they all belong to soil group Aridisols. Characteristically, Aralhisols has some properties of Aridisols, Alfisols, and Histosols. Araloxhisols is a new soil term with properties of Aridisols, Alfisols, Oxisols and Histosols, while Arhioxalsols refer to new soil type with combination of Aridisols, Histosols, Oxisols and Alfisols. The terms Aralsols, Aransols and Arhisols represent the properties of Aridisols-Alfisols, Aridisols-Anthrosols and Aridisols-Histosols respectively.

Figure 1: Images of the assessment sites in the dryland areas indicating the scales of the various soil groups

The terms Enmoinarsols and Hicaoxalsols are the only two new soil group names classified under the surface areas of Entisols and Histosols. The term Enmoinarsols has the properties of Entisols in combination with Molisols, Inceptisols and Aridisols, while Hicaoxalsols is a combination of Histosols, Calsisols, Oxisols and Alfisols. However, Inalmosols and Inmoalsols are two new soil group names classified from the surface areas of Inceptisols in fadama flood plain areas. Inalmosols is a combination of three soil groups namely: Inceptisols, Alfisols and Molisols. The term Inmoalsols represents a soil group with more properties of Inceptisols followed by Molisols, and Alfisols. The two new soil terms Vehisols and Vemohisols are classified from the surface areas of Vertisols in fadama area. Vehisols is a combination of two surface soil properties – the Vertisols and Histosols. However, Vemohisols has the properties of three major soil types namely –Vertisols, Molisols, and Histosols.

Figure 2: Images of the assessment sites in the fadama areas indicating the scales of the various soil groups

Table 3: Scales of the assessment sites and major textural parent materials in dryland areas

Area code[1]	Soil group[2] and area covered (m)	Scale of each site: Total sum of the area covered by each soil group (m)	New soil group name (CSTE)	Major textural classes[3]
DL-01	Aridisols = 48.3 Aridisols = 12.7 Histosols = 5.1	65.8	Arhisols	Sand Silt Loam
DL-02	Aridisols = 36.5 Anthrosols = 26 Anthrosols = 1.5	63.5	Aransols	Sand Silt
DL-03	Aridisols = 36.5 Alfisols = 31.3	67.8	Aralsols	Sand Loam
DL-04	Aridisols = 31 Histosols = 29.2 Oxisols = 21.8 Alfisols = 11.7	93.7	Araloxhisols	Sand Silt Loam
DL-05	Aridisols = 24.1 Alfisols = 19.6 Histosols = 9	52.7	Aralhisols	Sand Silt Loam
DL-06	Aridisols = 44.1 Oxisols = 17.2 Histosols = 4.6 Alfisols = 3.8	69.7	Arhioxalsols	Sandy loam Silt
DL-07	Alfisols = 6.4 Histosols = 6.1 Alfisols = 4.6 Oxisols = 1.3	18.4	Alhioxsols	Sand Silt loam
DL-08	Histosols = 42.7 Alfisols = 20.5 Oxisols = 2.3 Calsisols = 1.1	66.6	Hicaoxalsols	Silt loam Sandy loam Silt

[1]Surface area codes are site codes given to each study site. [2]Soil groups according to FAO-USDA classification systems. [3]Classes of textural parent materials according to Doneen and Westcot (1988)

Table 4: Scales of the assessment sites and major textural parent materials in fadama areas

Area code[1]	Soil group[2] and area covered (m)	Scale of each site: Total sum of the area covered by each soil group (m)	New soil group name	Major textural classes[3]
FL-09	Inceptisols = 43.6 Molisols = 16.7 Alfisols = 5.9	66.2	Inmoalsols	Silt clay Clay loam Loam
FL-10	Vertisols = 63.1 Histosols = 34.8	97.9	Vehisols	Clay Clay loam
FL-11	Entisols = 28.5 Molisols = 17 Inceptisols = 16.8 Aridisols = 12.2	74.5	Enmoinarsols	Clay Silt clay Clay loam Sandy clay
F-L12	Vertisols = 37.4 Molisols = 28.1 Histosols = 13.8	79.3	Vemohisols	Clay Clay loam
F-L13	Alfisols = 40.9 Anthrosols = 35.1 Histosols = 11.6	87.6	Alanhisols	
F-L14	Inceptisols = 52.2 Alfisols = 29 Molisols = 25.1	106.3	Inalmosols	

[1]Surface area codes are site codes given to each study site. [2]Soil groups according to FAO-USDA classification systems. [3]Classes of textural parent materials according to Doneen and Westcot (1988)

IV. Discussion

Results of the present classification indicate that it is very possible to classify the agricultural surface soils using mathematical equation such as CSTE following careful use of FAO/USDA guidelines in the field. Although, the procedure used has differs from that of FAO/USDA guides, however, the contextualised classification system is still remained the same. Sometime this would be inaccurate-classification, if careful attention is not been given during the physical observation in the field and at time of mathematical calculations under CSTE. It must be aware that agricultural surface soils are components of terrestrial soil environment (Muellar *et al.,* 2010) that covered most lands of the earth with different physical nature and dynamic functions (Blum, 2006); therefore, the suitability of agricultural surface soils classification is good to take consideration of many distinct physical soil characteristics under specific agricultural activities as used in this study. In the present classification, the new soil group names are more of agricultural land use surface limitations such as flood plains, irrigated land, dry soils, valley land, millet land, rice land, sandy soil, clayed soils, decomposed organic material soils, sticky soils, moist soils, carbonated soils, coloured soils, deposited soils, transported soils and residual soils. It took us eight months to develop the method, and was then used to classify and name the surface soil conditions of mixed particle materials, which were believed to have inherent characteristics of two or more soil groups formed within the study area (see Table 1). The terminologies used are of international standard and correspond to other specific soil and land evaluation and classification systems. Examples of these classification systems are: Land Suitability Rating System (LSRS), which consists of soil factors that describe the surface soils for agricultural suitability (LSRS) (AIWG, 1995), Soil Survey Manual for land and soil assessment in Somalia (SWALIM, 2007a), Land Suitability Evaluation System (LSES) for growing cereals based on soil information and climate data in Ukraine (Medvedev *et al.,* 2002).

By manner of this classification under the new CSTE, soil physical properties are important surface soil components that can be use to describe the physical parent particles of the new soil groups (e.g. Usman, 2007; FAO, 2008). Thus, the limitations of other soil data (e.g. chemical and hydraulic properties) in new soil groups are still unknown. Even though, the need to evaluate these properties at stand scale is demanded (Augusto *et al.,* 2010), it is important to mention that surface soil characterised by poor physical appearance was generally attributed to has poor physical quality (e.g. Letey, 1985; Dexter 2004, Usman, 2007). Despite this, we considered only some selected properties in this description as recommended by Verma and Sharma, (2008), Defoer *et al.* (2000) and Raji *et al.* (2006). These selected soil physical properties are the most important soil properties of a growing medium under agricultural surface soil condition (ACECA, 1998; Ustun *et al.,* 2005). They are colour, texture, structure, and consistency. It must be point out that in the approach of the present new CSTE of grouping the agricultural surface soils with integrated physical soil dynamic nature, the most limiting factor is associated with lack of quantitative soil analysis. Notwithstanding, some technicalities were used at global scale to compare the physical surface soil nature of all the new soil groups with those of other soils of which they have quantitative analyses or personal knowledge.

Texturally, the surface physical appearances of all the new soil groups correspond to textural names defined by Doneen and Wesrcot (1988) under agricultural soils in the United State. These textural names are sandy loam, loam, silt loam, clay loam, and clay (Tables 3, 4). According to definitions (Doneen and Wesrcot, 1988): sandy loam is a soil containing a large portion of sand, but which has enough silt and clay to make it slightly cohesive; the individual sand grains can readily be seen and felt. They also defined loam as a soil having a mixture of the different grades of sand, silt and clay in such proportions that no characteristics predominates; silt loam as a soil having a moderate amount of the fine grades of sand and only a small amount of clay, over half of the particles being of the silt; clay loam is a fine-textured soil which usually break into clods or lumps that are hard when dry; whereas clay is a fine-textured soil that usually forms very hard lumps or clods and is quite plastic and usually sticky when wet. In line with these definitions, sandy, sandy clay, and silt sand are also very common by physical appearance. The sand is a soil texture having large proportion of sand, whereas sand clay and silt sand both have equal proportion of sand and clay or silt (e.g. Atkinson, 1993; USDA-NRCS, 2002). The new soil groups in this study appeared to have significant variations in term of these textural names.

At the world scale, the textural names of the six new soil groups in our present classification – i.e. [Ar] – groups: Aralhisols, Araloxhisols, Aralsols, Aransols, Arhioxalsols, and Arhisols were categorise into sandy, sandy loam, silt loam and silt sand (Table 3). They are physically belonged to massive and single grains types of soil structure, felt by hand-touch as loose, soft, and ashy in their consistency nature. Aralsols, Aransols, and Arhisols might have more sand content than Aralhisols, Araloxhisols and Arhioxalsols. According to their physical appearances, the formers can be attributed to sandy mineral soils whereas the latter ones as coarse sand mineral soils. By examination, Augusto *et al*. (2010) found that in sandy mineral soils layers, the sand content can be up to 98%, whereas in coarse sand surface layer it is 79%. Another examination (see Chesworth, 2008) shows that sandy soils have 80% sand and 10% clay; classified as poor soil physical nature. The surface soil colours of the particle parent materials as tallied with Munsell Soil Colour Chart (Munsell, 1971) are yellowish brown (5YR 5/8 and 10YR 6/6), light yellowish (10YR 8/4), pale brown (10YR 6/3), milky yellow-brown (7.5YR 7/6) and light yellowish-grey (10YR 8/6). If not managed well, the surfaces textural soil particles of these six new soil groups would be easily moved away by water and wind causing surface erosions, leaching, particle transport and subsequently low soil fertility and yield. However, regular application of animal manures will help to improve the textural quality, soil colour and structural formation in these soils.

Alanhisols and Alhioxsols have loam, silt loam and loamy sand textures. The surface colour is light black (5YR 7/4), black-brown (5YR 3/3) and reddish-brown (5YR 5/6). Soil structures are granular (very small size) and single grain characterised by slightly hard, soft and loose consistencies. In the same way, also Enmoinarsols has loam, silt loam textures; soft and loose consistencies as well as massive and single grains structures. Their main resemble features are described elsewhere (Soil Survey Staff, 1999) and some of their percentage textural proportions are similar to those of six Ar – groups as stated earlier.

The main textural names of Hicaoxalsols are clay loam, silt clay and silt. The proportion of clay in this new soil group was high than those of 'Ar' and 'Al' groups, because of Calsisols properties; however, soil colours remain almost the same. Soil structures are granular (medium size) and single grains both characterised by hard and slightly sticky consistencies. Doneen and Westcot (1988) reported that soils having these properties, when kneaded in the hand it does not crumble readily, but tend to work into a heavy compact mass.

Clay loam, silt clay and silt loam are three textural names belonging to Inalmosols and Inmoalsols. Part of these soils squeeze when dry and are slightly or moderately plastic when moist (e.g. Doneen and Westcot 1988; Soil Survey Staff, 2010). Structurally, they are granular, sub-angular (small size), and single grains (large size). Unlike Hicaoxalsols, the surfaces soil consistency under Inalmosols and Inmoalsols are sticky, hard and plastic tend to breaks into clods and lumps when fully dried. The surface colours are dark greyish brown (10YR 4/1), light black (10YR 5/1) and light black brown (10YR 5/2).

Three textural names were attributed to Vehisols and Vemohisols soil groups namely – clay, clay loam, and silt clay. Munssel Colour Chart revealed that dark grey (10YR 3/2), very dark greyish brown (10YR 3/2), very dark brown (10YR 3/3) and dark blacker (5YR 5/1) are the main surface soil colours that can be found under Vehisols and Vemohisols. Because of their high clay content (e.g. Brady and Weil, 2004; FAO, 2006; Usman, 2007) five different types of soil structures are attributed to these two soil groups. They are granular, angular, plate-like, blocky and columnar. Swelling, shrinkage, periodic cracking, and high clay content (30% – 90%) were reported (e.g. Doneen and Westcot, 1988; Singh *et al.*, 2004) as major physical characteristics of all Ve – groups including new Vehisols and Vemohisols. Their network of surface and sub-surface periodic cracks were measured to be within the range of 9 cm to 20 cm (Somasundaram *et al.*, 2011).

V. Conclusion

In conclusion, our study indicates that the use of new Combine Soil Type Equation (CSTE) has provided another way of classifying soil base on Visual Soil Assessment in the field. Although, some difficulties and errors might occur in trying to adapt or use the same equation in another geographical area due to environmental and regional soil factors, however, it is believe that the new CSTE can be consider as an alternative option in selection for soil classification in the field. The method has provided a best way of defining the current status of the dynamic surface soil condition under different agricultural soil conditions in the study area. It also helped in addressing the quality of surface soil at that very time of assessment in the field, and thus can be use as a tool for information gathering in the context of future sustainable soil management practices.

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APPENDIX

Surface area 20: Inceptisols + Molisols + Alfisols

$$\frac{IN}{1!} + \frac{MO}{1!} + \frac{AL}{1!} = \text{INMOALSOLS}$$

Surface area: 47 Vertisols + Histosols

$$\frac{VE}{1!} + \frac{HI}{1!} = \text{VEHISOLS}$$

Surface area 29: Entisols + Molisols + Inceptisols + Aridisols

$$\frac{EN}{1!} + \frac{MO}{1!} + \frac{IN}{1!} + \frac{AR}{1!} = \text{ENMOINARSOLS}$$

Surface area 18: Vertisols + Molisols + Histosols

$$\frac{VE}{1!} + \frac{MO}{1!} + \frac{HI}{1!} = \text{VEMOHISOLS}$$

Surface area 06: (Aridisols x Aridisols) + Histosols

$$\frac{AR}{1!} x \frac{AR}{1!} + \frac{HI}{1!} = \text{ARHISOLS}$$

Surface area 22: Aridisols + Anthrosols x Anthrosols

$$\frac{AR}{1!} + \frac{AN}{1!} x \frac{AN}{1!} = \text{ARANSOLS}$$

Alfisols: Surface area 16: Alfisols + Anthrosols + Histosols

$$\frac{AL}{1!} + \frac{AN}{1!} + \frac{HI}{1!} = \text{ALANHISOLS}$$

Surface area 38: Aridisols + Alfisols

$$\frac{AR}{1!} + \frac{AL}{1!} = \text{ARALSOLS}$$

Surface area 08: Inceptisols + Alfisols x Alfisols + [Molisols + Molisols]

$$\frac{IN}{1!} + \frac{AL}{1!} x \frac{AL}{1!} + \frac{MO}{1!} x \frac{MO}{1!} = \text{INALMOSOLS}$$

Surface area 61: Aridisols + Alfisols + Oxisols + Histosols

$$\frac{AR}{1!} + \frac{AL}{1!} + \frac{OX}{1!} + \frac{HI}{1!} = \text{ARALOXHISOLS}$$

Surface area 50: Aridisols x Aridisols + Alfisols + Histosols

$$\frac{AR}{1!}x\,\frac{AR}{1!} + \frac{AL}{1!}\,x\,\frac{HI}{1!} = \text{ARALHISOLS}$$

Surface area 70: Aridisols + Histosols + Oxisols + Alfisols

$$\frac{AR}{1!} + \frac{HI}{1!}\,x\,\frac{OX}{1!} + \frac{AL}{1!} = \text{ARHIOXALSOLS}$$

Surface area 59: Alfisols x Alfisols + Histosols x Histosols + Oxisols

$$\frac{AL}{1!}x\,\frac{AL}{1!} + \frac{HI}{1!}\,x\,\frac{HI}{1!} + \frac{OX}{1!} = \text{ALHIOXSOLS}$$

Surface area 04: Histosols + Calsisols + Oxisols + Alfisols

$$\frac{HI}{1!} + \frac{CA}{1!} + \frac{OX}{1!} + \frac{AL}{1!} = \text{HICAOXALSOLS}$$