Journal of Biology, Agriculture and Healthcare
ISSN 2224-3208 (Paper) ISSN 2225-093X (Online)
Vol.6, No.1, 2016

A Review on Effects of Fire and Traditional Practices of Soil Burning on Soil Physico-Chemical Properties

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Abstract

The fertility status of a soil is important to assess the productivity of a soil as it is one of the parameters of soil productivity. Most soil physical and chemical fertility are mainly dependent on organic matter. Thus, the consumed soil organic matter during soil burning affects both soil physical and chemical fertility of soil. Little is known about impacts of traditional practices of soil burning and fire on soil properties besides the yield increment. Therefore, this paper was initiated with the aim of reviewing the effects of fire and traditional practice of soil burning on soil physicochemical properties. High concentrations of available plant nutrients immediately following fire and traditional practices of soil burning may negate the advantage of fertilizing for at least 1 year. The soil gives good yield for two years. However, it negatively affects soil physical and chemical quality and the overall soil health. The decrease in soil physical and chemical fertility of the soil negatively affects continuous crop production and complete loss of land values. Also the nutrient lost from burned soil as result of traditional practices of soil burning and fire regain its fertility after fallowing for many years. Therefore, there is need to find an alternative to fire and traditional practices of soil burning and identify means of reclaiming lands abandoned for crop production and reclaiming soil quality deteriorated due to fire and traditional practices of soil burning by adding OM from available sources.
Keywords: Fire, soil burning, Organic matter, physical fertility, chemical fertility

Introduction

Soil fertility maintenance is a major concern in tropical Africa, particularly with the rapid population increase, which has occurred in the past few decades. Without maintaining soil fertility, one cannot talk about increment of agricultural production in feeding the alarmingly increasing population. Therefore, to get optimum, sustained-long lasting and self-sufficient crop production, soil fertility has to be maintained.

Fire and traditional practices of soil burning can have a marked effect on the OM stock because almost all OM is consumed during fire and burning which affects long term crop productivity and soil fertility. Since fire and traditional practices of soil burning removes OM and their colloids fractions, and since such materials furnish most of the microbiological activities and the base Exchange capacity of the soils thereby providing ample storage for plant food, the removal of such essential particles and their colloids decrease the fertility of the soils (Assefa, 1978).

The vast majority of soils are burned annually for cropping of virgin land in different parts of Ethiopia (Kiya, 2015). This specialized form of shifting cultivation is locally called *Guie*. Traditionally, farmers in the area sow crops to mature on residual moisture, fallow the land in the main rainy season, and burn, or "*Guie*" the soil (Berhanu, 1985). The practice of soil burning before planting crops is not unique to Ethiopia. The same practice is done in Kenya and locally known as "Belset ab Tindinyek ".

This exacerbates soil quality decline due to fire and soil burning leading to soil degradation which may ultimately lead to complete loss of land values. The consumed soil OM during soil burning affects both soil physical and chemical quality of soil. These variations of soil physicochemical properties due to soil burning indicate the risk to the sustainable crop production. Therefore, the objective of this paper is to review the effects of fire and traditional practices of soil burning on soil physicochemical properties.

Literature Review

Soil Physical Properties

The physical properties of soils determine their adaptability to cultivation and the level of biological activity that can be supported by the soil. Soil physical properties also largely determine the soil's water and air supplying capacity to plants. Soil physical fertility or soil structure can have as large impact on plant growth as chemical fertility (Cass, 1999; Geeves *et al.,* 2007).

Soil Color

Soil color is the most noticeable altered in burned soil (Ulery and Graham, 1993). Generally, the color of soil is determined by the amount and state of iron and/or OM it contains (Singh *et al.,* 2004). The hue of the soil color depends on the presence of iron oxides that are significantly affected at different temperatures reached during heating (Terefe *et al.,* 2008). At higher temperature reddening of soil matrix occurs. Redder hue appears in the burned soils is apparently because of Fe-oxides transformation and OM (Ulery and Graham, 1993; Certini, 2005).

Surface patches of the reddened soil indicate the place where soil was severely burned. Changes induced in the color properties by fire are more or less permanent (Terefe *et al.,* 2005). Ash color can be used as an indicator of fire severity, and depending on the consumption of the OM, can range from producing black to producing white ash (complete ashing) (Neary *et al*., 1999; Bodi *et al.,* 2011).

Soil Texture

The components of soil texture (sand, silt, and clay) if subjected to high temperatures are altered. The most sensitive textural fraction is clay, which begins changing when clay hydration and clay lattice structure begin to collapse. At high temperature there is the complete destruction of internal clay structure can occur (Neary *et al*., 2008). The observed variation in soil separates after soil burning may be related to the exposure of the soils to **high temperature**s resulting in the fusion of clay and silt particles into sand-sized particles (Ketterings *et al*., 2000). Soil that exposed to severe fire caused increased in sand content with correspond decrease in clay content (Oguntunde *et al*., 2004). Clay particles to turn into sand-size particles might be also due to the calcination of iron and aluminosilicate (Terefe *et al*., 2008). The reddened soil layers after fire had less clay content than unburned soil (Ulery and Graham, 1993). Sand-sized aggregates formed in the surface soils during burning alter the particle-size distribution and resulting in coarser textures due to a greater proportion of sand.

Bulk and Particle Densities

Bulk density of soils increases as a result of fire (Certini, 2005; Boerner *et al*., 2009). This increase in the bulk density of the soil may be attributed to the combustion of OM. As a result of the loss of OM in heated soils, soil structure was destroyed which lead to the increase in the bulk density of the soil (Choromanska and DeLuca, 2002). Campbell *et al.* (1995) also reported the same result. The increase in sand fraction due to burning may also contribute to the reduction of soil bulk density at burned sites.

Soil burning increased particle density. The increased in particle density could be because of the decrease in OM. The redder hue of burned soil is indication of highest consumption of OM which in turn increases particle density. The redder hue appears in the burned soils is apparently because of complete removal of OM (Ulery and Graham, 1993; Certini, 2005).

Total Porosity

Soil burning affects soil total porosity. A decrease in total porosity is observed after soil burning. A decrease in total porosity in the burned soil attributed to a reduction in pore size distribution. Destroyed soil particles binding agents decreased in soil total porosity after soil burning. Cohesiveness is mediated by binding agents such as humic substances, which form strong complexes with Fe, Al and Mg (Nwadialo and Mbagwu, 1991). These binding agents are deeply affected by fire temperature and, in connection with clays, promoting important changes in soil structure. Micro-aggregation is affected by fire being involved in the structural soil changes. The degradation of soil microstructure could produce a decrease in porosity and reducing cohesiveness of soil particles and favoring runoff production and soil removal by water erosion (Giovaninni, 1994; Reichert and Darrell, 1994).

Soil Water Content and Retention Capacity

Soil burning decreased soil water retention capacity both at the field capacity and permanent wilting point which finally reduced soil available water holding capacity. The increase in sand and decrease in clay content after fire decrease soil available water holding capacity. Emerson (1995) also concluded that the increase in clay content increases water holding capacity at both the field capacity and the permanent wilting point. The other reason for the reduction of soil water holding capacity is reduction in the total OM of the soil which is burnt off during soil burning. This may be attributed to the fact that OM improves water retention (Brady and Weil, 1999) and that most OM within the soil contains 50-90% water (Assunta *et al.,* 2004).

Soil Water Repellency

High surface temperatures 'burn' off organic residue and create vapours that move downward in response to a temperature gradient and then condense on soil particles causing them to become water repellent (Letey, 2001). Water repellency is caused by presence of organic compound with hydrophobic properties on soil particle surface (Doerr *et al.,* 2009). Highly variable water repellent soil conditions have been reported after fires DeBano (2000), Robichaud and Hungerford (2000) and MacDonald and Huffman (2004).

Soil water repellency is highly variable in time and space (Doerr *et al*., 2008). The three predictive variables of soil water repellency are burn severity, sand content, and soil moisture could only explain 30-41% of the variability in soil water repellency measured on two wild and three prescribed fires (Huffman *et al.,* 2001). Soil water repellency strengthens with increasing burn severity and sand content, and decreases with increasing soil moisture content (Huffman *et al*., 2001). As soils wet up they no longer are water repellent (Leighton-Boyce *et al*., 2003; Hubbert and Oriol, 2005). Studies indicate that postfire soil water repellency is unlikely to increase runoff rates once the soils have wetted up, but soil water repellency can be re-established once the soils dry out (Leighton-Boyce *et al*., 2003).

Soil Chemical Properties

Soil chemical properties are the most important among the factors that determine the nutrient supplying power of the soil to the plants and microbes. The chemical reactions that occur in the soil affect processes leading to soil development and soil fertility build up. Minerals inherited from the soil parent materials overtime release chemical elements that undergo various changes and transformations within the soil.

Soil Reaction (pH)

Soil pH is increased after soil burning. When OM is burned, basic cations are released and consequently, soil pH is increased (Ulery *et al.,* 1993). The initial fuel loading and soil pH, fire intensity, and post fire rainfalls are factors affecting the extent and duration of pH changes. The increase in pH at higher temperatures was also caused by formation of metal oxides (Giovannini *et al.,* 1990). Ash residues are generally dominated by carbonates of alkali and alkaline earth metals, variable amounts of silica, heavy metals, sesquioxides, phosphates and small amounts of organic and inorganic N. The ash has the capacity to neutralize the acidic soil after fire (Khanna *et.al*., 1994; Arocena and Opio, 2003). As the percentage base saturation increases, the soil pH and the availability of basic nutrient cations to plants also increases (Bohn *et al*., 2001).

Soil Organic Matter

The most intuitive change soil experience during burning is loss of OM (Certini, 2005). The effect of fire on soil OM is highly dependent on the type and intensity of the fire, among other factors, soil moisture, soil type, and nature of the burned materials. Therefore, the effect on soil processes and their intensity influenced by fire are highly variable and no generalized tendencies can be suggested for most of the fire-induced changes in humus composition (Gonza´lez-Pe´rez *et al*., 2004). Low-intensity prescribed fire usually results in little change in soil carbon, but intense prescribed fire or wildfire can result in a huge loss of soil carbon (Johnson, 1992). Fernandez *et al*. (1997) suggested that in low intensity fire, lipids are least affected group whereas 90% of water soluble cellulose, hemicelluloses and lignin are destroyed.

Total Nitrogen

The immediate effect of fire on soil N is its loss through volatilization because of high temperature (Neary *et al*., 1999; Certini, 2005). Nitrogen volatilization during prescribed fire is the dominant mechanism of N loss from these systems (Caldwell *et al*., 2002). Nitrogen lost is usually in form of ammonia and other related N gases. Nitrogen is an extremely important nutrient because it is the one that is most likely to limit growth in ecosystems. Because of this inherent limitation, significant losses of N during a fire could adversely affect long-term site productivity. Nitrogen contained in unburned soil is released solely by biological processes and is referred to as being regulated by biochemical cycling.

The most significant short-term effects of the fire are the increases in the soil solution concentrations and/or leaching of mineral forms of N and P (Murphy *et al*., 2006). This probably explains why plant response quicker on the burned sites. However, the total amount of N decreases (Knight, 1996). Due to burning of crop residues, loss of N up to 80% was also reported by Dawit *et al*. (2007). The decreased in the total N content of soil with increasing degree of heating was related to the decrease in N contained in OM (Knight, 1996). After fire total nitrogen that is a component of OM, turning to gas depending on oxidation process (Giovannini and Lucchesi, 1997).

Available Phosphorus

The most significant effects of the fire on available P are the increases in the soil solution concentrations and leaching of mineral forms of P (Murphy *et al*., 2006). Available P increased linearly with the degree of heating. Increasing temperature caused an increase in available P because of the mineralization of OM (Giovannini *et al*., 1990). The increase in available P at burning sites could be due to the presence of ash which is rich in P (Ogundele *et al*., 2011). Similarly, Tekalign and Haque (1987) reported that soil OM as the main source of available P.

Exchangeable Sodium and Potassium

Soil burning affects both exchangeable Na and K. Increasing temperature caused a decrease in exchangeable Na in the soils. This is because aggregation of the sand-size particles leading to less extractability from water (Giovannini *et al*., 1990; Marcos *et al.,* 2007). Exchangeable K increases at all soil heating temperatures (Iwuafor *et al*., 2000). Exchangeable K showed an increase due to fusion in the soils as the temperature rose

(Giovannini *et al.,* 1990; Marcos *et al.,* 2007). The increase in soil pH after soil burning could be the other reason for the increase in soil exchangeable K. Mesfin (1996) reported that high K was recorded under high pH tropical soils.

Exchangeable Magnesium and Calcium

Soil burning affects both exchangeable Ca and Mg. Exchangeable Ca steadily decreased in the soils with rising temperature. Extractability of Ca was diminished due to aggregation of the thin particles. Exchangeable Mg also showed similar change with exchangeable Ca with the temperature (Giovannini *et al*., 1990). The reasons might be that soil samples did not form soluble MgO and those small ions such as Mg was forced into octahedral structure of clay minerals during dehydration (Sahlemedhin and Sanchez, 1978).

Cation Exchange Capacity

Generally, processes that affect texture such as clay and OM changes also affect CEC of soils. Cation exchange capacity decreases after a severe fire probably because of a great reduction in humus content. Reduction in CEC after burning was also reported by Giovannini *et al*. (1990) and Marcos *et al.* (2007) who stated CEC diminished with increasing temperature because Structural change in clay minerals, combustion of OM and turning of clay particles to sand-size particles. Important role of soil OM in soil CEC and retention of ions was also reported by (Tisdale *et al.,* 1995, Crasswell and Lefroy, 2001) which is affected by fire.

Micronutrients (Fe, Mn, Zn and Cu)

The behavior of micronutrients, such as Fe, Mn, Cu and Zn with respect to fire is not well known because specific studies are lacking (Certini, 2005). The influence of fire on micronutrient availability is useful to understand its effect on the post-fire recovery of soils and plants (García-Marco and González-Prieto, 2008). Few studies are suggesting that micronutrients also experience reduction in the amount after fire. García-Marco and González-Prieto (2008) studied short and medium term effects of fire on soil micronutrients availability. They reported that prescribed fire cause short-term changes in the soil micronutrients availability, increasing that of Mn and Zn and decreasing that of Fe and Co; they found no effect on Cu availability.

Summary and Conclusions

The fertility status of a soil is important to assess the productivity of a soil as it is one of the parameters of soil productivity. Most soil physical and chemical fertility are mainly dependent on organic matter. Thus, the consumed soil organic matter during soil burning affects both soil physical and chemical fertility of soil. Little is known about impacts of traditional practices of soil burning and fire on soil properties besides the yield increment. Therefore, this paper was initiated with the aim of reviewing the effects of fire and traditional practices of soil burning on soil physicochemical properties. High concentrations of available plant nutrients immediately following fire may negate the advantage of fertilizing for at least 1 year after burning. The soil gives good yield for two years. However, it negatively affects soil physical and chemical quality and the overall soil health. The decrease in soil physical and chemical fertility of the soil negatively affects continuous crop production and complete loss of land values. Also the nutrient lost from burned soil as result of soil burning regain its fertility after fallowing for many years.

From this review, it can be concluded that;

- ❖ The traditional practices of soil burning and fire destroyed soil OM which affects both soil physical and chemical quality of the soil.
- ❖ Therefore, there is need to find an alternative to fire and traditional practices of soil burning and identify means of reclaiming lands abandoned for crop production and reclaiming soil quality deteriorated by adding OM from available sources.

References

Arocena, J.M. and Opio, C., 2003. Prescribed fire induced changes in properties of sub-boreal forest soils. *Geoderma*, 113: 1-16.

Assefa Kuru, 1978. Effects of humus on water retention capacity of the soil, and its role in fight against desertification. MSc Thesis, Department of Environmental Science, Helsinki University.

Assunta, M.P., Giacomo, G., Sergio, L., Stefano, D. and Piero, P., 2004. Effect of fire on soil C, N and microbial biomass. INRA, EDP Sciences 2004, France. *Agronomy for Sustainable Development*, 24: 47-53.

Berhanu Debele, 1985. The Vertisols of Ethiopia: their properties, classification and management. *In: Fifth Meeting of the Eastern African Sub-Committee for Soil Correlation and Land Evaluation. Wad Medani, Sudan. 5-10 December 1983.* World Soil Resources Reports No. 56. FAO (Food and Agriculture Organization), Rome.

Bodi, M.B., Mataix-Solera, J., Doerr, S.H. and Cerda, A., 2011. The wettability of ash from burned vegetation and its relationship to Mediterranean plant species type, burn severity and total organic carbon content. *Geoderma,* 160: 599–607.

Boerner, R.E.C., Hart, S. and Huang, J., 2009. Impacts of Fire and Fire Surrogate treatments. *Ecological Applications,* 19(2): 338-358.

Bohn, H.L, McNeal, B.L. and O'Connor, G.A., 2001. Soil Chemistry. 3rd Edition. John Wiley and Sons, Inc., New York, USA.

Brady, N.C. and Weil, R.R., 1999. The Nature and Properties of Soils. 12th Edition. Upper Saddle River, Prentice-Hall Inc., New Jersey, USA.

Caldwell, T.G, Johnson, D.W. and Miller, W.W., 2002. Forest floor carbon and nitrogen loss due to prescribed fire. *American Journal of Soil Science Society*, 66: 262-267.

Campbell, G.S, Jungbauer, Jr.J.D, Bristow, K.L. and Hungerford, R.D., 1995. Soil temperature and water content beneath a surface fire. *Soil Science*; 159: 363-74.

Cass, A., 1999. Interpretation of some soil physical indicators for assessing soil physical fertility. pp. 95-102, *In:* Peverill, K.I., Sparrow, L.A., and Reuter, D.J. (eds.), Soil Analysis: An Interpretation Manual'. 2nd Edition. CSIRO Publishing, Melbourne.

Certini, G., 2005. Effect of fire on properties of soil . A review. *Oecologia,* 143: 1-10.

Choromanska, U. and DeLuca, T.M., 2002. Microbial activity and nitrogen mineralization in forest mineral soils following heating: Evaluation of post-fire effects. *Soil Biology and Biochemistry*, 34, 263-271.

Craswell, E.T. and Lefroy, R.D.B., 2001. The role and function of organic matter in tropical soils. *Nutrient Cycling in Agro ecosystem*, 61: 7-18.

Dawit Solomon, Lehmann, J., Thies, J., Schafer, T. and Liang, B., 2007. Molecular signature and sources of biochemical recalcitrance of organic C in Amazonian dark earths. Geochim. Cosmochim. *Acta*, 71: 2285-2298.

DeBano, L.F., 2000. The role of fire and soil heating on water repellency in wildland environments: A review. *Journal of Hydrology*, 231-232: 195-206.

Doerr, S., Shakesby, R.A. and MacDonald, L.H., 2008. Soil water repellency: a key factor in post-fire erosion. pp. 197-224, *In:* Cerda, A. and Robichaud, P.R. (eds.), Fire Effects on Soils and Restoration Strategies. Science Publishers, Inc., Enfield, New Hampshire, USA.

Doerr, S., Woods, S. and Martin, D., 2009. Natural background' soil water repellency in conifer forests of the north-western USA: Its prediction and relationship to wildfire occurrence. *Journal of Hydrology*, 371(1-4): 12-21.

Emerson, W.W., 1995. Water retention, organic carbon and soil texture. *Australian Journal of Soil Research,* 33: 241-251.

Fernandez, I, Cabaneiro, A. and Carballas, T., 1997. Organic matter changes after a wildfire in an atlantic forest soil and comparison with laboratory soil heating. *Soil Biology and Biochemistry*, 29(1): 1-11.

García-Marco, S. and González-Prieto, S., 2008. Short- and medium- term effects of fire and fire-fighting chemicals on soil micronutrient availability. *The Science of Total Environment*, 407: 297-303.

Geeves, G.W., Craze, B. and Hamilton, G.J., 2007. Soil physical properties. pp. 168-191, *In:* Charman, P.E.V. and Murphy, B.W. (eds.), Soils, Their Properties and Management. 3rd Edition. Oxford University Press, Melbourne.

Giovannini, G., Lucchesi, S. and Giachetti, M., 1990. Effect of heating on some chemical parameters related to soil aggregation and erodibility. *Soil Science*, 149, 344-350.

Giovannini, G. and Lucchesi, S., 1997. Modifications induced in soil physico-chemical parameters by experimental fires at different intensities. *Soil Science*, 162: 479-486.

Giovannini, G., 1994. The effect of fire on soil quality. pp. 15-29, *In:* Sala, M. and Rubio, J.L. (eds.), Soil Erosion As a Consequence of Forest Fires. Geoforma Ediciones, Logroño.

Gonza´lez-Pe´rez, J.A. and Gonza´lez-Vila, F.J, Almendros G, 2004. The effect of fire on soil organic matter. A review. *Environment International*, 30: 855-870.

Hubbert, K.R. and Oriol, V., 2005. Temporal fluctuations in soil water repellency following wildfire in chaparral steeplands, southern California. *International Journal of Wildland Fire,* 14: 439-447.

Huffman, E.L., MacDonald, L.H. and Stednick, J.D., 2001. Strength and persistence of fire-induced soil hydrophobicity under ponderosa and lodgepole pine, Colorado Front Range. *Hydrological Processes*, 15: 2877-2892.

Iwuafor, E.N.O., Tarfa, B.D., Pam, E. and Yaro, D.T., 2000. Effect of soil heating on soil properties and maize growth in an Alfisol in northern Guinea Savanna. *Nigeria Journal of Soil Research,* 1:35-41.

Johnson, D.W., 1992. Effects of forest management on soil carbon storage. *Water, Air and Soil Pollution,* 64: 83-120.

Ketterings, Q.M. and Bigham, J.M., 2000. Soil color as an indicator of slash-and-burn fire severity and soil fertility in Sumatra, Indonesia. *American Journal of Soil Science Society*, 64: 1826-1833.

Khanna, P.K., Raison, R.J. and Falkiner, R.A., 1994. Chemical properties of ash derived from Eucalyptus litter and its effects on forest soils. *For. Ecol. Manage*., 66: 107-125.

Kiya Adare, 2015. Effects of Traditional Practice of Soil Burning (Guie) on Soil Chemical Properties at Sheno Areas of North Shoa, Oromia Region, Ethiopia. Journal of Plant Sciences. 3(6): 342-348

Knight, H., 1996. Loss of nitrogen from the forest floor by burning. *The Forestry Chronicle*, 42(2): 149-152.

Leighton-Boyce, G., Doerr, S.H., Walsh, R.P.D., Shakesby, R.A., Ferreira, A.J.D., Boulet, A. and Coelho, C.O.A., 2003. Spatio-temporal patterns of soil water repellency in Portuguese eucalyptus forests and implications for slope hydrology. pp. 111-116, *In:* Servant, E., Najem, W., Leduc, C. and Shakeel, A. (eds.), Hydrology of Mediterranean and Semiarid Regions. IAHS Publication 278.

Letey, J., 2001. Causes and consequences of fire-induced soil water repellency. *Hydrological Processes*, 15: 2867-2875.

MacDonald, L.H. and Huffman, E.L., 2004. Post-fire soil water repellency: Persistence and soil moisture thresholds. *American Journal of Soil Science Society,* 68: 1729-1734.

Marcos, E., Tarrega, R. and Luis, E., 2007. Changes in a Humic Cambisol heated (100-500 °C) under laboratory conditions: The significance of heating time. *Geoderma*, 138: 237-243.

Mesfin Abebe, 1996. The challenges and future prospects of soil chemistry in Ethiopia. pp. 78-96, *In*: Teshome Yizengaw, Eyasu Mekonnen and Mintesinot Behailu (Eds*.) Proceedings of the 3rd Conference of the Ethiopian Society of Soil Science (ESSS*). 28th-29th February 1996, Ethiopian Science and Technology Commission. Addis Ababa, Ethiopia.

Murphy, J.D., Johnson, D.W. and Walker, W.W., 2006. Wildfire effects on soil nutrients and leaching in a Tahoe Basin Watershed. *Journal of Environmental Quality*, 35: 479-489.

Neary, D.G, Klopatek, C.C. and DeBano, L.F., 1999. Fire effects on belowground sustainability: A review and synthesis. *Forest Ecology and Management*, 122: 51-71.

Neary, D.G., Ryan, K.C. and DeBano, L.F., 2008. Wildland Fire in Ecosystems: Effects of Fire on Soils and Water. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, USA.

Nwadialo, B.E. and Mbagwu, J.S.C., 1991. An analysis of soil components active in microaggregate stability. *Soil Tech.*, 4: 343-350.

Ogundele, A.T., Eludoyin, O.S. and Oladapo, O.S., 2011. Assessment of impacts of charcoal production on soil properties in the derived savanna, Oyo state, Nigeria. *Journal of Soil Science and Environmental Management,* 2: 142-146.

Oguntunde, P.G., Fosu, M., Ajayi, A.E. and Giesen, N., 2004. Effects of charcoal production on maize yield, chemical properties and texture of soil. *Biol. Fertil. Soils,* 39: 295-299.

Reichert, J.M. and Darrell, L., 1994. Aggregate stability and rain-impacted sheet erosion of air-dried and prewetted clayey surface soils under intense rain. *Soil Science,* 158(3): 159-169.

Robichaud, P. and Hungerford, R., 2000. Water repellency by laboratory burning of four northern. *Journal of Hydrology*, 231-232: 207-219.

Sahlemedhin Sertsu and Sanchez, P.A., 1978. Effects of heating on some changes in soil properties in relation to an Ethiopian land management practice. *American Journal of Soil Science Society*, 42:940-944.

Singh, D., Herlin, I., Berroir, J.P., Silva, E.F. and Simoes Meirelles, M., 2004. An approach to correlate NDVI with soil color for erosion process using NOAA/AVHRR DATA. *Advances in Space Research,* 33: 328-332.

Tekalign Mamo and Haque, I., 1987. Phosphorus status of some Ethiopian soils. *Plant and Soil,* 102: 261-266.

Terefe Wondafrash, Mariscal, S.I., Peregrina, F. and Espejo, R., 2008. Influence of heating on various properties of six Mediterranean soils: A laboratory study. *Geoderma*, 143: 273-280.

Terefe Wondafrash, Mariscal, S.I., Gomez, M.V. and Espejo, S.R., 2005. Relationship between soil colour and temperature in the surface horizon of Mediterranean soils: A laboratory study. *Soil Science,* 170(7): 495-503.

Tisdale, S.L., Nelson, W.L., Beaton, J.D. and Havlin, J.L., 1995. Soil Fertility and Fertilizer. 5th Edition. Prentice of India, New Delhi, India.

Ulery, A.L., Graham, R.C. and Amrhein, C., 1993. Wood ash composition and soil pH following intense burning. *Soil Science,* 156: 358-364.

Ulery, A.L. and Graham, R.C., 1993. Forest fire effects on soil color and texture. *American Journal of Soil Science Society*, 57(1): 135-140.