The Effect of Agroforestry Practices and Elevation Gradients on Soil Chemical Properties in Gununo Watershed, Ethiopia

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***Abstract*—** *This study was conducted in Gunugo watershed at Wolayitta zone to assess the amount of some soil chemical properties affected by traditional agroforestry practices and along different elevation gradients. The dominant agroforestry practices (homegarden, parkland and woodlot), and three elevation gradients (upper, middle and lower) were used to collect soil samples. One composite sample was taken from each sampling point from each soil depths, under three agroforestry practices and three elevation gradient with three replications to have a total of 54 soil samples at 20 x 20 m plot. Then the selected soil chemical properties among agroforestry practices and along elevation gradient was determined at p<0.05. The EC, pH and CEC of the top soil was significantly higher on homegarden than parkland and woodlot while EC, pH and total nitrogen of the sub soil were significantly higher on homegarden than parkland and woodlot. Further, only the top soil EC and CEC were significantly higher on lower elevation than upper and middle elevation and there was no significant difference in sub soil chemical parameters among elevation levels. In relation to this, most of the soil chemical properties show as the study area is being degraded. Therefore, are recommended for sustainable soil chemical property management. Hence, homegarden is suggested as a better agroforestry practice for rehabilitation of the area in a sustainable manner through enhanced accumulation of total nitrogen, good EC and CEC at all elevation gradients.*

***Keywords*— Chemical property, Elevation, Homegarden, Parkland, Soil, Woodlot.**

I. INTRODUCTION

Increasing world population lead to land scarcity (HDRA, 2001), and resulting in soil erosion, loss of soil fertility, and land degradation (Nair, 1993; Young, 1989). Ethiopian highlands are typically characterized by high population density, small land holdings and associated land degradation (Tilahun *et al.,* 2001). This is also true in Southern Ethiopia particularly to Gununo watershed, with a population density of about 450 people per km^2, about 0.25 ha per household land holding, and cultivation on steeper slope and deforestation (Mowo *et al*., 2011; Tilahun *et al.,* 2001).

Despite of the problems mentioned, agroforestry has been serving as a land use system with several contributions for agricultural sustainability in combating land degradation in Ethiopian highland (Jama and Zeila, 2005; Badege and Abdu, 2003). It is recently taken as one of the development objectives in PASDEP of national development policy of the country (Amdissa, 2006; FDRE, 2003). It becoming one of the common features in watershed management (Mahdi and Saueborn, 2001). In Gununo watershed, traditional agroforestry practices have been a main feature in the watershed and serving numerous protective and productive functions in up streamers and down streamers.

Different land uses have different impact on soil quality. In addition, different landscape contains different land uses and elevation gradient with different species composition and structure (Schjønning *et al.*, 2004). The more the land occupied by diverse species, the more the soil will be fertile (Schjønning *et al.,* 2004; Nair, 1993; Young, 1989, 1985). Consequently, complex multistory agroforests and home gardens are better land uses in terms of site nutrient status/quality and overall biogeochemistry than conventional agricultural systems (Kumar and Nair, 2004). Similar land use but different floristic composition generate different soil property effect (Mulugeta *et al*., 2004), in agroforestry practice with diverse species and multilayer structure possessed greater positive effect on soil (Nair, 1993; Young, 1989; 1985). Additionally, different extent of component interaction within agroforestry system and practice has different effect on soil properties (Rao *et al.,* 1998).

Further, elevation gradient have an effect on properties of soil. Consequently, soil erosion and runoff are the main reason for variation in soil chemical properties among elevations (Schroth *et al.,* 2003; Foth**,** 1990). This is due to accumulation of runoff and soil erosion from upper slopes/contour to foot slopes (Schjønning *et al.,* 2004; Schroth *et al.,* 2003; Foth**,** 1990) and these runoff/sediments accumulated to lower contour carry different chemical parameters (Schjønning *et al.,* 2004; Allisont 1973). The effect of elevation on chemical properties was reported in different areas of tropics and temperate by Sheleme (2011) and Ashenafi (2010).

However, there is research gap concerning soil chemical properties affected as the result of different agroforestry practices and elevation gradient in the Gununo watershed. This research was therefore intended to fill that gap in the watershed.

General objective: the study was conducted to assess the effect of different agroforestry practices and elevation gradients on selected soil chemical properties. Specifically, the study was conducted to assess the effect of different agroforestry practices on soil chemical properties, and to assess the variation of some selected soil chemical properties due to elevation gradient under agroforestry practices.

II. MATERIALS AND METHODS

2.1 Study area description

Wolayitta zone is in southern nations, nationalities and peoples (SNNP) region of Ethiopia with a total land area of 4537.5 square kilometers is located between 6º4´N to 7º 1´N latitudes and 37º4´E to 38º2´E longitudes. It is located 22 km from Sodo town and about 330 km from Addis Ababa. The watershed has an area of about 544 hectare with three rural Kebeles namely: *Demba Zamine* (middle elevation), *Doge Hunchucho* (lower elevation) and *Chew kare* (upper elevation).

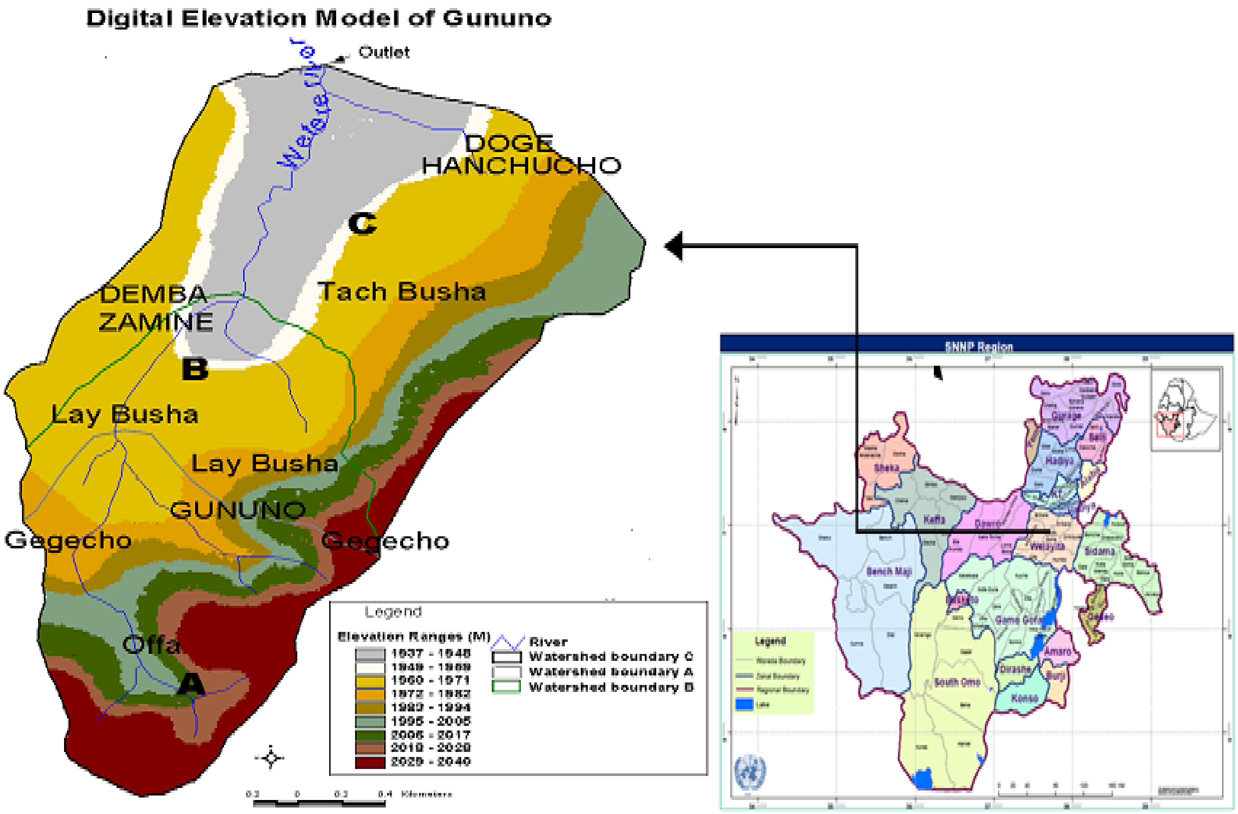

FIGURE 1: MAP OF WOLAYITTA ZONE AND GUNUNO WATERSHED, SOUTHERN ETHIOPIA (ADOPTED FROM MOWO ET AL., 2011)

Gununo watershed has plain lands, plateaus, hills and rugged mountains topography with an altitude ranging from 1937 to 2100 meter above sea level. The mean annual temperature of the site is 19.2^{0}C and the mean annual rainfall is 1335mm with bimodal rain pattern (Mowo *et al.*, 2011; WZFEDD, 2008).

Soil of the watershed is Eutric Nitosol according to FAO/UN classification system (Belay, 1992). Soil erosion in watershed is severe due to conversion of natural forests to other land uses. The study area has high population pressure i.e. around 450 person per km^2 (WZFEDD, 2008), and an average land holding is about 0.25 ha per household and drive farmers to cultivate slope lands (Tilahun *et al.*, 2001). Agroforestry is one of the major land uses at the area. Different species (tree crops and woody species) such as *Enset ventricosum Musa accuminata*, *Moringa oleifera* and *Brassica oleracea* serve as primary food source while *Croton macrostachyus* and different Acacia species are the dominant trees in the degraded natural forest of Wolayitta (WZFEDD, 2008). From the agroforestry practices in the watershed, homegardn, parkland and woodlot agroforestry practices are the dominant ones.

2.2 Sampling procedures and data collection

The topography of the watershed has steep slopes and undulating landscapes. This heterogeneous landscape was stratified in to three different homogeneous transects after delineating topographic map of the watershed. Consequently, from upper (2006 to 2040), middle (1972 to 2006) and lower zone (1937 to 1971) meters above sea level (m.a.s.l.) representative samples were taken. At each zone, the middle point was chosen for horizontal transect walk i.e. at 2023, 1989 and 1954 m.a.s.l. for upper, middle and lower transect respectively. These transect lines thatches all the three Kebeles that the watershed contains. The distance of each transect line was measured from the delineated watershed map and sampling points were distributed proportionally. Accordingly, at each horizontal transect line the first sampling point was randomly selected i.e. some distance away from initial standing point. Then the next sampling point was allocated systematically at every two kilometer by using GPS.

The spatial analogue approach (Mulugeta *et al.*, 2004) which is important to study the effect of different land use on soil properties was used to take soil samples. At every sampling point from selected agroforestry practices along each elevation gradient, 20 x 20 m square plot was taken for soil sampling from each corner and at center of the plot. From the top (0 - 15 cm) and sub soil (15 - 30 cm) soil depths, samples were taken by using auger. Two samples were taken from each sampling point after compositing the same depths together to get one representative sample. Three elevation level * three agroforestry practices * three replication * two soil depth, and hence total of 54 soil samples were taken. The soil samples were analyzed in Melka Werer Agricultural Research Center soil laboratory. Soil pH and EC were measured using a digital pH-meter and EC meter, respectively in the suspension of 1:2.5 soils to distilled water mixture. Total nitrogen was determined following Kjeldahl Method (Pansu and Gautheyrou, 2006). Cation exchange capacity of the soil was determined by repeated saturation using NH_4OAc followed by washing with ethanol, distillation, and titration (Soil Survey Staff, 1996). Then, two way ANOVA was carried out at $P < 0.05$ with the help of (SPSS versions 16), to analyze data of soil chemical properties on agroforestry practices and elevation gradients. Least significant difference (LSD) test was used to separate the means.

III. RESULTS

The top and sub-soil were higher in electrical conductivity (EC), pH, cation exchange capacity (CEC), and total nitrogen under homegardens followed by parkland and woodlot respectively (Table 1 and 2). Consequently, significantly higher EC, pH and CEC was observed in the top soil under homegarden than parkland and woodlot (Table 1) while significantly higher EC, pH and total nitrogen was seen at sub-soil under homegarden than parkland and woodlot (Table 2).

TABLE 1
TOP SOIL CHEMICAL PARAMETERS AMONG AGROFORESTRY PRACTICES IN GUNUNO WATERSHED,

Agroforestry practices	EC(dSm^{-2})	pH	CEC($cmolkg^{-1}$)	N (%)
Home garden	0.26±0.09a	6.73±0.5a	23.41±5.1a	0.16±0.02
Parkland	0.08±0.01b	4.90±0.06b	10.81±1.6b	0.14±0.006
Woodlot	0.10±0.03b	4.63±0.5b	10.49±2.8b	0.13±0.06
P value	P= 0.024	P=0.026	P=0.006	ns

Note: EC refers to electrical conductivity, CEC refers to cation exchange capacity, and N refers to total nitrogen. Different letter shows a significant difference among means.

TABLE 2
SUB SOIL CHEMICAL PARAMETERS AMONG AGROFORESTRY PRACTICES IN GUNUNO WATERSHED

EC(dSm^{-2})	EC(dSm^{-2})	pH	CEC($cmolkg^{-1}$)	N (%)
Home garden	0.2±0.037a	5.9±.115a	15.05±1.10	0.14±0.03a
Parkland	0.08±0.003b	4.63±0.265b	10.1±2.011	0.12±0.03b
Woodlot	0.076±0.01b	4.5±0.5b	10.08±2.5	0.11±0.0b
P value	P=0.029	P=0.018	ns	P=0.023

Note: EC refers to electrical conductivity, CEC refers to cation exchange capacity, and N refers to total nitrogen. Different letter shows a significant difference among means.

Across elevation gradient, the top soil chemical properties were higher in the lower elevation than upper and middle elevation except pH; which was highest in upper elevation (6.1) (Table 3). However, all the sub soil chemical properties were higher in lower elevation than middle and upper elevation (Table 4). Despite of this, only the top soil EC and CEC were significantly highest on lower elevation (Table 3) while no significant difference was observed in the sub soil chemical properties among elevation levels (Table 4).

TABLE 3
TOP SOIL CHEMICAL PARAMETERS ALONG ELEVATION CONTOUR IN GUNUNO WATERSHED

Elevation	EC(dSm^{-2})	PH	CEC ($cmolkg^{-1}$)	N (%)
Lower	0.15±0.04a	5.11±0.81	21.03±6.2a	0.15±0.022
Middle	0.12±0.09ab	5.06±0.8	12.82±4.06b	0.14±0.019
Upper	0.07±0.02c	6.1±0.42	10.85±2.7b	0.13±0.010
P value	P=0.05	ns	P=0.019	ns

Note: EC refers to electrical conductivity, CEC refers to cation exchange capacity, and N refers to total nitrogen. Different letter shows a significant difference among means.

TABLE 4
SUB SOIL CHEMICAL PARAMETERS ALONG ELEVATION CONTOUR IN GUNUNO WATERSHED

Slope	EC(dSm^{-2})	PH	CEC($cmolkg^{-1}$)	N (%)
Lower	0.13±0.042	5.47±0.318	14.04±0.515	0.123±.009
Middle	0.12±0.034	5.12±0.617	10.30±3.140	0.12±.006
Upper	0.07±0.012	5.1±.551	11.58±2.898	0.12±.003
P value	ns	ns	ns	ns

Note: EC refers to electrical conductivity, CEC refers to cation exchange capacity, and N refers to total nitrogen. Different letter shows a significant difference among means.

IV. DISCUSSION

Some selected soil chemical properties among agroforestry practices and elevation

The Electrical Conductivity (EC) of the study area can be rated as non saline and the soil's salinity effect on the plant is therefore negligible (Hazelton and Murphy, 2007). Similar result was reported in Wolayitta by Ashenafi *et al*., (2010). Significantly higher value of EC on home garden could be related with relatively high amount of CEC as a consequence of organic matter accumulation under homegarden. Organic matter in the soil could release Na^+, Ca^{2+} and other cations. Consequently, these cations can increase the EC of a soil (Jones, 2001). Similarly, this could be the reason for higher EC of parkland than woodlot. Significantly highest value of EC in the lower elevation could be linked with soil erosion effect which would wash Na^+, Ca^{2+} and other cations from upper elevation and accumulate to middle and lower elevation.

The soil pH of the study area was 5.42 in average i.e. a strong acidic soil according to Hazelton and Murphy (2007). Consequently, comparing agroforestry practices (both top and sub soil) the pH of homegarden was neutral while the parkland and woodlot were very strong acidic soil according to Hazelton and Murphy (2007). The reason for significantly lower soil pH (acidic) in parkland and woodlot could be associated with fertilizer application and root depth. Acid forming fertilizers cause the soil to be acidic (Keefer, 2000) and deep roots produces acid to the soil i.e. release of H+ and absorption of positively charged basic cations (Keefer, 2000). Consequently as eucalyptus which was used as major woodlot species in watershed is of deeply rooted tree it would have greater chance to make the soil more acidic. Therefore, this can also be the reason for higher acidity on woodlot than parkland and home garden. Misana *et al.*, (2003) also found acidic PH on eucalyptus woodlots than other land uses. The result has revealed that homegardens are better in optimizing pH than other agroforestry practices.

Similarly, the upper and middle/lower contours soil was moderately acidic and strongly acidic, respectively (Hazelton and Murphy, 2007). The reason for lower pH in the lower elevation could be associated with runoff and erosion effect. As the rain water come and pass through soil, the positively charged bases of neutral soils would be replaced by hydrogen ions and through time soil become acidic (Keefer, 2000). Consequently, the basic cations will be accumulated to deposition site (foot/lower elevation contour) to make the soil less acidic in lower elevation contour (Keefer, 2000, Misana *et al.,* 2003). This is also seen from lower pH in the middle elevation compared to upper elevation. Therefore, the result is consistent with the claim of lower pH in the lower elevation and it is suggested that in order to better optimize the soil pH of the area home gardens are appreciable; especially to the lower elevations.

The study area in general has moderate CEC and showing exchangeable cation of calcium is in low proportion according to Hazelton and Murphy (2007). Similar result was reported in Wolayitta i.e. in a watershed close to the study site (Sheleme 2011, Ashenafi *et al*., 2010). The CEC in lower elevation contour is rated as moderate (Hazelton and Murphy, 2007) and it is relatively higher than upper and middle elevation contour which is rated as low (Hazelton and Murphy, 2007). Among agroforestry practices homegardens were highest in CEC (rated as moderate CEC) than parklands and woodlots (rated as low CEC). Higher result of CEC in home garden and lower elevation contour could be due to relatively higher organic matter in homegarden and lower elevation, respectively. The CEC is highly related with soil organic matter (humification and buffering capacity) i.e. the greater soil organic matter, the greater the CEC during humification (Keefer, 2000). Consequently, moderate CEC of the study site is related to moderate OM in the watershed. Therefore, the result is consistent with the claim of higher CEC in the lower elevations. Further, it is observed that home gardens are better in CEC than other agroforestry practices; suggesting that home gardens need to be introduced in degraded areas and lower elevation than other agroforestry practices in terms of releasing higher CEC.

The total nitrogen in the study area can be categorized as low according to Hazelton and Murphy (2007). Similar result was reported by Sheleme (2011) in wolayitta zone. Consequently, home garden and lower elevation had higher total nitrogen. The reason for higher value of total nitrogen on homegarden could be associated with higher organic matter in it. In addition, better availability of nitrogen fixing trees (*E. brucei* and *E. abyssinica*) and mycorhizal association (in coffee) in home garden can make the soil rich in nitrogen. Further, the management practice such as burning, remove nitrogen to atmosphere (Blanco and Lal, 2008; Hazelton and Murphy, 2007). This is also the case for woodlot in which the local people use burning as one management strategy, and exhibited the list nitrogen stored in the soil.

Moreover, nitrogen can also be lost from the system through run off and soil erosion (Hall, 2008; Wolf and Snyder, 2003) and this might be the reason for reduction in nitrogen along elevation contour in the order of upper<middle<lower. Prasad (2002) also found higher total nitrogen at lower elevation than upper. In addition, total nitrogen was decreased at lower elevation according to the report of Misana *et al.,* (2003) due to reduction of organic matter; which is the main source of nitrogen. The result is consistent with the claim of higher total nitrogen in the lower elevation than upper elevation.

In general the result is consistent with the argument of different land use which exhibit different soil chemical properties. Variation of the studied chemical parameters were also studied by different authors along toposequence and soil depth and they have shown difference in chemical parameters among different land uses (Aghasi *et al.,* 2011; Kasahun *et al.,* 2011; Sheleme, 2011; Ashenafi *et al.,* 2010; Göl *et al*., 2010; Yao *et al.,* 2010; Maitima *et al.,* 2009; Yüksek *et al*., 2009; Wang *et al.,* 2008; Fantaw, 2007; Mulugeta *et al*., 2004). Therefore, it can be said that home gardens are better in most of chemical parameters studied and very helpful for sustainable soil management than other agroforestry practices in this study.

V. CONCLUSIONS AND RECOMMENDATIONS

All the soil chemical properties studied were higher under homegarden agroforestry compared to parkland and woodlot agroforestry practices. Since the area covered by homegardens is relatively lower, it is exposed to soil erosion which is aggravated by conversion of fragile and steep lands to crop cultivation. The run of is higher in upper and middle slopes. Therefore, higher EC, CEC and total nitrogen, while lower pH was observed at lower slope gradient. In relation to this, most of the soil chemical properties shows that the study area is being degraded. Hence, homegarden is suggested as a better agroforestry practice for rehabilitation of the area in a sustainable manner through enhanced accumulation of total nitrogen, good EC, CEC at all elevation gradients.

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