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RESEARCH ARTICLE

STUDIES ON PHYSICO CHEMICAL PROPERTIES OF SELECTED SOILS IN KINDO KOYSHA DISTRICT, SOUTHERN ETHIOPIA

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ABSTRACT

A study was conducted on agricultural soils in Kindo Koysha District, Southern Ethiopia, with the objective of evaluating soil physico chemical properties. Physical and chemical characteristics of soils were evaluated using standard methods. Soil properties varied according to the sites. pH varied from strongly acidic (4.7) to slightly acidic (6.5). The levels of organic carbon (OC) and total nitrogen (N) were 1 to 1.83% and 0.086 to 0.157%, respectively. The soil OC contents were in low to moderate range. The carbon to nitrogen ratio (C:N) in all the studied sites was greater than 10. The available phosphorus (P) contents of the soils in all studied sites were qualifying very low range. The cation exchange capacity (CEC) of the soils ranged from 3.4 (low) to 21.5 $Cmol_{(+)}$ kg^{-1} (moderate). The textural classification was sandy loam in all sites. Therefore, researchers, local farmers and investors give due to attention for site specific fertilizer management and selecting varieties which resist soil acidity.

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INTRODUCTION

Soil is a complex system comprised of minerals, soil organic matter (SOM), water, and air (Visha *et al*., 2009; Hector, 2011). Soil quality includes mutually interactive attributes of physical, chemical and biological properties, which affect many processes in the soil that make it suitable for agricultural practices and other purpose (Rakesh *et al*., 2012). The physicochemical properties soils play important roles in vegetation development. Soil texture and acidity affects the absorption and accumulation of mineral elements by plants and thus play a very important role in vegetation establishment and development at such sites (Mamun *et al*., 2011; Triphati and Misra, 2012). Soil organic matter is important in the transportation of metallic ions in soils, sediments and waters, as chelates of various stabilities, and in supplying these ions to plants in soils (Robin and James, 2003; Motuzova *et al*., 2008, Rash *et al*., 2012). SOM is around 2-5% of the total soil mass and plays an important role in regulating water-holding capacity of the soil and its ion-exchange capacity. Lignin is the main components of plants that contribute to SOM in the form of humic substances which are classified as humic, fulvic and humin acids (Connel, 1997; Alina and Henyk, 2000).

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Cation exchange capacity (CEC) is a measure of the amount of cations which the soil can absorb or hold (Ayidnalp and Marinova, 2003). Soil particles and OM are negatively charged resulting in the attraction of the positive cations (Na^+, Ca^{2+}, Mg^{2+}, H^+ and $NH4^+$) in the soil (Alloway, 1997). The CEC on most soils range from 5 to 35 meq/100g depending upon the soil type, amount or combinations of clay minerals (Kabata-Pendias, 2004). Soils with high CEC generally have higher levels of clay and OM. CEC is responsible for exchangeable cations such as Ca^{2+}, Mg^{2+}, and K^+, which are readily available for plant uptake; and cations adsorbed to exchange sites are more resistant to leaching, or downward movement in soils with water (Mamun *et al*., 2011). Soil reaction is in dynamic equilibrium with the predominantly charged surfaces of soil particles (Tukura *et al*., 2009; Snober *et al*., 2011). pH value of soil is influenced by the type of parent materials from which the soil was formed and is affected by rainfall, due to leaching of basic nutrients such as Ca^{2+} and Mg^{2+} from the soil, and their replacement by acidic elements, such as Al^{3+} and Fe^{2+} (Michael and Aguin, 2010). pH greatly affects trace metal complexation, either through solubility equilibria or due to complexation by soluble and surface ligands (Tukura *et al*., 2007). Soil fertility decline is considered as an important cause for low productivity of many soils (Sanchez, 2002). It has not received much research attention; probably because as soil fertility decline is less visible and less spectacular, and more difficult to assess. Assessing soil fertility decline is difficult because most soil chemical properties either change very slowly or have large seasonal fluctuations. This decline includes; nutrient depletion, nutrient mining, acidification (decline in pH and or an increase in exchangeable Al), loss of organic matter and increase in toxic elements (e.g., Al, Mn) (Hartemink, 2006). Physico chemical properties of soil are complex, often non-linearly related, and spatially and temporally dynamic (Rakesh *et al*., 2012).

maize, barley, sweet potato and teff. On the other hand, urea and diammonium phosphate (DAP) was commonly used as a fertilizer by the farmers in this Zone.

Composite surface soil samples (0–20 cm) were collected from experimental sites. The samples were bagged, labeled, and transported to the laboratory for preparation and analysis of selected soil properties following standard laboratory procedure.

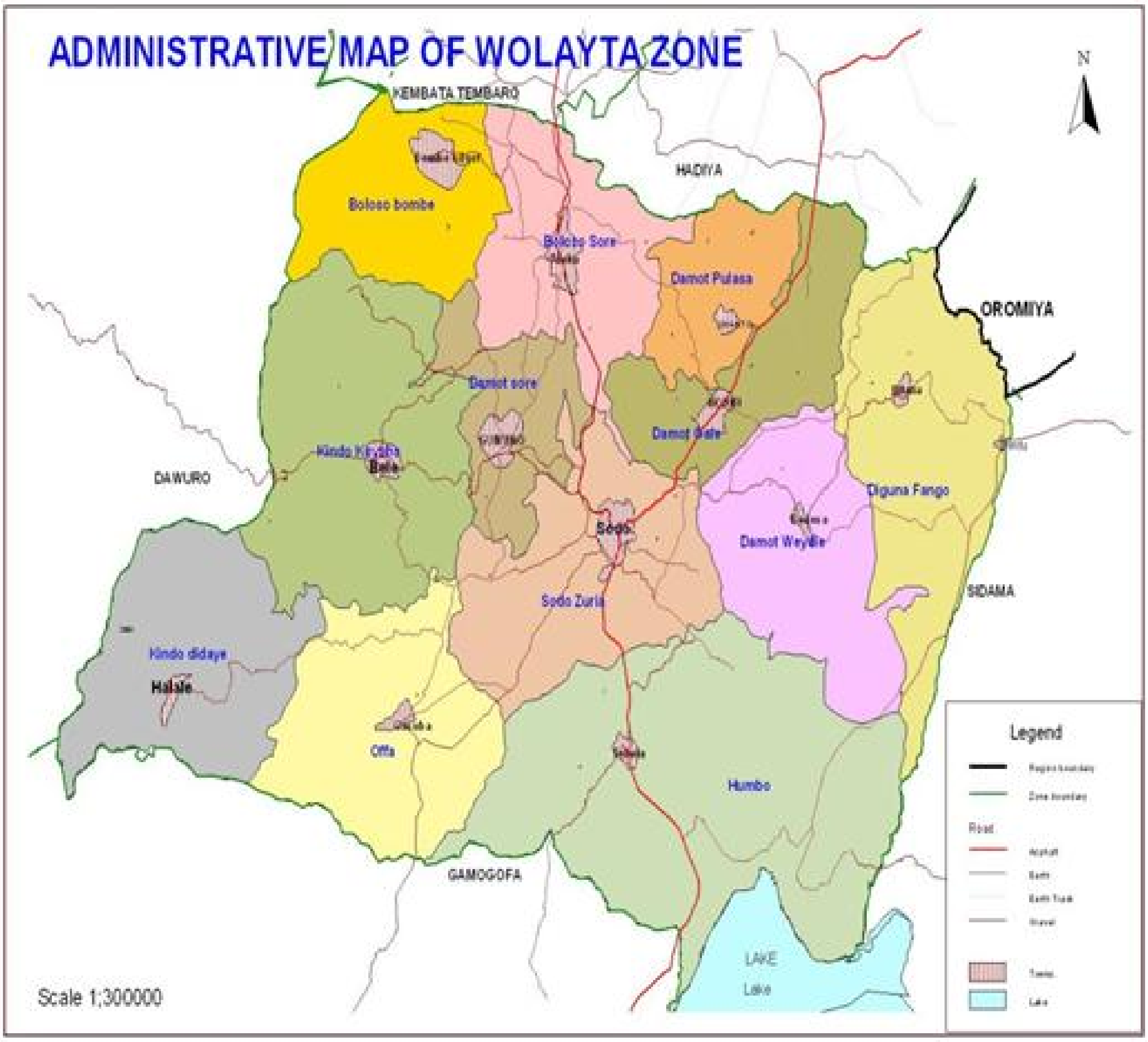

Figure 1. Location map of the study area

Many researches on soil physicochemical parameters have been conducted around the world (Iwugbue *et al*., 2006; Hector *et al*., 2011; Snober *et al*., 2011; Rai *et al*., 2012) but information on the physical and chemical properties of selected soils of Kindo Koysha District are limited. Therefore, the objective of this study is to evaluate the physicochemical properties of soil samples collected from eight selected sites in the study area.

MATERIALS AND METHODS

The study was conducted in Wolaita Zone, Kindo Koysha District. Wolaita Zone is roughly located between 6.4 and 7.1 ° N and 37.4 and 38.2° E, latitude and longitude, respectively. The rainfall in the zone is characterized by a bimodal distribution pattern. The annual average temperature of the zone is 21.86 °C. The altitude of the zone ranges from 501 to 3000 masl (Mesfin *et al*., 2015). Considering the land use, the land was intensively cultivated for the major crops including

A stainless steel soil sampling auger was used to collect all the soil samples from sampling sites. All the soil samples were weighed on a digital analytical balance (Mettler Toledo, Switzerland) with ± 0.0001 g precision. A pH meter (Belgium, C835) was used during pH measurement of the soil. Soil pH was measured potentiometrically in H_2O and 1 M KCl solution at the ratio of 1:2.5 for soil: H_2O and soil: KCl solutions using a combined glass electrode pH meter (Van Reeuwijk, 1992; Freese *et al.,* 1995). The cation exchange capacity (CEC) of the soil was determined from the NH_4^+ saturated samples that were subsequently replaced by K from a percolated KCl solution. The excess salt was removed by washing with ethanol and the ammonium that was displaced by K was measured using the micro-Kjeldahl procedure. (Bremner and Mulvaney, 1982). The determination of available P was determined by Olsen method (Olsen *et al*., 1954). Electrical conductivity (EC) of the soil samples were measured using conductivity meter (Van Reeuwijk, 1992). Organic carbon

(OC) of the soil was determined by using Walkley and Black method by dichromate ($K_2Cr_2O_7$) oxidation technique (Neilson and Sommers, 1982). Total nitrogen (N) was determined by the micro-Kjeldahl wet digestion and distillation method (Bremner and Mulvaney 1982). The texture of the soil was determined by the hydrometer method after dispersion of the soil with sodium hexa meta phosphate (Day, 1965).

of debris deposited on each of the site. Total nitrogen levels were ranged from 0.086% to 0.157% (Table 2). Nitrogen is an essential constituent of metabolically active compounds such as amino acids, proteins, enzymes and some non proteinous compounds. The levels of organic carbon (OC) and total nitrogen (TN) were 1 to 1.83% and 0.086 to 0.157 %, respectively.

Table 1. Soil pH and electrical conductivity

Experimental Site	pH (H_2O)	pH (KCl)	ΔpH	EC (ds m^{-1})
Site 1	5.7	4.9	-.0.8	0.11
Site 2	5.8	4.8	-1.0	0.09
Site 3	5.9	4.8	-1.1	0.03
Site 4	6.2	5.3	-0.9	0.05
Site 5	6.5	5.7	-0.8	0.06
Site 6	5.9	4.8	-1.1	0.01
Site 7	4.7	3.7	-1.0	0.003
Site 8	5.2	4.5	-0.7	0.02

RESULTS AND DISCUSSION

Soil pH and electrical conductivity

The effect of soil pH is profound on the solubility of minerals and nutrients. It is regarded as a useful indicator of other soil parameters. Particularly, profound yields useful information about the availabilities of exchangeable cations (e.g Ca^{2+}, $Mg^{2+}$and K^{+}) in soils. Most minerals and nutrients are more soluble or available in acid soils than in neutral or slightly alkaline soils. The pH (H_2O) varied from 4.7 to 6.5 (Table 1). The lowest value was observed in site 7, whereas the highest was found in site 5. Electrical conductivity (EC) of the soils ranged from 0.003-0.09 dS m^{-1} (Table 1). The pH (H_2O) varied from 4.7 to 6.5. The lowest value was observed in site 7, whereas the highest was found in site 5. According to *Tekalign*, 1991, the pH ranges of the soils in the studied areas are from strongly acidic to slightly acidic. The higher acidity of the soils for site 7 was mainly due to the leaching of some basic cations (Iwara *et al*., 2013). *Owuor et al,* 1990 had reported that the increasing rates of nitrogenous fertilizers generally increase soil acidity. *Ishibashi et al*, 2004 had reported that nitrogenous fertilizers are known to produce H^{+} by soil bacteria. The soil pH values are within the range for optimum plant growth except site 7 and 8. This is in agreement with the values reported by (Vishal et al., 2009). Soil pH measured in water was higher by about 0.7 to 1 unit than the respective pH values measured in KCl solution (Table 1). The low soil pH with KCl determination indicates the presence of substantial quantity of exchangeable hydrogen ion. According to *Anon*, 1993, high soil acidity with KCl solution determination showed the presence of high potential acidity and weatherable minerals. In all the sites, ΔpH (pH (KCl) – pH (H_2O) values were negative, ranging from –0.7 to –1.1. According to *Uehara and Gillman*, 1981, negative ΔpH value is an indication of the presence of net negative charges in soils**.** Electrical conductivity (EC) of the soils ranged from0.005-0.61 dS m^{-1}. According to *Waskom et al,* 2012, this range is categorized as non saline and implies that the soils are not salt affected.

Organic carbon and total nitrogen

Organic carbon (OC) content varied according to site. The lowest and highest OC values were recorded at sites 1 and 4, respectively, which might be attributed to variation in the level

According to the rating suggested by *Tekalign et al.* 1991, the soil OC contents were in low to moderate range (1.00 to 1.83 %). Low OC in site 1 could be due to intensive cultivation which significantly depleted OC content of the soil. Similarly, the total N contents of all the soils in the studied sites were in low to moderate range (0.08 to 0.16%). The distribution pattern of total N was similar to that of OC. The C: N in all the studied sites was greater than 10. According to *Gavlak et al,* 1994, soils in the studied areas can be categorized as medium. This implies that there is optimum range for microbial activities such as humification and mineralization of organic residue in the studied areas.

Available phosphorus and Cation exchange capacity

Phosphorus plays an important role in energy transformations and metabolic processes in plants. The highest phosphorus level was recorded at site 6 (0.66 mg/kg), and the lowest at site 5 (0.04 mg/kg). The CEC is a measure of the soil's ability to adsorb (and release) cations. It is highly needed for the estimation of contaminant transport potential and sorption capacity for any soil location i.e. the total number of cations it can retain on its adsorbent complex at a given pH. The CEC ranged from 3.4 to 21.5 cmol (+) kg^{-1} of soil (Table 3) and the values were higher for site 4 and lower for site 1. The Olsen extractable P contents of the soils studied varied from 0.08 to 0.66 mg kg^{-1}(Table 3).

As per the rating established by *Tekalign et al*, 1991, the available P contents for studied sites were qualifying very low range. Soil samples collected from these sites were below the critical limit for available P. According to *Tekalign et al,* 1991 the critical level of available P is 8 mg kg^{-1}. The soils in the studied areas, similar to the other agricultural soils of the tropics, are generally low in available P. Previous research results (Lupwayi and Haque, 1996; Shiferaw, 2004) indicated that most of the highland soils of Ethiopia are inherently P deficient and hence it is one of the limiting nutrient elements in crop production in the region. The low availability of P is due to the fact that it readily forms insoluble complexes with cation such as aluminum (Al) and iron (Fe) under acidic soil condition and with Ca and Mg under alkaline soil conditions (Vance *et al.,* 2003). On the other hand, the poor P fertilizer recovery is due to the fact that the P applied in the form of fertilizers is mainly adsorbed by the soil, and is not available for plants lacking specific adaptations. The CEC ranged from 3.4 to 21.5 $cmol_{(+)}$ kg^{-1} and the values were higher for site 4 and lower for site 1 (Table 3). According to *Hazelton and Murphy*, 2007, the CEC of the soils for the studied sites ranged from low to moderate. The low CEC in site 1 may be due to the lowest clay fraction and the highest sand fractions of the soil. This may be the main reason followed by their low OC content. Therefore, the depletion of OM as a result of intensive cultivation has reduced the CEC and that is in harmony with previous finding (Gao and Chang, 1996).

Table 2. Organic carbon (OC) and Total nitrogen (N)

Experimental Site	OC (%)	N (%)	C:N
Site 1	1.00	0.086	11.62
Site 2	1.19	0.102	11.66
Site 3	1.22	0.105	11.61
Site 4	1.83	0.157	11.65
Site 5	1.67	0.144	11.59
Site 6	1.60	0.137	11.67
Site 7	1.39	0.119	11.68
Site 8	1.71	0.147	11.63

Table 3. Available phosphorus (P) and Cation exchange capacity (CEC)

Experimental site	Available Phosphorus (P) mg kg^{-1}	Cation exchange capacity (CEC) cmol (+) kg^{-1}
Site 1	0.36	3.4
Site 2	0.18	12.8
Site 3	0.14	14.8
Site 4	0.26	21.5
Site 5	0.04	15.4
Site 6	0.66	9.80
Site 7	0.30	5.4
Site 8	0.08	6.8

Table 4. Particle size

	Particle size			
Experimental site	Sand (%)	Silt (%)	Clay(%)	Textural class
Site 1	70	26	4	SL
Site 2	58	33	9	SL
Site 3	54	36	10	SL
Site 4	50	39	11	SL
Site 5	57	38	5	SL
Site 6	68	25	7	SL
Site 7	54	34	12	SL
Site 8	69	22	9	SL

SL = sandy loam

Particle size

Particle size results are presented in Table 4. Relative proportion of different sizes of soil particles is an important physical parameter to determine soil texture. Soil texture has an extremely significant influence on the physical and mechanical behaviors of the soil. One possible confounding factor that could explain some of the variations in soil physicochemical characteristics from the various locations is difference in grain size distribution (Table 4). The soil contains significant percentage of sand, particularly at site 1, while high proportion of silt and clay were recorded at site 4. There were textural variations among soils of the studied sites. The sand contents of the studied soils varied, with the lowest value (site 4) and the highest value (site 1). The clay contents also varied among the studied soils, which was higher in site 4 and lower for site 1. Texture is an intrinsic soil property, but intensive cultivation contributed to the variations in particle size distribution of the cultivated lands. The textural classification was sandy loamy for all the farms. This is expected as soil texture is mainly inherited from the soil forming material. According to *Herring et al*, 2010 soil texture is one of the most important properties and it influences many other properties of land use management.

Conclusions

Based on the findings, it is obvious that the dominant limiting factors of soil fertility include low organic matter content, low available phosphorus and low soil CEC. Physical and chemical properties of the soils differed according to sites. Soil pH varied from strongly acidic to slightly acidic, and it was within the range for optimum growth of plants. The total nitrogen in the studied sites was found in the low range. Therefore, the local farmers and investors in the area should apply fertilizers containing phosphorus and select crops and variety that resist soil acidity and fix nitrogen.

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REFERENCES

Alina, P. and Henyk, P. 2000. Trace elements in soils and plants, (3rd ed.) C.R.C Press, Amazon, U.K.

Alloway, B.J. and Ayres, D.C. 1997. Chemical principles of environmental pollution, Blackie Academic and professional.

Anon. 1993. Soil Chemical Analysis: Improvement of Soil Services for Agricultural Development. Ministry of Natural Resources Development and Environmental Protection. UNDP, FAO, Addis Ababa, Ethiopia.

Aydinalp, C. and Marinova, S. 2003. Distribution and forms of heavy metals in some agricultural soils, *Polish Journal of Environmental Studies*. 12(5).

Bremner, G.M. and Mulvaney, C.S. 1982. Total Nitrogen. In: Black, C.A. (ed.), Methods of Soil Analysis. *American Society of Agronomy Inc. Madison*, Wisconsin.

Connel, D.W. 1997. Basic Concepts of Environmental Chemistry. Lewis Publications, Boca Raton. New York.

Day, P.R., 1965. Hydrometer method of particle size analysis. In: C.A. Black (ed.), Methods of Soil Analysis. American Society of Agronomy. Madison, Wisconsin, USA.

Freese, D., Lookman, R., Merckx, R. and Riemsdijk, W.H. 1995. New method for long term phosphate desorption from soils. *Soil Science Society of America Journal*. 59(5): 1295 -1300.

Gao, G. and Chang, C. 1996. Changes in cation exchange capacity and particle size distribution of soils. *Soil Scienve,* 161(2):115-120.

Gavlak, R.G., Horneck, D.A. and Miller, R.O. 1994**.** Plant, Soil and Water Reference Methods for the Western Region, 2nd Edition. Western Regional Publication. Alaska, USA.

Hartemink, A.E. 2006. Soil Fertility Decline: Definitions and Assessment. *Encyclopedia of Soil Science.* 1618-1621.

Hazelton, P. and B. Murphy, 2007. Interpreting soil test results: What do all the numbers mean? 2nd Edition. CSIRO Publishing.

Héctor .F, Oscar R. M, Enrique M., Ma. Del Carmen O. and Ana L. B. 2011. Heavy metals in agricultural soils and irrigation wastewater of Mixquiahuala, Hidalgo, Mexico. *African Journal of Agricultural Research.* 6(24).

Herring, S.L., Koenning, S.R, Heitman, J.L. 2010. Impact of Rotylenchulus reniformis on cotton yield as affected by soil texture and irrigation. *Journal of Nematology*. 42: 319–323.

Ishibashi, Y., Matsuo, H., Baba, Y., Nagafuchi, Y., Imato, T. and Hirata, T. 2004. Association of manganese effluent with the application of fertilizer and manure on tea field. Water Research, 38(12): 2821–2826.

Iwara, A.I., Gani, B. S., Adeyemi, J.A. and Ewa, E. E. 2013. Effect of road construction on adjoining soil properties in Tinapa Resort, south-southern Nigeria. *Open Journal of Advanced Engineering Techniques.* 1 (3): 42 – 48.

Iwegbue, C. M. A., Egobueze, F. E. and Opuene, K. 2006. Preliminary assessment of heavy metals levels of soils of an oil field in the Niger Delta, Nigeria. *International Journal of Environmental Science and Technology*. 3(2): 167-172

Kabata, P.A.. 2004. Soil-plant transfer of trace elements-an environmental issue. Geoderma. 122: 143-149.

Mamun, S. A., Rahman F., Yeasmin F. and Islam M. A. 2011. Suitability of the physical properties of soil for crop production: A Study in Tangail Sadar. *Journal of Environmental Science and Natural Resources*. 4(2).

Lupwayi, N.Z. and Haque, I. 1996. Phosphorous: A prerequisite for increased productivity of forage and browse/free legumes in the Ethiopian highlands. In: Proceedings of the Second Conference of the Ethiopian Society of Soil Science. Addis Ababa, Ethiopia.

Mesfin Bibiso, Abi M. Taddesse, Heluf Gebrekidan and Asmare Melese 2015. Evaluation of universal extractants for determination of some macronutrients from soil. Communication in soil science and plant analysis. 46: 2425-2448.

Michael, P. and Arguin, H. 2010. Soil. In Encyclopedia of Earth. Eds. Cutler, J. Cleveland, Washington, D.C. Environmental information coalition, National council for science and the environment.

Motuzova, G. V., Minkina, T. M. and Nazar-Enko, O. G. 2008. Interaction of heavy metals with organic matter. 5th International Symposium ISMOM, Pucón, Chile.

Neilson, D.W. and Sommers, I.E. 1982. Total carbon, organic carbon and organic matter, chemical and microbiological properties. *American Society of Agronomy Journal.* 9: 639-679.

Olsen, S.R., Cole, C.V., Watanabe, F.S. and Dean, L.A. 1954. Estimation of available P in soils by extraction with sodium bicarbonate. USDA Circular.

Owuor, P.O., Gone, F.O., Onchiri, D.B. and Jumba, I.O. 1990. Levels of aluminum in green leaf of clonal teas, black tea and black tea liquors and effects of rates of nitrogen fertilizers on the aluminium black tea contents. *Food Chemistry.* 35(1): 59–68.

Rakesh, K., Rakesh, K.U., Kishan, S. and Brijesh, Y. 2012.Vertical Distribution of Physico-Chemical Properties under DifferentTopo-sequence in Soils of Jharkhand. *Journal of Agricultural Physics.*12 (1): 63- 69.

Rai , S., Chopra A.K., Chakresh P., Dinesh K., Renu S.and Gupta, P. M. 2012. Comparative study of some physicochemical parameters of soil irrigated with sewage water and canal water of Dehradun city. *India International Journal of Environmental sciences.* 3(3): 318 – 325.

Robin, D., Graham, J. and Stangoulis, C. R. 2003. Trace element uptake and distribution in plants. *Journal of Nutrition.* 13: 1502-1508.

Sanchez, P.A. 2002. Soil fertility and hunger in Africa. Science. 295: 2019–2020.

Shiferaw Boke. 2004. Soil phosphorous fractions influenced by different cropping system in Andosols and Nitisols in Kambata-Tenbaro and Wolaita Zones, SNNPRS, Ethiopia. M.Sc. Thesis, Haramaya University, Haramaya, Ethiopia.

Snober. H. B., Afshana B. D., Mohd S.D. and Masood M. G. 2011. Correlation of soil physico-chemical factors with vam fungi distribution under different agroecological conditions. International Journal of Pharma and Bio Sciences. 2(2): 99-106.

Tekalign Tadese, Haque, I. and Aduayi, E.A. 1991. Soil, Plant, Water, Fertilizer, Animal Manure and Compost Analysis Manual. Plant Science Division Working Document. International Livestock Research Center for Africa, Addis Ababa.

Tripathi, A. and Misra, D. R. 2012. A study of physico-chemical properties and heavy metals in contaminated soils of municipal waste dumpsites at Allahabad, India. International Journal of Environmental Sciences. 2(4).

Tukura , B.W., Gimba C.C. and Ndukwe I.G. 2007. Effects of pH and total organic carbon (TOC) on the distribution of trace metals in Kubanni Dam Sediments, Zaria, Nigeria. Science World Journal. 3(2): 1-6.

Tukura, B.W., Gimba C. C. and Ndukwe I. G. 2009. Effects of pH and seasonal variations on dissolved and suspended heavy metals in dam surface water. Chemicals Journal. 6: 27-30.

Uehara, G. and Gilman, G. 1981. The mineralogy, chemistry and physics of tropical soils with variable charge clays. West view Tropical Agricultural Series, Boulder, Colorado. 4: 170.

Vance, C.P., Stone, C.U. and Allan, D. 2003. Phosphorus acquisition and use: critical adaptation by plants for securing non-renewable resources. New Phytologist. 15(3): 423-447.

Van Reeuwijk, L.P. 1992. Procedures for Soil Analysis, 3rd Edition. International Soil Reference and Information Center (ISRIC), Wageningen, the Netherlands.

Vishal, D. J., Narahari N. P., and Punit R. R. 2009. Physico-Chemical properties of four farm site soils in area surrounding Rajkot, Gujarat, India. *International Journal of ChemTech Research.* 1(3): 709-713.

Waskom, R.M., Bauder, T., Davis, J.A. and Andales, A.A. 2012. Diagnosing Saline and Sodic Soil Problems. Colorado State University Extension. Fort Collins, Colorado.

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