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Review on Effect of Topo sequence on Soil Physico chemical Properties

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Abstract

Reviewing the effect of toposequence on soil properties are essential for addressing the proper land use and land management. In view of this, it was conducted to review the effect of different topographic position and slope level on the selected physicochemical properties of soils. Four differen slope level, such as upper slop, middle slope, foot slope, and lower slope were considered. Not only the slope level direction of the slope faces important when slope is > than 10 %.Noticeable in South east mountain. North Slope colder soils, Less evaporation, more leaching thus more soil development, whereas South Slope warmer soils, more evaporation, less leaching thus less soil development. The results of the review, shows that cation exchange capacity, soil organic matter, soil Organic carbon content, total nitrogen, copper, total porosity, bulk density, infiltration rate of the shoulder slope level was lower than the upper slope level and the middle slope.

In the other case, soil reaction, cation exchange capacity, Micronutrient, total nitrogen, and available phosphorous is high depend on organic carbon, organic matter, and the clay particle. Bulk density, total porosity, infiltration, and hydraulic conductivity depend on soil particle distribution. This review finally, concluded that the soil properties were maintained relatively under upper slope, and back slope, whereas under the shoulder due to steepness of the slope, and under the foot slope due to the deposition of materials from upslope may be near water table or may have greatest leaching due to water from upslope and rainfall were negative impact on *the soils. This indicating that a need for application of integrated natural resource management in sustainable manner to optimize and maintain the soil physicochemical properties.*

Key words: *Tope sequence, middle slope, upper slop, foot slope*

Introduction

There have been several attempts to relate soil properties to landscape position for many landscapes (Norton and Smith, 1930; Kleiss, 1970; Dahiya et al., 1984; Wysocki et al., 2001). This may be partly due to the realization of the role topographic position plays in influencing runoff, soil erosion and hence soil formation (Babalola et al., 2007). Soil properties such as clay content has been found highly correlated with topographic position (Wang et al., 2001) while soil organic matter has been shown to vary with topographic position (Miller et al., 1988). The spatial variation of soil properties is significantly influenced by some environmental factors such as climate, topography, parent materials, vegetation, and disturbance due to human activity (Jenny, 1941; Chen et al., 1997; Chaplot et al., 2001; McKenzie and Ryan, 1999; Ollinger et al., 2002).

Some studies have indicated that soil properties are related to topographic positions in different forest ecosystems (Malo et al., 1974; Nizeyimana and Bicki, 1992; Stolt et al., 1993; Chen et al., 1997; De Bruin and Stein, 1998; King et al., 1999; Bohlen et al., 2001; Venterea et al., 2003).Soil moisture content is affected by the slope and aspect in the landscape (Franzmeier et al., 1969; Butler et al., 1986; Daniels et al., 1987). Spatial information about soil properties is usually a limiting factor for both land management and the application of spatially distributed models (Park and Vlek, 2002).

Information from soil maps is usually low resolution and the values of soil attributes are assumed to be uniform although there is often great variation within soil units (Zhu et al., 1997). Thus, there is much interest in relating different properties of the soil and habitat to readily available data such as elevation data. Elevation data can then be used to generate digital maps of soil properties or soil types (Behrens et al., 2005). Together with parent material, climate, biota, and time, topography is one of the five fundamental elements of the soil forming factor theory

(Amundsen et al., 1994; Jenny, 1941). Likewise, topography is central to the catena concept for soil development (Hook and Burke, 2000), which is characterized by leaching and redistribution of elements and soil material along hill slopes.

The effect of topography is more pronounced on young and rolling soils than on old and level soils (Fisher and Binkley, 2000). The direction of the slope (i.e. the aspect) influences the amount and intensity of solar radiation to which a location is exposed and subsequently the temperature regime, which affects soil biological and chemical processes as well as evaporation. The local slope determines not only the intensity of such processes as erosion and sediment redistribution, but also local drainage capacity. However, the most important effect of topography on soils in, for instance, boreal regions is its influence on water flow patterns at the landscape level. Topographical features such as curvature, slope, and upslope area influence the hydrological conditions of a location, generate different soil moisture conditions, and flow patterns.

Loess soils are believed to develop from parent materials, which before pedo chemical weathering contain large amount of silt and about 10 - 20% clay (Buol *et al*., 1997). Typically, loess is a loose deposit of remarkably uniform physical composition mainly of silt texture (Buol *et al*., 1997). Soil genesis in loess causes distinct changes in morphological, physical and chemical properties. Morphological changes in soils developed in loess deposits include variation in color, solum thickness, degree of horizonation, depth of leaching and structural development (Young and Hammer, 2000; Schumacher *et al*., 1987). The current study carried out to examine the morphological, physical and chemical properties of soils developed on loess deposit and evaluates the influence of toposequence on their properties, pedogenesis, and classification and management implications.

Depending on the location on a slope physical and chemical properties of the soil will also vary either minimally or maximally. Soil physical and chemical properties are necessary to define and evaluate soil types, slopes, existing land use or natural cover under given condition of management. Soil variation occurs naturally from pedogenic factors and across multiple geographic scales ranging from small fields to very large fields. Therefore, the objective of this study was to review the effect of toposequence on soil physicochemical properties.

Literature review

Concepts of toposequence

The concept of toposequence, which involves processes that cause properties differentiation along hillslopes and among soil, horizons have improved evaluating the interaction of pedogenic and geomorphic processes (Gessler *et al*.,). Many soil scientists especially in the United States use the term toposequence interchange-ably with catena. The soils differ as a result of erosion, transportation, and deposition of surficial material as well as leaching, translocation and deposition of chemical and particulate constituents in the soil.

These processes result in morphological changes, associated with soil color (grayness) and horizonation as a result of changes in hydrology related to topographic position (Hall, 1983). The soil morphology of each catena member is continuously adjusting to the given dynamic conditions controlled by the landscape position it occupies (Dan and Yaalon, 1964). Differences in characteristics of soils occupying different landscape positions on a toposequence are principally caused by water and material movement and distribution on the slope.

Although runoff is the most obvious and often most dramatic process of water distribution, water movement below the surface (throughflow) is more important than overland flow in soils of the humid region (Hall, 1983). Subsurface lateral flow could be both saturated and unsaturated, with saturated flow being dominant in concave positions. The magnitude and direction of the down hill flux of infiltrating water depend on the degree of soil anisotropy and the slope gradient (Saslavsky and Rogowski, 1969). Relief / topography distribute matter and energy over the earth's surface and in this way influences soil formation.

Effects of toposequence on soil physical properties

Bulk density is the weight of the soil solids per unit weight of total soil. Bulk density is a measure of the mass of soil per unit volume. When soil particles are pushed close together, increasing the mass per unit volume, the soil is compacted. Soil compaction is an increase in bulk density due to external load leading to the degradation of physical soil properties such as root penetration, hydraulic conductivity and aeration (Mitiku *et al.,* 2006). The dry bulk density expresses the ratio of the mass of solids to the total soil volume (solids and pores together).

The bulk specific gravity of sandy soils with a relatively low volume of pores may be as high as 1.6, whereas that of aggregated loams and clay soils may be below 1.2. The low bulk density and gravel content at FS position indicates low level of soil compactness and associated improvement in root penetration (Ogban and Babalola, 2003), and hence favourable root activity (Ogban and Babalola, 2009). In addition, changes in gravel content may explain why there were changes in soil physical properties (Fasina *et al.,* 2007). Highest values of sand content at US position could also be explained by the effect of soil erosion.

The particle size distribution of the soil under the various landscape positions. Compared to the other landforms, the elevated landform had low sand and high clay contents at the mid slope position. In contrast, the depressed landforms had high sand and low silt contents at the top slope position. In the level landform, there were negligible variations in the particle size distribution among the three slope positions. During such an event, there is bound to be even distribution of the fine particles in the flooding water, the subsequent sedimentation of which accounted for the observation. Following a similar study in Indonesia and Thailand, Boling *et al*. (2008) reported that only clay fraction of the soil increased from the top of the valley to its bottom in Indonesia.

Soil texture refers to the relative proportion of stone, gravel, sand, silt and clay in a specified quantity of soil. Sand particles are 2.00-0.05 mm in diameter, silt 0.050- 0.002mm and clay <0.002mm. Soil texture determines soil workability, water-holding capacity, soil structure and nutrient retention. Compared to sandy soils, clay soils hold more water and retain nutrients. Clay particles are lighter than sand particles, and once detached by erosion they are easily transported. Therefore, unchecked erosion leads to a loss of soil productivity (Gachene and Kimaru, 2003).

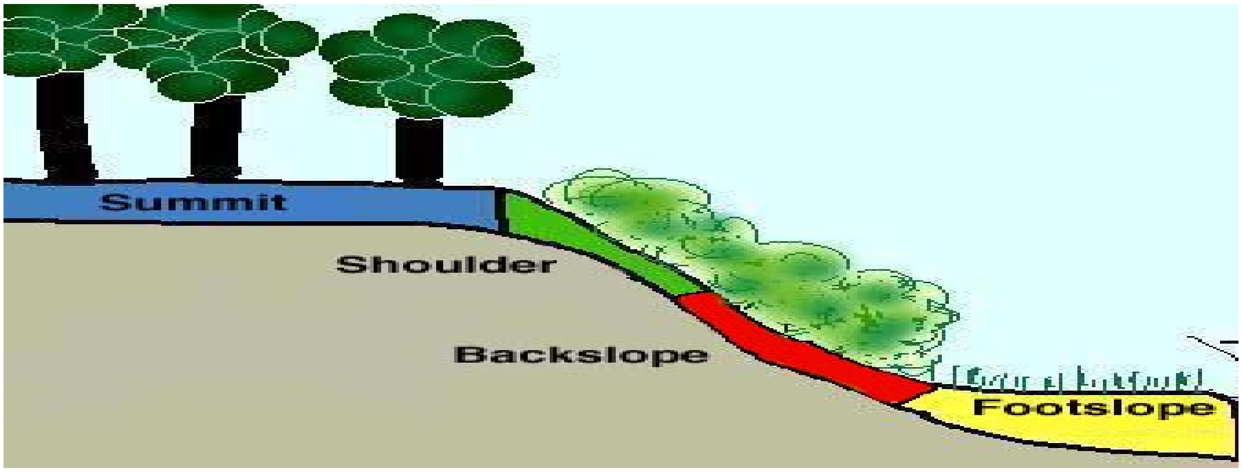
The particle size distribution of the soils varied along the toposequence. Soils situated at the middle slope position had relatively higher clay content (25 - 85%), throughout the profile, followed by soils located at upper (15 - 60%), toe (35 - 55%) and lower slope (25 - 30%) positions. The sand contents also varied among the soils, with values ranging from 20 - 50%, 30 - 40%, 20 to 40% and 10 - 35% at upper, lower, toe and middle slope positions, respectively. Soils at the upper and middle slope positions have discernable increase in clay content with soil depth compared to those found at lower and toe slopes, which have slight clay increase. According to Buol *et al.* (2003), the presence of clay cutans or clay skins and textural differentiation in the profile are indicators of clay migration.

The accumulation of clay in the subsurface horizon could have been contributed by the *in situ* synthesis of secondary clays, the weathering of primary minerals in the B-horizon, or the residual concentration of clays from the selective dissolution of more soluble minerals of coarser grain sized in the B-horizon (Buol et al., 2003).This implies that no excessive compaction and no restriction to root development (Werner, 1997).Irrespective of slope position, sand and clay fractions indicated statistically same values among the three landforms. Variations occurred only for the silt fraction that showed lower value in the elevated landform compared to the other two landforms. This is an indication that the soil is highly weathered and is therefore poor in weather able minerals.

The trend of percentage silt in the four landforms reflects the density-dependent pattern of surface flow, transportation and deposition of soil materials from upland to lowland. The clay nature of the entire field as depicted by the textural classes reflects the underlying Tertiary or Cretaceous Shale parent materials on the soil texture (Abe *et al*. 2009). It could also be due partly to deposition by runoff from the adjacent upland and partly to low erosion status of the soil at the present level of cultivation (Ogban & Babalola 2003, 2009). This observation did not conform to expectation that clay content are commonly higher at foot slopes due washing away of clay-rich materials from upper slopes as explained by Babalola et al. (2007). According to Ovales and Collins (1986), sand particles due to their size are normally deposited at the upper slopes. In general, properties, such as percentage sand, clay were affected by topographic position.

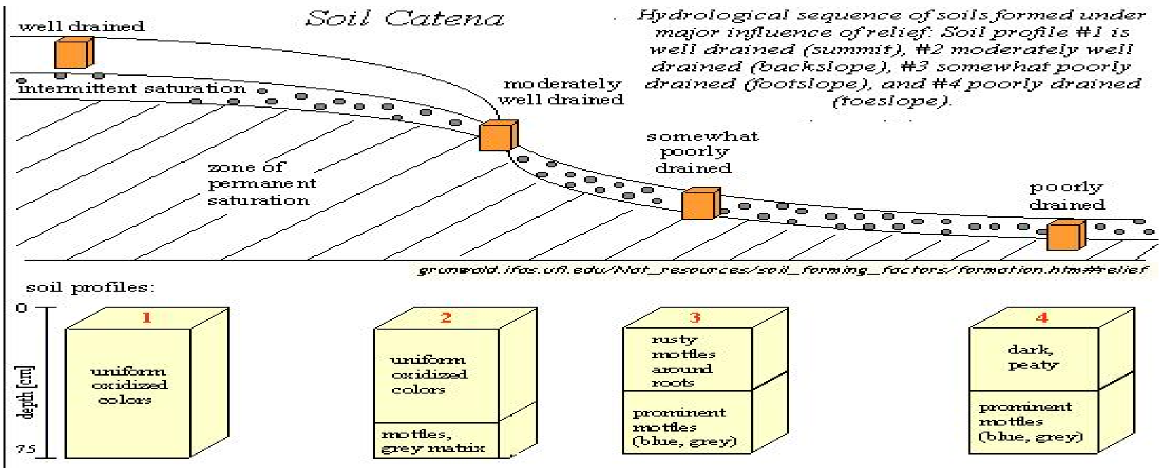
Infiltration is the downward entry of water from the surface into the soil profile (Lal, 1990**).** It is the key to soil and water conservation because it determines the amount of runoff over the soil surface during rainstorms. The relation between the rate of water supply to the soil and the rate of infiltration through it determine the distribution of such water between runoff and storage in the root zone (Pla, 2007). Thus, the ability of the soil surface to accept continuous heavy rainfall or irrigation depends on the infiltration behavior or characteristics of the soil.

According to Ogban *et al*. (2000), low values of the infiltration characteristics indicate a potentially high runoff (erosion) on such toposequences or slopes. These will invariably affect the water economy of the rooting zone of plants. Such soil will have difficulty in meeting the water needs for crop production where water is a major limiting factor (Wuddivira and Abdulkadir, 2000). The infiltration rate of a soil depends on texture, structure, antecedent soil moisture content (i.e., the moisture content of soil profile before rainfall or irrigation begins), continuity and stability of pores, and soil matric potential. Greatest erosion, least water infiltration greatest runoff, and minimal soil developmental shoulder.



Summit will have minimum erosion and maximum soil development (greatest horizonation). Back slope will be similar to summit unless slope is > 20%. Greatest erosion least water infiltration greatest runoff minimal soil developmental at shoulder. Deposition of materials from upslope may be near water table - may have greatest leaching due to water from upslope and rainfall at foot slope.

The term hydraulic conductivity**,** which has been defined as the meters per day of water seeping into the soil under the pull of gravity or under a unit hydraulic gradient. The values of soil moisture content were highest at the foot slopes (FS) under all land use. This is very much expected and is an indication of seepage and the concentration of runoff from upper slopes as was found by Tsegaye *et al.* (2006). This also indicates that soil moisture content is highly influenced by slope position.



Catena: - a series of soils with different horizons due to differences in their depth to the water table Drainage classes Well-drained at summit Moderately well-drained at back slope Somewhat poorly drained at foot slope Poorly drained at toe slope.

Porosity is an index of the relative pore space in a soil. Its value generally ranges from 0.3 to 0.6 (30–60%). Coarse-textured soils tend to be less porous than fine-textured soils, though the mean size of individual pores is greater in the former. In clay soils, the porosity is highly variable because the soil alternately swells, shrinks, aggregates, disperses, compacts, and cracks. Total porosity (TP) values ranged from 45.10 to 59.65%. Except for plantain land use, total porosity values were highest at the foot slopes (FS). Sand particles have large macrospores, which have direct effect on total porosity (USDA, 2001). Total porosity (TP) of the soils ranged from 53 to 61 (V%) and macro pores (pores at field capacity) between 12 and 28 (V%). According to Brady and Weil (2002), ideal total pore space values, which are acceptable for crop production, are around 50%. Hence, the soils have an acceptable range of total porosity values for crop production.

Effect of toposequence on soil chemical properties

Cation Exchange Capacity (CEC) is the parameter used in the analysis of the chemical properties of soils. The ability of a soil to retain cations (positively charged ions) such as potassium (K+), ammonium (NH4+), hydrogen (H+), calcium (Ca++), and magnesium (Mg++) in a form that is available to plants is known as cation exchange capacity (CEC). These cations are in the soil solution and are in dynamic equilibrium with the cations adsorbed on the surface of clay and organic matter. The negative charge on the very large external surfaces of clay and humus attract positive charged ions. As a result, these ions are loosely adsorbed at the surface of the solid phase (Ilaco, 1985). The cation exchange capacity of the soils was low both within and between profiles along the toposequence. The distribution trend within the profiles is similar to that of clay content.

The CEC values within the toposequence position also follow the pattern of clay distribution with the upper slope position having the highest value of clay contains and the lower slope position having the lowest value clay contains. Furthermore, the upper and middle pedons have relatively higher CEC than the lower and toe slope pedons. According to Landon (1991), CEC values are rated < 5 as very low, 5 - 15 as low; 15 - 25 as medium, 25 - 40 as high and > 40 as very high. The CEC of the soils in the surface layers ranged from medium to high. According to Brady and Weil (2002), CEC depends on the nature and number of colloidal particles.

The availability of most plant essential elements depends on soil pH; it is an indication of relative availability of plant nutrients. Thus, soil pH is generally both a symptom of a soils condition and a cause of many of the reactions that occur in soil. Most soils have pH values between four and eight; nearly all soils with pH values above eight have a higher percentage of Na+ ions on their cation exchange sites. Most soils with pH values below four contain sulfuric acid. By strict definition, any pH below 7.0 is acid and any pH above 7.0 is alkaline. More practically, a small zone near 7.0 may be considered neutral (Foth and Ellis, 1997).

Soil pH depends on a variety of factors including the season of the year, cropping practices, the soil horizon sampled, the water content at the sampling time and the way the pH is determined (Troeh and Thompson, 1993). The toposequence affect the soil ph thus, least values at the US positions indicate that acidity decreases down the slope. It must be stated that the prevalence of acidity at the upper slopes is an indication of strong chemical weathering and leaching of plants nutrients as reported by Babalola et al. (2007). On weremadu (2007) reports that increased pH at foot slopes account for high total nitrogen, cation exchange capacity and organic matter.

Soil organic carbon (SOC) is an important soil component that plays key roles in the functions of both natural ecosystems (greatly influencing soil structure, fertility, and water-holding capacity) and agricultural systems, in which it also affects food production and quality (Lal, 2004a). Topography affects soil C through erosion and redistribution of fine soil particles and organic matter across landscape, and through water redistribution leading to varying leaching, infi ltration, and runoff potentials (Creed *et al.,* 2002). Topography is one of the key factors of soil formation and its effects on soil C have been well documented; many researchers reported a strong relationship between terrain attributes and soil C at a field scale (Papiernik *et al.,* 2007).

General topographical influences on soil C are likely to differ in magnitude under agricultural systems with different tillage. Tillage controls soil organic matter dynamics by three major actions, such as periodic disruption of soil structure, incorporating plant residues within soil horizon, and altering soil microclimate (Balesdent *et al.*, 2000). These three major mechanisms in turn influence various soil processes, such as soil aggregation, erosion, mineralization rates, as well as soil moisture, temperature, and aeration regimes (Hernanz *et al.*, 2002) .

The term available phosphorous (AP) refers to the inorganic form, occurring in soil solution, which is almost exclusively, orthophosphate. This orthophosphate occurs in several forms and combinations, and only a small fraction of the total amount present may be available to plants, which is of direct relevance in assessing the P fertility level. Soluble P may be adoptively retained at the surface of colloidal particles. In most soils, the main source of orthophosphate is organic matter (Buruah and Barthakur, 1997). The available phosphorus content decreased with depth with all the profile. Soil pH has been reported to have a profound influence on the amount and manner in which soluble phosphorus become fixed. Adsorption of phosphorus by iron and aluminum oxides declines with increasing pH. The available phosphorus content distribution along the toposequence followed similar pattern as the organic carbon with upper slope position having the highest amount and lower slope position having the lowest amount.

Soil organic matter is the organic fraction of soil derived from the decayed tissue of plants and animals, and from animal excreta, particularly urine. Generally, soils with comparatively higher organic matter content are considered more fertile than soils low in organic matter content. Soil OM reduces compaction by promoting soil aggregation and increasing porosity (Teklu Erkossa, 2005). Highest concentration of SOM and TN occurred at the FS position whiles least concentrations occurred at US position. The high concentrations of these nutrients at foot slopes suggest that overland flow and surface runoff may have transported these soil nutrients to the foot slope. This observation is consistent with findings made by (Babalola *et al.,* 2007). The values of these soil nutrients under plantain land use at the foot slope were almost the same as those at the upper slope. The slightly higher values at the foot slope may be partly due to vegetation cover. Organic matter was also found to decrease downslope this is not the typical trend as organic matter would be expected to deposit downslope with gravity and water movement (Birkeland, 1984).

The decreasing trend may be explained by a difference in soil forming processes from the shoulder to the footslope. For instance, the toeslope may be washed out by Stenner Creek every few years, stripping the top soil of organic matter. Another possibility is that the vegetation was much drier on the shoulder than on the footslope so there may have been more seeds and pieces of dry grass in the shoulder's surface in spite of efforts to remove these particles. Since nitrogen was used to estimate organic matter differences, the carbon nitrogen ratio may have introduced this variation. Typically, the carbon and nitrogen ratio depend on the degree of decomposition and source of organic matter.

Nitrogen is one of the major nutrients required for the nutrition of plants. Of the total amount of nitrogen present in soils, nearly 95-99% is in the organic form and 1-5% in the inorganic form as ammonium and nitrates (Buruah and Barthakur, 1997). Total nitrogen is merely an indicator of the soil potential for the element, but not the measure in which it becomes available to the plant. Nitrogen contents of soils are also needed for the evaluation of C: N ratios of soils, which give an indication of the processes of transformations of organic nitrogen to available nitrogen like ammonical nitrite (Buruah and Barthakur, 1997).

Micronutrient (Zn, Cu, Fe, Mn) distribution along the topo sequence.

Cottenie *et al*. (1981) has shown that within a soil association, the position of a profile in the toposequence has a stronger influence on the micronutrient status. They concluded that upper slope profiles contained more Mn, Fe, Cu, Zn and B than did the lower members of the toposequence.

The Zn content was generally high in the soils. However, within the profiles, extractable zinc generally decreased with depth. Along the toposequence, the zinc distribution were regularly distributed and the highest value were at the upper slope position Corresponding to the position with the highest amount of organic carbon and the lowest value were at the lower slope position. The accumulation of zinc in surface horizon in all the pedons might be due to the addition through plant residues left over by the proceeding crop as intensive cropping system, which resulted in complexing of Zn with organic matter. Odunze, A. C and Kurch, I (2007) reported that high clay content and exchange acidity build up in soils could encourage this high availability of micronutrients such as Zn in soils.

The Cu varied from irrespective of top-position and depth. The available Cu status decreased with increasing soil depth that could be attributed to the accumulation of biomass in the surface layers of soils leading to higher organic carbon content in the surface than subsurface soils Setia, R.K and K.N. Sharma (2004). Along the toposequence, the Cu distribution were regularly distributed and the highest value were at the upper slope position corresponding to the position with highest amount of organic carbon and the lowest value were at the lowest slope position. Plant cycling are considered as a leading factor and anthropogenic and leaching were the factor that affect the vertical distribution and top soil accumulation of micronutrients as suggesting by Jiang, Y., Zhang, G., Zhou, D., Qin, Y., Liang, W.J (2009). Jiang, Y., Zhang, Y.G., Hao, W. and Hang, W. J. (2006) Pointed out that, in the soil surface horizon, micronutrient distribution is controlled by pH, organic matter and CEC. Biological cycling generally moves nutrient upwards because, some proportions of the nutrient absorbed by plants are transported above ground and then recycled to the soil surface by litter fall through fall.

The content of Fe range varied in respective of depth and slope position there were a sharp increased in Fe content with increasing depth. Even through the soil contained iron above the critical 2.5 mgkg-1 given by Esu, I.E (1991). A long the toposequence the Fe content was highest at the upper lope position and the least value at the medium slope position. The high values are apparently due to the nature of parent rock, namely, highly ferruginised sandstone, this is especially so when viewed against the backdrop of reports Mengel, K and G. Geurtzen, (1986). That Fe deficiency is very unlikely in acid soils; as it known to be soluble under relatively acid and reducing conditions Chesworth, W., (1991).

The fluctuation in the organic carbon also caused the inconsistent pattern of available micronutrient distribution. The distribution of manganese along the toposequence revealed that Mn was highest in the upper slope followed by middle slope. Like Zn, the lowest amounts of Mn were found in lower slope. The high content of available Mn in the soils may be related to the acidic nature of the soils. Sillanpaa, M., (1982) reported that availability of Mn is very low when the soil pH is above 7.5; this is because of the formation of hydroxides and carbonates.

Summary and Conclusion

This review indicates that the difference in slope level, and land scape position has an influence on soil physical and chemical properties. The properties of soils along a toposequence showed that landscape position, erosion, aspect, and drainage significantly influenced variation in soil depth, particle size distribution, available water holding capacity, exchangeable bases, cation exchange capacity and base saturation. Particle size distribution of the soils varied along the toposequence. Soils at the upper and middle slope positions have discernable increase in clay content with soil depth compared to those found at lower and toe slopes, which have slight clay increase. The low bulk density and gravel content at FS position indicates low level of soil compactness.

The available phosphorus distribution along the toposequence followed similar pattern as the organic carbon with upper slope position having the highest amount and lower slope position having the lowest amount, and also the zinc distribution were regularly distributed and the highest value were at the upper slope position Corresponding to the position with the highest amount of organic carbon and the lowest value were at the lower slope position. Not only Zink along the toposequence the Fe content also highest at the upper lope position and the least value at the medium slope position.

Organic carbon correlated with total nitrogen and available phosphorus; hence, soil management involving use of organic matter will improve soil condition and their fertility for crop production. This revealed that soil properties such as water content, total porosity, sand content, clay content, bulk density, soil pH, organic matter and carbon and total nitrogen are influenced by topographic position. In general toposequence has a great influence on soil physicochemical properties.

Prospective

From this review it could be concluded that more of the soil careful assessment of the land resources is essential to make any change in the natural ecosystem. Encroachment on such areas by agriculture to provide more food may lead to deterioration of soil health through the rapid loss of soil fertility parameters. Appropriate legislation is important to safeguard the biodiversity of our ecosystem against deforestation and other anthropogenic activities by man in the course of meeting human needs. Increase in residue return, less mixing and less soil disturbance ensures higher moisture control, reduced soil surface temperature, proliferation of root growth and bio-activity and decrease risk of soil erosion and productivity decline.

Contrary will accelerate the mineralization of soil organic carbon, which in turn affects negatively the productivity potentials of the soil. The ridge-furrow system has been suitable for soil and water conservation in structurally unsuitable soils. Since it conserves water, and also increases effective root volume on poorly drained soils and on nutrient deficient soils, it is recommended for practical application by rural farmers and agriculturist farming. There is the need for further study on effects of topo sequence on soil and soil-related properties to generate sufficient information for demonstrating soil nutrient transfer from upper land scape to the lower land scap.

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