The Pharma Innovation Journal 2022; 11(2): 242-246

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; 11(2): 242-246

www.thepharmajournal.com
Received: 02-12-2021
Accepted: 12-01-2022

Basta Ram
Department of Soil Science, G. B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India

Ajeet Pratap Singh
Department of Soil Science, G. B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India

Vijay Kant Singh
Department of Soil Science, Punjab Agricultural University, Ludhiana, Punjab, India

Nidhi Luthra
Division of Soil Science and Agricultural Chemistry, Indian Agricultural Research Institute, New Delhi, India

Anil Nath
Department of Soil Science, G. B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India

Corresponding Author:
Basta Ram
Department of Soil Science, G. B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India

Effect of different land uses on chemical properties of soil in a Mollisol

Basta Ram, Ajeet Pratap Singh, Vijay Kant Singh, Nidhi Luthra and Anil Nath

Abstract
The different land-use system has a significant impact on soil chemical properties. In order to ascertain the effect of different land-use systems on soil chemical properties, the present study was carried out at Norman E. Borlaug Crop Research Centre, G. B. Pant University of Agriculture and Technology, Pantnagar. The land-use systems selected for study were T_1 (rice–potato–okra), T_2 (rice–pea (vegetable)–maize), T_3 (sorghum multi-cut (fodder)–yellow sarson–black gram), T_4 (rice-wheat–green gram), T_5 (rice–berseem + oat + mustard (fodder)–maize + cowpea (fodder)), T_6 (guava + lemon), S_7 (poplar + turmeric), T_8 (eucalyptus + turmeric), T_9 (fallow (uncultivated land))T_1 (rice – potato – okra), T_2 (rice – pea (vegetable) – maize), T_3 (sorghum multicut (fodder) – yellow sarson – black gram), T_4 (rice – wheat – green gram), T_5 (rice – berseem + oat + mustard (fodder) – maize + cowpea (fodder)), T_6 (guava + lemon), S_7 (poplar + turmeric), T_8 (eucalyptus + turmeric), T_9 (fallow (uncultivated land)). The highest value of were obtained for organic carbon (1.51%), organic matter (2.59%), available soil nitrogen (312.00 kg ha^{-1}), available soil phosphorus (24.80kg ha^{-1}) and available soil potassium (259.11 kg ha^{-1}) under $T_{8,}$ which was significantly higher than T_9. According to the above-mentioned result, soil under agroforestry based land-use systems was found to be better soil fertility concerning soil chemical properties than other land-use systems.

Keywords: Organic matter, macronutrient, mollisol, land-use systems

1. Introduction
The thin layer of soil covering the earth's surface represents the difference between survival extinction for most terrestrial life (Doran and Parkin, 1994) [4]. Soil is the biologically active, porous medium developed below the continental land surface on our earth. Soils are one of the most complex and dynamic natural systems. Therefore, knowledge about their physical, chemical and biological properties is more important for sustaining the productivity of the land. On the basis of the amount of the elements required for the normal growth of plants, nutrient are classified as macronutrients or micronutrients (Allaway, 1975; Epstein and Bloom, 2005) [1]. Macronutrients are required in large amounts and usually constitute 1000 mg kg^{-1} (0.1%) or more of the dry weight of the plant. On the other hand, micronutrients are also required for the plants in small quantities. Plants contain small amounts of 90 or more elements, but only 17 are known to be essential to higher plants (Epstein and Bloom, 2005; Finkl, 1988) [6]. Macro and micronutrients both contribute to soil fertility and crop productivity. Nitrogen is essential for all amino acids, which are the building blocks of all proteins, including the enzymes, which control virtually all biological processes. The upper soil horizons content much more organic form nitrogen because nitrogen reserve is stored in the soil as organic matter. That stored reserve of organic nitrogen (N) release plant available form of nitrogen by mineralization (nitrate, nitrite and ammonia) in the upper horizon of soil. Many aspects of soil and plant are completed by phosphorous (P), including plant physiology, photosynthesis, nitrogen fixation, flowering, fruiting, root growth, lateral roots and fibrous rootlets etc. Available form of P ions usually in inorganic form (HPO_4^{2-} and $H_2PO_4^{2-}$) in soils and sometimes as soluble organic P. Potassium (K) is the third most essential nutrient after N and P. K work as an activator for 80 different enzymes and that enzymes utilized in plant and animal processes like energy metabolism, starch synthesis, nitrate reduction, photosynthesis, and sugar degradation.

The agro-forestry, agri-horticulture, and agri-pastoral systems can reduce erosion, runoff, increase soil fertility chemical properties, nitrogen fixation, and increase nutrient recycling in soil (Nair, 1985). The agro-forestry-based land-use systems contribute an important role in increasing the productivity, fertility, and health of soil and improving the soil quality. Several researchers also found that the agro-forestry land-use system increases the soil organic carbon content, total nutrients, and available nitrogen, phosphorus, and potassium to the crop plants. Keeping in mind these findings, objective of our study was to assess the effect of different land-use systems i.e. fallow land, agricultural land and agroforestry land on soil chemical properties.

2. Materials and Methods

2.1 Physiographic description of the study area

The present study was conducted at Norman E. Borlaug crop research centre, G. B. Pant University, Pantnagar, and District U.S. Nagar in the Terai region of Uttarakhand. The order of the soil was Mollisol. Pantnagar falls under sub-humid and sub-tropical climate zone with hot, dry summer and cool winter. The region has thick vegetation because of the prevalence of high moisture in the Tarai belt, and the forest area is classified as low alluvial savannah (Puri, 1960) [17]. Soil samples were collected from the plough layer 0-20 cm depth representing the whole area randomly from different land-use systems.

2.2 Treatment details

Nive land-use system have been taken as a treatment with three replication. The land-use systems selected for study were T_1 (rice–potato–okra), T_2 (rice–pea (vegetable)–maize), T_3 (sorghum multi-cut (fodder)–yellow sarson–black gram), T_4 (rice-wheat–green gram), T_5 (rice–berseem + oat + mustard (fodder)–maize + cowpea (fodder)), T_6 (guava + lemon), S_7 (poplar + turmeric), T_8 (eucalyptus + turmeric), T_9 (fallow (uncultivated land).

2.3 Soil analysis

2.3.1 Soil organic carbon and organic matter

The organic carbon content in soil was determined by the wet digestion method given by Walkley and Black (1934). In which, one gram of air dried soil sample was put in a 500 mL capacity conical flask. Then 10 mL of 1 *N*$K_2Cr_2O_7$ was added to conical flask. Flask was gently shaken for mixing. Then after, 20 mL of concentrated H_2SO_4 was added in conical flask. The flask was keep for half an hour for complete digestion. Then, the soil was diluted with 200 mL distilled water and, 10 mL of 85% H_3PO_4, 0.2 g of NaF and 30 drops of DPA were added and mixed. The dull green colour is seen immediately after the addition of the indicator in the soil. It was then titrated with 0.5 *N* ferrous ammonium sulphate (FAS) solution till a brilliant green colour appeared as an endpoint. The same procedure was carried for blank.

Soil organic carbon (%) was then determined using the following formula:

$$OC(\%) = \frac{(\text{meq. of } K_2Cr_2O_7 - \text{meq. of FAS}) \times 0.003 \times 100 \times 1.3}{\text{wt. of soil (g)}}$$

Where

meq. of $K_2Cr_2O_7$ = Volume x normality

meq. of FAS = FAS consumed in titration with soil × Normality of FAS

Normality of FAS = meq. of $K_2Cr_2O_7$ / Volume of FAS solution consumed in titration without soil, i.e. blank

0.003 = Factor, i.e. 1ml of*N* $K_2Cr_2O_7$reacts with 0.003 g of C.

A deviser 0.76, the average fraction of OM oxidized, can replace the multiplier 1.3.

Organic carbon content is the indirect determination of organic matter through the correction factor (Pribyl, D. W. (2010) [15]. The "Van Bemmelen factor" of 1.724 has been used to calculate organic matter (%). The equation used for the estimation of the organic matter as:

OM (%) = 1.724 x OC (%)

2.3.2 Available soil nitrogen

Available nitrogen in soil was determined by alkaline potassium permanganate method (Subbiah and Asija, 1956) [20]. Twenty gram of soil sample was taken in the kjeldahl's flask and was treated within (0.32%) alkaline $KMnO_4$ (with 2.5% NaOH) and was immediately usedin the distillation process. The NH_3 was absorbed in 2% boric acid containing with mixed indicator, adjusted pH 4.5. It was titrated with 0.02 *N* H_2SO_4. Available nitrogen was calculated by using the following formula:

$$\text{Available N (kg ha}^{-1}) = \frac{(S-B) x \ N x 14 x 1000 \times 2.24}{W}$$

Where, S=Volume (mL) of 0.02 *N* $H_2SO_4$is required for titration of sample; B= Volume(mL) of 0.02 *N* H_2SO_4 required for titration of blank; W=Weight of soil(g); 14=equivalent weight of nitrogen; 100 = to convert in mg kg.

2.3.3 Available soil phosphorus

Available phosphorus in soil was extracted by sodium bicarbonate (0.5 *M* $NaHCO_3$) at pH 8.5 (Olsen *et al*., 1954) [12]. For this, 1g of soil sample was treated with 20 mL of extracting solution (0.5 *M* $NaHCO_3$) of pH 8.5. The suspension was filtered, and the extracted solution was treated with ammonium molybdate and ascorbic acid. The blue colour was developed using ascorbic acid described by Murphy and Riley (1962) [10]. The blue colour intensity was recorded with the help of a spectrophotometer at 882 nm.

Available P (Kg ha^{-1}) was then calculated using the following formula:

Available P (Kg ha^{-1}) = Concentration of P (ppm) from standard curve x dilution factorx 2.24

2.3.4 Available soil potassium

Available K in soil was determined by neutral *N* ammonium acetate (1*N* NH_4OAc) at adjusted pH 7 method given by Black (1965) [2]. was taken 5.0 g of soil sample, then added 25 mL of extracting solution and after it was shaken on a reciprocating shaker for 5 minutes. The soil sample was filtered through whatman no. 42 filter paper to obtain a clear extract. The potassium concentration in the filtrate was measured using flame photometer and worked out with the help of standard curve.

$$\text{Available K (kg ha}^{-1}) = \text{Concentration (ppm) of K as read from standard curve x dilution factor x 2.24}$$

2.4 Statistical analysis
Randomized block design was used to conduct the experiment, in which 9 treatments were replicated 3 times. The obtained experimental data were statistically analyzed by applying the analysis of variance (ANOVA) technique (Panse and Suchatme, 1978). The difference among treatments was compared by applying "F" test of significance at 5 per cent level of significance (0.05 LSD).

3. Results and Discussion
3.1 Soil organic carbon (OC)
The data on the OC content in soil under different land-use systems are given in table 1. It is found from the data that the OC in soil significantly differed under different land-use systems. The OC content in different land-use systems were ranged between 0.51 to 1.5% at 0-20 cm depth. The highest OC (1.5%) was obtained under the treatment T_8treatment, It was significantly higher than that under T_1 (0.98%), T_2 (0.63%), T_3 (0.72%), T_4 (0.82%), T_5 (0.93%), T_6 (0.60%), T_7 (1.24%) and T_9 (0.51%) treatment. Treatment T_9(0.51%) obtained a significantly lower value than all other treatments. The over dominance agroforestry-based treatment (i.e. eucalyptus + turmeric followed by poplar + turmeric) over agricultural land-use systems might be due to more canopy on the surface, increasing more nutrients in the soil by reducing soil erosion. While among agricultural land-ue systems, rice-potato-okra was obtained better as compared to others due to higher accumulation of organic matter. Rice crops added more high root biomass, and okra contributes more litter fall on the soil surface that promotes higher accumulation of organic matter in the soil. Lowest soil OC content under fallow treatment due to poor vegetation on the soil, regular cutting of weed and grasses from the soil surface. The agroforestry based land-use system contain more OC and organic matter due to more fall of litter by the tree on soil surface Singh *et al.* (2006) [18] and Patil and Prasad (2004) [14]. The maize-based cropping systemas agricultural land-use system hasthe lowest OC due to maize being a highly exhaustive cereals crop (Yadda, 2007) [23]. Cultivated soil contains more OC and organic matter than uncultivated soil due to the addition of more crop residue by cultivation (Tiwari *et al.*, 1995).

3.2 Organic matter (OM)
The data on the OM in soil under different land-use systems is tabulated in table 1. It is obtained from the data that the OM in soil significantly differed under different treatments. The OM in soil varied between 0.87 to 2.59% at 0-20 cm depth. The highest OM (2.59%) was obtained under the treatment T_8eucalyptus + turmeric land-use system, which was significantly higher than all other land-use systems. T_9(0.87%) treatment was obtained significantly lower value then other all treatment. T_8eucalyptus + turmeric was significantly higher than that under T_1 (1.68%), T_2 (1.05%), T_3 (1.25%), T_4 (1.41%), T_5 (1.60%), T_6 (1.03%), T_7 (2.14%) and T_9 (0.87%) treatment. T_9 (0.87%) fallow uncultivated treatment was obtained lowest value of soil OM then that under T_1 (1.68%), T_2 (1.05%), T_3 (1.25%), T_4 (1.41%), T_5 (1.60%), T_6 (1.03%), T_7 (2.14%) and T_8 (0.87%) treatment. Agroforestry based land-use system accumulates more OM and organic carbon due to more accumulation of litter and root residue on the surface of soil under this land uses in soil. Land use changes affect soil OM accumulation in topsoil and subsoil due to more organic residue in soil Benjapon *et al*. (2020). Soil OM content as a function of different land-use and change of land-use create a positive effect on soil OM in soil (Pulleman *et al*., 2000) [16].

Table 1: Effect of different land-use systems on the chemical properties at 20 cm soil depth

Symbol	Treatment	Soil organic carbon (%)	Soil organic matter (%)	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
T_1	Rice – potato – okra	0.98	1.68	230.00	22.53	232.25
T_2	Rice – pea vegetable – maize	0.63	1.05	171.33	15.25	170.56
T_3	Sorghum multicutfodder– yellow sarson – black gram	0.72	1.25	181.00	16.49	182.19
T_4	Rice – wheat – green gram	0.82	1.41	191.33	18.36	190.88
T_5	Rice – berseem + oat + mustard – maize + cowpea fodder	0.93	1.60	198.00	20.49	204.84
T_6	Guava + lemon	0.60	1.03	161.00	14.80	161.60
T_7	Poplar + turmeric	1.24	2.14	288.00	23.46	243.25
T_8	Eucalyptus + turmeric	1.51	2.59	312.00	24.80	259.11
T_9	Fallow uncultivated land	0.51	0.87	148.00	13.76	154.14
S.Em±		0.007	0.015	2.003	0.265	1.038
CD at 5%		0.022	0.046	6.057	0.801	3.139

3.3 Available nitrogen (N) in soil
The data on the available N under different land-use systems is given in table 1. It is noted from the data that the available Nin soil significantly differed under different treatments. The available Nin soil varied between 148.00 to 312.00kg ha^{-1} at 0-20 cm depth. The highest available N(312.00 kg ha^{-1}) was obtained under the treatment T_8(eucalyptus + turmeric) land-use system, which was significantly higher than all other land-use systems. T_9(148.00 kg ha^{-1}) treatment was obtained significantly lower value available N then other all treatment. T_8(eucalyptus + turmeric) was significantly higher than that under T_1 (230.00 kg ha^{-1}), T_2 (171.33 kg ha^{-1}), T_3 (181.00 kg ha^{-1}), T_4 (191.33 kg ha^{-1}), T_5 (198.00 kg ha^{-1}), T_6 (161.00), T_7 (288.00 kg ha^{-1}) and T_9 (148.00 kg ha^{-1}) treatment. T_9 (148.00 kg ha^{-1}) fallow uncultivated treatment was obtained lowest value of available N then that under T_1, T_2, T_3, T_4, T_5, T_6, $T_7$and T_8 treatment. High availability of N in agro-forestry land-use system is due to the congenial condition of agroforestry system contribute high OM and OC. That type soil have high water holding capacity, porosity.

Dinesh (2015) reported that OC and O Mare considered directly related to the available nitrogen content of soils. Tisdale *et al.* (1995) also observed that the total nitrogen content of a soil directly relates to OC content. Srivastava *et al*. (2015) [19] recorded that fruit crop-based land-use systems have a lower value of available N due to their high exhaustive ability.

3.4 Available phosphorus (P)

The data on the available phosphorus under different land-use systems is tabulated in table 1. It is observed from the data that the available phosphorus in soil significantly differed under different treatment. The available phosphorus in soil varied between 13.76 to 24.80(kg ha^{-1}) at 0-20 cm depth. The highest available phosphorus (24.80 kg ha^{-1}) was obtained under the treatment T_8eucalyptus + turmeric land-use system, which was significantly higher than all other land-use systems. T_9(13.76 kg ha^{-1}) treatment was obtained significantly lower value available nitrogen then other all treatment. T_8eucalyptus + turmeric (24.80 kgha^{-1}) was significantly higher than that under T_1 (22.53 kg ha^{-1}), T_2 (15.25kg ha^{-1}), T_3 (16.49 kg ha^{-1}), T_4 (18.36 kg ha^{-1}), T_5 (20.49 kg ha^{-1}), T_6 (14.80 kg ha^{-1}), T_7 (23.46 kg ha^{-1}) and T_9 (13.76 kg ha^{-1}) treatment. T_9 (13.76 kg ha^{-1}) fallow uncultivated treatment was obtained lowest value of available nitrogen then that under T_1 (22.53 kg ha^{-1}), T_2 (15.25kg ha^{-1}), T_3 (16.49 kg ha^{-1}), T_4 (18.36 kg ha^{-1}), T_5 (20.49 kg ha^{-1}), T_6 (14.80 kg ha^{-1}), T_7 (23.46 kg ha^{-1}) and T_8 (24.80 kg ha^{-1}) treatment. The results of the this study are in correlate with the findings of Yadda *et al*., (2007) [23] who reported that with increase in the organic carbon content and organic matter of the soil then the available phosphorus increases because of its fast mineralization in agroforestry based land use systems. The phosphorus content under Cultivated land use systems was significantly higher phosphorus content over uncultivated(fallow) land use system. This due to be because of use of phosphate fertilization. Under field crop based land use systems have lower value of phosphorus due to legume remove more amount phosphorus. (Tiwari*et al*., 1995).

3.5 Available potassium (K)

The data on the available K under different land-use systems is categorized in table 1. It is evacuated from the data that the available K in soil significantly differed under different treatments. The soil's available K ranged from 154.14 to 259.11kg ha^{-1} at 0-20 cm depth. The highest available K (259.11kg ha^{-1}) was obtained under the treatment T_8(eucalyptus + turmeric) land-use system, which was significantly higher than all other land-use systems. Treatment T_9(154.14 kg ha^{-1}) was obtained significantly lower valueavailable K than other all treatments. Treatment T_8(259.11kg ha^{-1}) was significantly higher K than that under T_1 (232.25kg ha^{-1}), T_2 (170.56kg ha^{-1}), T_3 (182.19kg ha^{-1}), T_4 (190.88kg ha^{-1}), T_5 (204.84 kg ha^{-1}), T_6 (161.60 kg ha^{-1}), T_7 (243.25kg ha^{-1}) and T_9 (154.14kg ha^{-1}) treatment. T_9 (154.14 kg ha^{-1}) fallow uncultivated treatment was obtained lowest value of available potassiumthan that under T_1, T_2, T_3, T_4, T_5, T_6, T_7 and T_8 treatment.The lower value of available K under field crop land-use system was recorded due to higher removal of nutrients by crop and loss by erosion, but under agro-forestry based land-use system is vice versa (Kumar, 2005 and Khongjee, 2012) [7]. Similar results were also recorded by Srivastava *et al*. (2016).

4. Conclusion

The OC, OM, available N, available P and available K in soil differed significantly under different land-use systems, and highest were found under T_8(eucalyptus + turmeric) treatment. At the same time, the lowest were under T_9 (fallow uncultivated) treatment. According to these findings, it can be concluded that among different land-use systems superior value of chemical parameters i.e. OC, OM, available N, available P and available K were found under agroforestry based land-use systems (T_8 andT_7 treatments). So, It is recommended that scientists should promote the agroforestry land-use system in combination with agricultural systems.

5. Acknowledgment

Authors are grateful to the Head, Department of Soil Science, G.B. Pant University of Agriculture &Technology, Pantnagar, for providing the necessary facilities and the researchers associated with the ICAR–AICRP on Integrated Farming System.

6. References

1. Allaway WH. The effect of soils and fertilizers on human and animal nutrition. Agricultural Research Service, US Department of Agriculture. 1975, 378.
2. Black CA. Methods of soil analysis. Part 2. American Society of Agronomy, inc. Madison, Wisconsin, U. S. A. 1965.
3. Black HN, Hower WE. Advantageous use of potassium chloride water for fracturing water-sensitive formations. In Drilling and Production Practice. American Petroleum Institute. 1965 Jan.
4. Doran JW, Parkin TB. Defining and assessing soil quality. Defining soil quality for a sustainable environment. 1994;35:1-21.
5. Epstein E. Silicon: its manifold roles in plants. Annals of applied Biology. 2009;155(2):155-160.
6. Finkljr CF, Walker J, Watson I. Shoreline erosion: management case history from southeast Florida. Ocean and Shoreline Management. 1988;11(2):129-143.
7. Khongjee S. Runoff and nutrient losses under different land uses in Ga3a micro watershed of Giririver in Solan district of Himachal Pradesh. M.Sc. Thesis, Dr. Y S Parmar University of Horticulture and Forestry, Nauni, Solan. 2012, 1-79.
8. Kumar D. Assessment of soil quality parameters under different land uses in barog-dhillon watershed in Solan district of Himachal Pradesh. Thesis, MSc. College of forestry, Solan. 2015, 47.
9. Kunlanit B, Khwanchum L, Vityakon P. Land Use Changes Affecting Soil Organic Matter Accumulation in Topsoil and Subsoil in Northeast Thailand. Applied and Environmental Soil Science. 2020.
10. Murphy J, Riley JP. A modified single solution method for the determination of phosphorus in natural waters. Analytica. Chin. Acta. 1962;27:31-36.
11. Nair PKR. Role of trees in soil productivity and conservation. Soil productivity aspects of agro-forestry. The International Council for Research in Agro-Forestry. Nairobi. 1984, 85.
12. Olsen SR, Cole CV, Watanabe FS, Dean LA. Estimation of Available phosphorus in soil by Extraction with sodium bicarbonate U.S., Washington; D. C. Circ. 1954;9:39-49.
13. Panse VG, Sukhatme PV. Statistical Methods for Agricultural Workers. Indian Council of Agricultural Research Publication. 1985, 87-89.
14. Patil RB, Prasad J. Characteristics and classification of some sal (Shorearobusta) supporting soils in Dindori district of Madhya Pradesh. Journal of Indian Society of Soil Science. 2004;52:119-125.

15. Pribyl DW. A critical review of the conventional SOC to SOM conversion factor. Geoderma. 2010;156(3-4):75-83.
16. Pulleman MM, Bouma J, Van Essen EA, Meijles EW. Soil organic matter content as a function of different land use history. Soil Science Society of America Journal. 2000;64(2):689-693.
17. Puri GS. Indian Forest Ecology, 1. Oxford Book and Stationery Co., New Delhi. 1960.
18. Singh R, Singh KD, Parandiyal AK. Characterization and erodibility of soils under different land uses for their management and sustained production. Indian Journal of Soil Conservation. 2006;34(3):226-228.
19. Srivastava K, Jat HS, Meena MD, Chaudhary M, Mishra AK, Chaudhary SK. Long term impact of different cropping systems on soil quality under silty loam soils of indo-gangetic plains of India. Journal of Applied and Natural Science. 2015;8(2):584-587.
20. Subbiah BV, Asija GL. A Rapid procedure for estimation of available nitrogen in rice soils. Curr. Sci. 1956;25:259-260.
21. Tisdale SL, Nelson WL, Beaton JD, Havlin JL. Soil fertility and fertilizer, 5th Edition Prentice Hall of India, New Delhi. 1995, 684.
22. Tiwari RC, Verma UN, Mishra AK. Effect of long term cropping system on chemical characteristics of soil profiles. Journal of the Indian Society of Soil Science. 1994;43(2):278-279.
23. Yadda TA. Effects of fruit based land use systems on soil physicochemical properties: the case of smallholders farming systems in gamogofa, southern Ethiopia. Thesis, M.Sc. Hawassa University, Awassa, Ethiopia. 2007, 49.