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Full Length Research Paper

Comparative performance of farming practices in terms of carbon sequestration potential of mulberry and soil organic carbon stock

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Experimentation under the study at Central Sericultural Research and Training Institute, Berhampore (West Bengal, India) was laid out in RBD comprising of seven treatments replicated thrice. The treatments consist of six different farming practices along with a fallow. Mulberry variety, S 1635, spaced at 60 x 60 cm was subjected to those farming practices under irrigated Gangetic alluvial soil. Three years' field experimentation revealed that yield attributes, carbon sequestration potential (CSP) and NPK uptake by mulberry was varied significantly with respect to farming practices as well as seasons. Mulberry growing under moderate tillage with grass cover registered the highest leaf productivity and CSP of 38.72 t ha^{-1} year^{-1} and 6.90 t ha^{-1} year^{-1}, respectively in comparison to the existing farming practice (intensive tillage without grass) registering the same two parameters as 38.16 t ha^{-1} year^{-1} and 6.54 t ha^{-1} year^{-1}, respectively. It shows that the former is capable of earning an annual carbon credit of 0.36 t from one hectare of land in comparison to the existing farming practice and of course without any compromise with the leaf productivity. Furthermore, the particular farming practice, moderate tillage with grass cover, registered 40.16 Mg ha^{-1}soil organic carbon stock (SOCS) estimated after completion of the field experimentation and the same was significantly higher than the existing farming practice registering the value of 35.25 Mg ha^{-1}. Thus, in terms of SOCS also, the same farming practice is capable of earning carbon credit to the tune of 4.91 Mg ha^{-1} in comparison to the existing farming practice over a time period of three years. It is also worthy to mention that the particular altered farming practice as mentioned can even earn a carbon credit of 1.14 Mg ha^{-1} in terms of SOCS in comparison to the fallow land over the same period of time.

Key words: Carbon sequestration potential, farming practice, mulberry, soil organic carbon stock.

INTRODUCTION

Environmental globalization through the participation of each country in terms of their every activity is the utmost

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need of the present day, as its consequences will sooner or later reach all. Global warming is increasing at an alarming rate of 0.2°C per decade with an estimated average rise in global temperature of 3°C by 2100, which is believed to be caused by rising level of atmospheric CO_2 (Lavania and Lavania, 2009). Ability of the terrestrial biosphere to sequester and store atmospheric CO_2 has been recognized as an effective and low-cost method of offsetting carbon emissions (Koul and Panwar, 2008). Wise use of plants is good but when they are destroyed without thinking of future, the consequences are extremely complex like global warming and climate change (Parmesan and Yohe, 2003; Lau and Tiffin, 2009). Inversely, halting the destruction activities can cut the same proportion of GHGs emission which would be beneficial, thereby bringing the reducing emission from deforestation and forest degradation (REDD+) mechanism into existence (Latham et al., 2014; Greg and Donna, 2015). Different plant species have different capacity to sequestrate carbon during photosynthesis. Slow growing plant species like *Shorea robusta*, *Terminalia tomentosa* and *Adina cordifolia* sequestrate carbon slowly (Mandal et al., 2016).

On the other hand, carbon sequestration potential (CSP) is reported to differed with variation in land-use/ farming system (Kundu et al., 2008; Chauhan et al., 2010) and the same will not only fulfil the requirements of food, fodder and timber but render environmental benefits too. Carbon farming is a new way to describe a collection of eco-friendly farming techniques like use of cover crops, conservation tillage, pasture cropping, mulching etc., which increases soil organic carbon stock (SOCS) (http://www.reuters.com/article/ idUSTRE55G01B20090617?pageNumber=2&virtualBran...). Mulberry is an important leaf crop of India, occupying an area of 2.03 lakh hectares, grown as sole food of silkworm, *Bombyx mori* L. Higher concentration of CO_2 can have a positive influence on photosynthesis under optimal growing condition of light, temperature, nutrient and moisture supply and thus, biomass production can be increased, especially of plant with C_3 photosynthetic metabolism (Sombroek and Gommes, 1996). Mulberry being a C_3 plant promises to be capable of storing carbon in its above-ground components through enzymatic regulation of photosynthetic CO_2 fixation (Woodrow and Berry, 1988). Besides, modification of agricultural practices is a recognized method of carbon sequestration as soil can act as an effective sink offsetting as much as 20% of CO_2 emission annually (http://en.wikipedia.org/wiki/CO2_sequestration). In mulberry farming, information on extent of carbon sequestration in terms of CSP and SOCS is scanty and hence, the present study has been initiated to assess the CSP of mulberry growing under varying farming practices with an extension to SOCS too for evaluation of comprehensive carbon sequestration within the system. The very object of the study is nothing but to match the current Global agenda for terrestrial sequestration of carbon with mulberry-culture in terms of its social value.

MATERIALS AND METHODS

The study was undertaken on a sandy clay loam soil (*Typic ustochrept*) at the experimental farm of the Institute as mentioned above (24°4′ N – 88°9′ E) and the same is confined to the Bengal-Assam plain, hot sub-humid eco-geographic region with alluvium derived soils. Bulk density, organic carbon, available N, P_2O_5 and K_2O content of the experimental soil at the initiation of the experimentation were 1.38 Mg m^{-3}, 5.80 g kg^{-1}, 271 kg ha^{-1}, 34 kg ha^{-1} and 355 kg ha^{-1}, respectively. Maximum temperature of the experimental site varied between 27 to 43°C while minimum temperature varied between 14 to 30°C. The annual rainfall was varying between 1093 mm to 1420 mm with rainy days of 141-173 days per year.

Experimentation under the study was laid out in RBD comprising of seven treatments replicated thrice. The treatments were: T1, Intensive tillage (IT); T2, IT + Grass cover; T3, IT + Grass Cover + Cover crop; T4, moderate tillage (MT); T5, MT + Grass cover; T6, MT + Grass Cover + Cover crop; T7, Fallow. Mulberry variety, S 1635, spaced at 60 x 60 cm was subjected to six (T1 to T6) different farming practices under irrigated Gangetic alluvial soil. Intensive tillage refers to deep digging of ~30 cm depth of soil while moderate tillage refers to single-surface digging of ~10 cm depth of soil. *Cyperus rotundus* and *Cynodon dactylon* were naturally grown as grass cover while *Vigna umbellata* was used as cover crop. The coverage of grass crop and grass crop + cover crop was 420 and 485 g m^{-2}, respectively.

Soil organic carbon stock (SOCS) before initiation of the experimentation was computed based on the estimated values of bulk density (BD) of the same and its organic carbon (OC) content. ‘Core cutter’ method (Blake and Hartage, 1986; Kar et al., 2013) was employed to determine BD and OC content was estimated by following the method of chromic acid digestion (Black, 1965; Kar et al., 2018). Ultimately, computation of SOCS was made with the help of the following equation:

$$S = \rho. C. d \quad (1)$$

Where, S = SOCS, ρ = BD, C = OC content, d = depth of soil.

Rearing waste compost @ 20 t/ ha/ year along with soil test-based NPK fertilizers were applied to the mulberry plantation under different farming practices.

Yield parameters of mulberry under different farming practices were recorded season wise for three years (2012 to 2013 to 2014 to 2015). Mulberry has been cultivated as bush for supply of its leaf to silkworm as feeding material. Annually five leaf crops was harvested during five different seasons followed by pruning of the plant at ~15 cm height and the shoot samples were subjected to composting after suitable chopping along with rearing waste. Age of the mulberry plantation during initiation of the experimentation was seven years. Carbon sequestration potential (CSP) and NPK uptake by mulberry for the same were also estimated season wise. Unlike trees, promotional increment of carbon stock in mulberry-biomass in terms of CSP over the years cannot be computed and thus, study on difference of carbon stock between the years does not appear to be pragmatic. Annual CSP of mulberry is computed by cumulating the contribution of five crops. CSP means potential of a plant to withdraw carbon from atmosphere as CO_2 through photosynthetic metabolism to store the same in its biomass (Lewandrowski et al., 2004). For estimation and calculation of the same, mulberry leaf and shoot samples were oven dried at 70°C and dry weights of the same were calculated using moisture content. The ash contents of the oven-dried leaf and shoot samples were determined by igniting 1 g of powdered sample at 550 °C for 6

Table 1. Season wise yield attributes of mulberry under different farming practices.

Farming practices	Leaf yield (t ha^{-1}) in different seasons					Shoot yield (t ha^{-1}) in different seasons				
	May	July	Sep	Nov	Feb	May	July	Sep	Nov	Feb
Intensive Tillage (IT)	7.74	9.10	8.84	7.09	5.39	4.62	5.80	7.44	3.02	3.58
IT + Grass	7.04	8.39	8.87	7.30	5.76	3.92	5.30	7.74	3.34	4.23
IT + Grass + Cover crop	6.45	7.69	7.82	6.62	4.96	3.67	4.86	6.26	2.98	3.29
Moderate Tillage (MT)	6.83	8.49	8.47	6.98	5.45	3.67	5.12	7.23	3.24	3.70
MT + Grass	7.73	8.96	8.84	7.41	5.78	4.37	5.91	7.43	3.49	4.30
MT + Grass + Cover crop	6.39	7.80	8.02	6.95	5.13	3.65	5.07	6.72	3.35	3.52
$CD^*_{\text{farming practice}}$			0.32					0.36		
CD^*_{season}			0.29					0.33		

h in a muffle furnace. A total of 50 % of the ash-free mass was taken as the carbon content (Nath and Das, 2011; Majumder et al., 2014). CSP of mulberry was calculated on hectare basis utilizing the dry weights of leaf and shoot as follows:

$$CSP = y.\ C.\ (100 - m).\ 10^{-4} \qquad (2)$$

Where, y = leaf/ shoot yield, C = leaf/ shoot carbon%, m = leaf/ shoot moisture%. Further, N, P and K contents of the oven-dried (70°C) leaf and shoot samples were determined by following the standard analytical protocols, namely, Kjeldahl, Vanadomolybdate – spectrophotometry and Flame Photometry, respectively (Jackson, 1973; Kar et al., 2017). NPK uptake by mulberry was calculated on hectare basis utilizing the dry weights of leaf and shoot.

After completion of the field experimentation for three years, soil samples were collected replication wise from each of the treatment. SOCS under different treatments were estimated by adopting the method as described earlier and changes in SOCS due to induction of altered farming practices were enumerated in comparison to the existing one (T1) as well as fallow (T7).

Based on the mulberry productivity, CSP and SOCS, the most efficient farming practice for the mulberry vegetation under irrigated Gangetic alluvial plain was identified.

RESULTS AND DISCUSSION

Initial SOCS

Soil sample collected before initiation of the experimentation was analyzed for estimation of bulk density and organic carbon content following the methodology as mentioned above. Bulk density of the sample was estimated as 1.38 Mg m^{-3} and that of organic carbon content was 5.80 g kg^{-1}. Considering standard conversion factor of 1.33 for incomplete oxidation under Walkley-Black method (Batjes, 1996; Kar et al., 2013), SOCS of the sample was computed as 31.94 Mg ha^{-1}upto 0.30 m depth of soil.

Yield attributes of mulberry

Season wise leaf and shoot yield of mulberry under different farming practices has also been pooled for three years and presented in Table 1.

Data pertaining to yield attributes of mulberry as presented in Table 1 reveals significant variations for farming practices and seasons with respect to leaf as well as shoot productivity. Three years' pool data highlighted the farming practice involving moderate tillage with grass cover in terms of maximum leaf (38.72 t ha^{-1} $year^{-1}$) as well as shoot (25.50 t ha^{-1} $year^{-1}$) productivity. In terms of seasonal influence, September crop corresponded to maximum leaf (8.48 t ha^{-1}) as well as shoot (7.14 t ha^{-1}) productivity. Such seasonal variation of mulberry productivity has already been reported to be correlated with seasonal variation of nutrient uptake (Majumdar et al., 2003) and the same has been furnished in the following part of elaboration (Table 3). However, the order of leaf productivity under different farming practices are as follows:

Leaf productivity (t ha^{-1} $year^{-1}$)

MT + grass (38.72) > IT (38.16) > IT + grass (37.36) > MT (36.22) > MT + grass + cover crop (34.29) > IT + grass + cover crop (33.55)

Comparative advantage of moderate tillage (MT) over intensive tillage (IT) may be postulated in terms of reduction in carbon reversion from soil to atmosphere and subsequent conversion of soil inorganic carbon (SIC) to soil organic carbon (SOC) resulting in improvement of soil organic ambience (Singh et al., 2005; Bhattacharya et al., 2009; Kar et. al. 2013). On the other hand, incorporation of grass and cover crops while digging is supposed to improve the soil organic ambience, in turn (Setua et al., 2012) but, competition between mulberry and cover crop in terms of nutrient assimilation exerted declining effect on mulberry yield attributes and the situation is worse in case of cover crop than grass crop. The resultant of these two reverse tendencies highlighted the treatment (MT + grass) in terms of better yield attributes of mulberry in comparison to others.

CSP and NPK uptake by mulberry

CSP of mulberry growing under different farming

Table 2. Season wise CSP of mulberry under different farming practices.

Farming practices	CSP of leaf (t ha^{-1}) in different seasons					CSP of shoot (t ha^{-1}) in different seasons				
	May	July	Sep	Nov	Feb	May	July	Sep	Nov	Feb
Intensive Tillage (IT)	0.712	0.892	0.930	0.721	0.501	0.497	0.661	0.923	0.372	0.329
IT + Grass	0.671	0.802	0.922	0.748	0.535	0.436	0.591	0.950	0.394	0.389
IT + Grass + Cover crop	0.618	0.747	0.788	0.669	0.460	0.420	0.540	0.735	0.335	0.306
Moderate Tillage (MT)	0.668	0.811	0.904	0.725	0.504	0.425	0.592	0.901	0.375	0.340
MT + Grass	0.755	0.896	0.941	0.777	0.559	0.476	0.694	0.945	0.419	0.435
MT + Grass + Cover crop	0.634	0.777	0.844	0.702	0.477	0.416	0.574	0.832	0.396	0.330
CD* $_{\text{farming practice}}$			0.038					0.040		
CD* $_{\text{season}}$			0.035					0.037		

practices has been estimated season wise in terms of its above-ground components, namely, leaf as well as shoot and three years' pool data of the same is presented in Table 2. Season wise NPK uptake by leaf and shoot samples of mulberry has also been estimated separately. Further, NPK uptake by mulberry biomass has been computed by cumulating the both and three years' pool data of the same is presented in Table 3.

CSP of mulberry leaf and shoot both has been varied significantly among farming practices as well as seasons (Table 2). Three years' pool data on CSP revealed that mulberry growing under moderate tillage with grass cover registered an annual CSP of 3.93 t and 2.97 t by leaf and shoot, respectively from one hectare of land followed by intensive tillage (existing practice) and other farming practices as follows:

CSP of leaf (t ha^{-1} $year^{-1}$)

MT + grass (3.93) > IT (3.76) > IT + grass (3.68) > MT (3.61) > MT + grass + cover crop (3.43) > IT + grass + cover crop (3.28).

CSP of shoot (t ha^{-1} $year^{-1}$)

MT + grass (2.97) > IT (2.78) > IT + grass (2.76) > MT (2.63) > MT + grass + cover crop (2.55) > IT + grass + cover crop (2.34).

CSP of mulberry leaf and shoot under different farming practices had good bearing with the biomass production of mulberry under different treatments as discussed earlier and the same is very much correlated with enzymatic regulation of photosynthetic CO_2 fixation (Woodrow and Berry, 1988; Lavania and Lavania, 2009). It is reported (Koul and Panwar, 2008; Mandal et al., 2016) that carbon sequestration depends upon biomass production capacity, which in turn depends upon interaction between edaphic, climatic and topographic factors of an area. Besides, seasonal fluctuation of CSP highlighted September crop further as the most capable one for capturing carbon by leaf (0.89 t ha^{-1}) and shoot (0.88 t ha^{-1}) both. The finding indicates its bearing with yield attributes of mulberry during the particular season.

NPK uptake by mulberry biomass was also affected similarly as that of CSP of mulberry under different farming practices and seasons (Table 3).

The variation of NPK uptake under farming practices and seasons was found significant. Based on the three years' pool data, the order of NPK uptake by mulberry biomass under different farming practices is as follows:

N uptake by mulberry (kg ha^{-1} $year^{-1}$)

MT + grass (430.34) > IT (391.81) > IT + grass (391.20) > MT (379.64) > MT + grass + cover crop (362.31) > IT + grass + cover crop (323.79).

P uptake by mulberry (kg ha^{-1} $year^{-1}$)

MT + grass (56.70) > IT + grass (51.40) > IT (51.00) > MT (49.92) > MT + grass + cover crop (47.94) > IT + grass + cover crop (44.16).

K uptake by mulberry (kg ha^{-1} $year^{-1}$)

MT + grass (291.26) > IT (275.37) > IT + grass (273.50) > MT (258.51) > MT + grass + cover crop (250.88) > IT + grass + cover crop (236.68).

The trend of NPK uptake by mulberry under different farming practices and seasons almost matches with the finding of CSP and thus, is supposed to be linked with the variation of yield attributes of mulberry under the same. The role of soil organics on nutrient mobilization into mulberry from soil has already been reported (Kar et al., 2012a, 2012b) and the same may, further, be correlated with SOCS under different farming practices (Table 4) as discussed later. Similar reports are also quite available in agricultural crops (Hati et al., 2008; Swarup and Singh, 2009). However, September crop is again highlighted in terms of uptake parameters registering 96.56, 13.60 and 67.26 kg ha^{-1} N, P and K uptake, respectively, which matches with the biomass production of mulberry (Table

Table 3. Season wise NPK uptake by mulberry biomass under different farming practices.

Farming practices	N uptake (kg ha^{-1}) in different seasons					P uptake (kg ha^{-1}) in different seasons				
	May	July	Sep	Nov	Feb	May	July	Sep	Nov	Feb
Intensive Tillage (IT)	72.76	91.02	101.25	68.17	58.61	8.81	11.11	13.80	9.69	7.58
IT + Grass	71.75	82.17	101.10	72.70	63.48	8.23	10.03	14.30	10.11	8.73
IT + Grass + Cover crop	63.99	68.85	81.91	58.96	50.08	7.87	9.18	11.16	8.75	7.19
Moderate Tillage (MT)	70.82	83.00	99.38	69.41	57.02	8.09	9.98	13.99	9.93	7.94
MT + Grass	79.71	93.58	107.58	79.40	70.08	9.52	11.72	15.30	10.43	9.72
MT + Grass + Cover crop	65.41	80.17	88.13	69.89	58.72	7.78	9.96	13.02	9.31	7.86
CD* $_{\text{farming practice}}$			5.12					0.67		
CD* $_{\text{season}}$			4.67					0.61		

	K uptake (kg ha^{-1}) in different seasons				
	May	July	Sep	Nov	Feb
Intensive Tillage (IT)	49.08	67.24	70.16	48.83	40.07
IT + Grass	45.58	60.10	71.25	51.54	45.03
IT + Grass + Cover crop	41.81	54.93	58.99	43.72	37.23
Moderate Tillage (MT)	43.88	59.54	67.10	48.41	39.57
MT + Grass	50.55	67.80	71.73	53.16	48.02
MT + Grass + Cover crop	42.99	57.28	64.30	46.12	40.20
CD* $_{\text{farming practice}}$				3.71	
CD* $_{\text{season}}$				3.38	

Table 4. SOCS and its components under different treatments.

Treatment	Bulk density (Mg m^{-3})	Organic carbon (g kg^{-1})	SOCS (Mg ha^{-1})
Intensive Tillage (IT)	1.29	6.87	35.25
IT + Grass	1.29	6.97	35.97
IT + Grass + Cover crop	1.30	6.93	35.98
Moderate Tillage (MT)	1.32	6.97	36.62
MT + Grass	1.31	7.70	40.16
MT + Grass + Cover crop	1.30	7.10	36.83
Fallow	1.43	6.83	39.02
CD*	0.06	0.37	2.99

1) in that particular season.

SOCS after field experimentation

After completion of the field experimentation for three years, soil samples were collected replication wise from each of the treatment. SOCS under different treatments were computed on the basis of estimated values of bulk density as well as organic carbon content and the same is presented in Table 4.

Soils subjected to different land use systems for three years have been analysed to compute SOCS up to the depth of 0.30 m based on the estimated values of bulk density and organic carbon content (Table 4). Changes in the soil parameters due to intervention of different farming practices have not only been compared with the fallow land but with the initial condition also. Intervention of farming practices improved the bulk density, organic carbon content and SOCS in comparison to the initial condition registering 1.38 Mg m^{-3}, 5.80 g kg^{-1} and 31.94 Mg ha^{-1}, respectively for the above three soil attributes. But, for fallow land, bulk density was worsened in comparison to the initial condition and reason for the same seems to be enhancement of soil compactness under serene land condition. On the other hand, organic carbon content and SOCS was improved in the fallow land in comparison to initial condition probably due to reduction of CO_2 reversion from soil to atmosphere under composed land (Kar et al., 2013).

Comparing the performances of different farming practices in terms of enhancement of SOCS, it was observed that SOCS under moderate tillage with grass cover was significantly higher than any other farming practices. As variation of bulk density of soil under different farming practices is at par, higher organic carbon content coupled with substantial reduction of CO_2 reversion seems to be the reason for higher SOCS under the particular farming practice. However, SOCS under the fallow land is substantial and comparable with the treatment cited above. Restricted CO_2 reversion from soil to atmosphere under compact soil condition is supposed to be the prime reason for the same.

Conclusion

Among the six farming practices under the study, mulberry growing under moderate tillage with grass cover registered the highest leaf productivity and CSP of 38.72 t ha^{-1} $year^{-1}$ and 6.90 t ha^{-1} $year^{-1}$, respectively in comparison to the existing farming practice (IT) registering the same two parameters as 38.16 t ha^{-1} $year^{-1}$ and 6.54 t ha^{-1} $year^{-1}$, respectively. Thus, mulberry growing under moderate tillage with grass cover is capable of earning an annual carbon credit of 0.36 t from one hectare of land in comparison to that under the existing farming practice (intensive tillage) and of course without any compromise with the leaf productivity.

Moreover, in terms of SOCS as estimated after completion of the field experimentation, moderate tillage with grass cover registered 40.16 Mg ha^{-1} SOCS and the same is significantly higher than existing farming practice (intensive tillage) registering the value of 35.25 Mg ha^{-1}. Thus, in terms of SOCS also, moderate tillage with grass cover is capable of earning carbon credit to the tune of 4.91 Mg ha^{-1} in comparison to the existing farming practice over a time period of three years. It is worthy to mention that the altered farming practice, moderate tillage with grass cover, can even earn a carbon credit of 1.14 Mg ha^{-1} in terms of SOCS in comparison to the fallow land over the same period of time.

In light of the above, suitable modification of existing farming practices in the form of 'moderate tillage with grass cover' is recommended for mulberry cultivation to achieve the target of offsetting carbon emission from the atmosphere at an enhanced rate and to store the same subsequently in terrestrial system for further use. The approach matches the current Global agenda for terrestrial sequestration of carbon and promises to act as an agent to save the Globe from warming.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Batjes NH (1996). Total carbon and nitrogen in the soils of the world. European Nigerian Journal of Soil Science 47:151-163.

Bhattacharyya T, Ray SK, Pal DK, Chandran P, Mandal C, Wani SP (2009). Soil carbon stocks in India - issues and priorities. Journal of the Indian Society of Soil Science 57:461-468.

Black CA (1965). Methods of Soil Analysis. American Society of Agronomy, Inc, Madison, Wisconsin, USA P 9.

Blake GR, Hartage KH (1986). Bulk Density, In: Methods of Soil Analysis (A. Klute, Ed), Madison, Wisconsin pp. 364-367.

Chauhan SK, Sharma SC, Beri V, Ritu, Yadav S, Gupta N (2010). Yield and carbon sequestration potential of wheat (*Triticum aestivum*) - poplar (*Populus deltoids*) based agri-silvicultural system. Indian Journal of Agricultural Science 80(2):129-135.

Greg F, Donna L (2015). Early Lessons from Jurisdictional REDD+ and Low Emissions Development Programs. The Nature Conservation, Forest Carbon Partnership Facility, The World Bank, Washington DC, USA.

Hati KM, Swarup A, Mishra B, Manna MC, Wanjari RH, Mandal KG, Mishra AK (2008). Impact of long-term application of fertilizer, manure and lime under intensive cropping on physical properties and organic carbon content of an Alfisol. Geoderma 148:173-179.

Jackson ML (1973). Soil Chemical Analysis. Indian Reprint, Prentice Hall of India Private Limited, New Delhi.

Kar R, Bindroo BB, Ghosh MK, Majumder SK, Bose PC (2012b). Molecular characterization of humic acids isolated from farmyard manure and vermicompost used under a long-term fertilizer experiment on mulberry (*Morus alba* L.). Natural science 10 (12):220-226.

Kar R, Bindroo BB, Ghosh MK, Majumder SK (2013). Carbon credit in soil under a long-term fertilizer experiment on mulberry. Natural science 11 (3):77-81.

Kar R, Bose PC, Majumder SK, Ghosh A (2012a). An account of soil organic carbon reserve under long-term fertilizer experiment in mulberry [*Morus alba* L.]. Journal of Crop and Weed 8(1):57-59.

Kar R, Ram RL, Ghosh MK, Trivedi K (2017). Response of Mulberry (*Morus alba* L.) to Foliar Supplementation of Nutrient-composite. International Journal of Agricultural Research 6(3):582-586.

Kar R, Vrajan V, Ghosh MK, Dutta SK, Trivedy K (2018). Prediction of nitrogen availability based on soil organic carbon in commercial mulberry vegetation of Eastern India. Journal of Soil Science and Environmental Management 9(3):30-34.

Koul DN, Panwar P (2008). Prioritizing land-management options for carbon sequestration potential. Current Science 95(5):658-663.

Kundu SK, Bhattacharyya R, Prakash V, Gupta HS (2008). Carbon sequestration potential of Inceptisols under long-term soyabean-wheat rotation in sub-temperate rainfed agro-ecosystem of North-West Himalayas. Journal of the Indian Society of Soil Science 56(4):423-429.

Latham J, Trivedi M, Amin R, D'Arcy L (2014). A Sourcebook of Biodiversity Monitoring for REDD+. Zoological Society of London, London, UK.

Lau JA, Tiffin P (2009). Elevated carbon dioxide concentrations indirectly affect plant fitness by altering plant tolerance to herbivory. Oecologia 161(2):401-410.

Lavania UC, Lavania S (2009). Sequestration of atmospheric carbon into subsoil horizons through deep-rooted grasses - vetiver grass model. Current Science 97(5):618-619.

Lewandrowski J, Peters M, Jones C, House R, Sperow M, Eve M, Paustian K (2004). Economics of sequestering carbon in the U.S. agriculture sector. Technical Bulletin No. (TB-1909) http://transcoder.usablenet.com/tt/http://www.ers.usda.gov/publications/ tb1909/.

Majumdar SK, Bose PC, Kar R, Banerjee ND, Ghosh JK (2003). Studies on the seasonal variation of NPK uptake by mulberry (*Morus alba* L.). Indian Journal of Sericulture 42(1):1-3.

Majumder SK, Kar R, Bindroo BB (2014). A study on carbon assimilation by mulberry plant under nutrient management system. *Abstracts:* National Conference on Sericulture for Livelihood Security, University of Agricultural Sciences, Bangalore, College of Sericulture, Chintamani P 32.

Mandal RA, Jha PK, Dutta IC, Thapa U, Karmacharya SB (2016). Carbon sequestration in tropical and subtropical plant species in collaborative and community forests of Nepal. Advances in Ecology, vol. 2016, Article ID 1529703, P 7 http://dx.doi.org/10.1155/

2016/1529703.
Nath AJ, Das AK (2011). Carbon storage and sequestration in bamboo-based smallholder home gardens of Barak valley, Assam. Curr. Sci Current Science 100:229-233.
Parmesan C, Yohe G (2003). A globally coherent fingerprint of climate change impacts across natural systems. Nature 421(2):37-42.
Setua GC, Misra AK, Kar R, Shivnath, Datta RN, Ghosh A (2012). Effect of planting geometry and intercropping on growth attributes, leaf yield, quality of mulberry (*Morus alba*) and its economics under irrigated, Gangetic alluvial soil conditions. Indian Journal of Agricultural Science 82(1):8-14.
Singh SK, Singh RS, Shyampura, RL, Narain P (2005). Organic and inorganic carbon stock in soils of Rajasthan. Journal of the Indian Society of Soil Science 53:281-287.
Sombroek WG, Gommes R (1996). The climate change - Agriculture conundrum, In: Global climate change and agriculture production (F. Bazzaz and W. Sombroek, eds.), pp. 1-14.
Swarup A, Singh M (2009). Soil carbon dynamics under intensive cropping systems. Journal of the Indian Society of Soil Science 57:469-476.
Woodrow IE, Berry JA (1988). Enzymatic regulation of photosynthetic CO_2 fixation in C_3 plants. Annual Review of Plant Physiology and Plant Molecular Biology 39:533-594.

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Climate Change Effect and Adaptation Measures on Selected Soil Properties

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Soil sustainability in climate changing trends is critical to address future food security and safety. This study investigated the effect of air and soil temperature on some selected soil properties. The impact of soil conditioning with composted organic wastes on the temperature effect was also assessed. Four different chambers were set up using electrical bulbs of 60, 100, 200, and 300 W given air temperature ranges of 30-32, 33-35, 36-38 and 39-41°C (10 h daily photoperiod) respectively with two other natural growth units (27-29°C) with or without organic compost were established and replicated four times under screen house for 95 days. Soil properties; particle size distribution, electrical conductivity (EC), pH, cation exchange capacity (CEC), organic carbon (OC), N, P, and K were determined using standard methods. Positive correlation was obtained for air and soil temperature, and soil parameters varied significantly ($P \leq 0.05$) for the different temperature ranges. Combined effect of elevated temperature and compost amendment increased soil properties by 0.45-54, 9-28, 0.4-0.6, 89–91 and 10-29% for C, K, pH, EC and CEC under different temperature regimes respectively. Nitrogen and phosphorus availability decreased by 16-21 and 8-37% with increased in temperature. The addition of compost cushioned the effects of increasing temperatures on soil factors. It is evident from the study that global warming could potentially alter fate of soil factors and which may be detrimental to sustainable food production and food security.

Key words: Climate Change, Soil Properties, Organic Compost, Mitigation, Food Security.

INTRODUCTION

In addressing future food security and safety, the study of climate and soil factors become more critical with the changing climate. Soil properties are affected by variety of environmental factors, in which temperature is one of the most influential. Often temperatures within the soil are continually changing (Karmakar et al., 2016). The system attempts to come to an equilibrium state but is continually uptight by heat inputs (predominantly solar radiation) and heat sinks including cooler soil at depth, cool air at the surface and water phase change (Brevik, 2013a).

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Temperature has been reported to affect the physical and chemical properties of the soil with off-putting impact on soil sustainability (Karmakar et al., 2016). Activities such as weathering, respiration, transpiration, chemical reaction in the soil, microbial activities, diffusion of solute and gases, water flow in the soil and availability of water to plant are temperature based (Akamigbo and Nnaji, 2011). The forecast on global temperature increase is put at 1.8 to 4.0°C in the next few decades given that the Earth's temperature is likely to rise by about 0.1 to 0.2°C per decade (International Panel for Climate Change, 2007). Upward variation in atmospheric temperature has been reported worldwide by Inter-governmental Panel on Climate Change (IPCC, 2007, 2014). The IPCC (2007) reported, that most of the observed increased in globally averaged temperatures since the mid-20th century were due to the observed increase in anthropogenic greenhouse gas concentrations and traceable to human influence.

With global concerns about increased temperature and based on the IPCC projection, the humid tropical area of Nigeria is expected to be characterized by increase in both precipitation and temperature, precipitation increase of about 2 to 3% for each degree of global warming may be expected (IPCC, 2014). The climate of Nigeria is mainly tropical in nature. Temperatures are high throughout the year, averaging from 25 to 28°C (Iloeje, 2001), however, temperature increases of about 0.2 - 0.3°C per decade in the various ecological zones of the country (Akamigbo and Nnaji, 2011) have been observed. Nigeria is likely to experience an increase in global warming from 1.4 to 5.8°C over the period 1990 to 2100 (IPCC, 2007).

If the view on global warming causing imbalance in the ecosystem is upheld, then, the impact of global warming on agriculture could be direct on plants or indirect by impacting factors that have bearing on crop productivity and soil sustainability (Adekunle, 2009). Having such impacts as stated above imply that the increased, sustainable and safe food production agenda of the country is at stake.

Soil vulnerability to climatic influence depends on both the physical and chemical characteristics of soils and at the same time, climate change has been reported to affect the physical and chemical properties of the soil with pronounced impact on soil sustainability (Buchas, 2001). Soil is important to food security (Pimentel 2006), and climate change has the potential to threaten food security through its effects on soil properties and processes (Brevik, 2013a). Studies have shown that with increase of incubation time of soil used in a screen house experiment, pH decreased (Brownmang and Brown, 2018; Ying et al., 2009). A decrease in soil pH, together with a temperature rise, produced a synergistic effect, ultimately reducing the respiratory activity of soil microorganisms thereby reducing organic matter decomposition rate and other essential metabolic processes in the soils (Rousk et al., 2009). Increased biological activity follows increase in temperature, everything being equal (rainfall, the amount of water percolating downward through the soil, aeration), increased acidity follows increase temperatures.

Wan et al. (2011) reported that increased temperatures will lead to increased CO_2 release from soils to the atmosphere, which leads to more increases in temperature. Link et al. (2003) in a study of soils in a semi-arid steppe reported that soil warming and drying led to reduction in soil carbon. The negative effect of increased temperatures on plant growth is also reported to cancel out any CO_2−fertilization effect that does take place (Jarvis et al., 2010). While, Sakaguchi et al. (2007) reported that electrical conductivities of sand decreased with temperature increase, which suggested that the conduction of heat decreased through the decrease in the water bridges as temperature increased. Seasonal fluctuations in soil temperature may affect electrical conductivity (EC).

Through climate change and anthropogenic activities, many of our world's soils have become or are expected to become more susceptible to erosion by wind and/or water (Zhang et al., 2004) leading to reduction in soil nutrients and crop produce. Apart from nutrients wash, increased temperature may also impact the available of soil nutrients such as phosphorus and nitrogen, and this may deleteriously affect plant growth (Hungate et al., 2003). Furthermore, soil temperature greatly influences the rates of biological, physical, and chemical processes in the soil (Davidson and Janssens, 2006) which governs the rates and directions of soil physical processes and chemical reactions, and influences biological processed upon which soil formation depends. Heat transfer capability tends to increase as soil texture becomes increasingly fine, with loam mixtures having an intermediate value between sand and clay. This aggregation affects erosion, movement of water, and plant root growth (Terefe et al., 2008). Under this scenario, adaptation will require the need to know how climate and soil factors interact and the way changes in climate will lead to corresponding alterations in soil factors which the study is set to attain through the following objectives: i) establishing the profiles of soil and atmospheric temperatures variation in the experimental environment; ii) assessing the effects of temperature change on selected soil characteristics; pH, organic matter, soil organic carbon, soil electrical conductivity and nutrient content (Nitrogen and phosphorus) and iii) evaluating the conditional roles of compost on temperature effects

MATERIALS AND METHODS

The research was carried out in the College of Environmental Resources Management, University of Agriculture Abeokuta along Alabata road in Odeda local government area of Ogun state, Southwestern Nigeria. It is situated between Latitude 7.9°N and 7.8°10'N and Longitude 3° 23'E and 3° 24'E, with average daily minimum and maximum temperature of about 21°C and 35°C, respectively (Akani et al., 1992). There are two distinct seasons in the area, namely, the rainy season which lasts from March/April to October/ November and the dry season which lasts for the rest of the year, October/November till March/April. The temperature is relatively high during the dry season with the mean around 30°C.

Description of the temperature chambers

Temperature chambers were constructed with wooden material wrapped with aluminum foils, and glass materials. Temperature variations during the experiment were achieved *via* installation of incandescent (240CV2 JUNSGAM0) electric bulbs of varying wattage (60, 100, 200 and 300 W). Where possible, two bulbs were connected together to obtain the desired temperature regime. Each of the temperature chambers was 7 cm in length, 5.5 cm in breath and with height of 7.5 cm, giving a volume of 288.7 cm^3.

The different temperature ranges and the systems comprised of (i) Soil alone, kept outside of the chamber, whose temperature range was between 27-29°C; (ii) Soil and compost amendment, also kept outside the chamber whose temperature range was obtained between 27-29°C; (iii) Soil and compost amendment, placed inside the temperature chamber with a temperature range of 30-32°C; (iv) Soil and compost amendment, placed inside the temperature chamber with a temperature range of 33-35°C; (v) soil and compost amendment, placed inside the temperature chamber with a temperature range of 36-38°C; (vi) soil and compost amendment, placed inside the temperature chamber with a temperature range of 39-41°C, making a total of six chamber treatments.

Screen house experiment

Twenty four pots were set up for the experiment, consisting of 6 treatments with 4 replicates. After filling each pot with 3 kg soil, the pots were transferred to the screen house, and placed accordingly. Each temperature chamber contained four replicates of a given system. To prevent loss of matter from the pots, no real drainage was made, but to avoid flooding, soils were watered at the required field.

Laboratory analysis

Soil samples were analyzed before and after the experiment for its physical and chemical properties. Particle size distribution was determined by the hydrometer method (Okalebo et al., 2002), organic carbon was done by wet dichromate acid oxidation method (Nelson and Sommers, 1982), soil pH was measured in a 1:1 (soil-water mixture) by glass electrode pH meter (MaClean, 1982), total nitrogen was determined by the micro Kjeldahl method (Bremner, 1982). Al^{3+} and H^+ were extracted with 1 N KCl (Thomas, 1982), Ca, Mg, Na and K were extracted with 1 N NH_4OAC pH 7.0 (Ammonium acetate). Potassium and sodium were determined with flame emission photometer while calcium and magnesium were determined with automatic adsorption spectrophotometer (Anderson and Ingram, 1993). Available phosphorus was extracted with Bray II solution and determined by the molybdenum blue method on the technicon auto-analyzer as modified by Oslem and Sommers (1982). ECEC was calculated by the summation of exchangeable base and exchangeable acidity (Anderson and Ingram, 1993).

Statistical analysis was carried out on the data obtained using SPSS version 16.0. Descriptive statistics were used to determine the mean mode, median and standard deviation and ANOVA was used to test means of levels of treatments. The Pearson correlation coefficient was used to determine the relationship between temperatures variation, soil properties (pH value, organic compost, exchangeable bases and soil texture.

RESULTS AND DISCUSSIONS

Daily temperature variation

Distinct soil temperature ranges were achieved by simulating the global warming scenario. The temperature dynamics obtained increased from 27 to 41°C, a difference of 14°C ranging from 23-27°C for mornings, 29-41°C for the afternoon and 29-35°C for evenings. The mean values were found in the range of 27-32°C. The highest temperature value 41^0C was attained in the chamber that was equipped with electric bulb of 300 W.

Correlation analysis revealed positive association between the air temperature and soil temperatures in all the treatments with the following values: +0.439 and +0.369 for non- composted treatment (27-29°) and composted treatment (27-29°); +0.434 (30-32°), + 0.628 (33-35°), +0.438 (36-38°) and +0.463 (39-41°) respectively. Correlation was significant at $P < 0.001$** and 0.05*. From the linear regression model, the change in soil temperature for unit change in prevailing atmospheric temperature ranged from 0.30 to 0.67°C.

The maximum (28-30.2°C) and the minimum (26.3 - 28.8°C) mean soil temperature values were observed at the temperature range of 39-41°C and soil alone 27-29°C) respectively, meaning that soil temperature is a function of the air temperature. The positive correlation values obtained indicated that with increase in air temperature, soil temperature increased with effect on soil factors since they are susceptible to temperature. Morning temperature was significantly ($P < 0.05$) different from afternoon and evening regimes. No significant difference was observed between soil temperatures in the afternoon and evening at $P \leq 0.05$. Ambient temperatures [morning, afternoon and evening became significantly different in (36-38°C) and 39-41°C)] systems. Results from the soil analysis showed that the soil texture (sand, silt and clay compositions) ranged from 78.27 to 78. 30% for sand, 6.58 to 7.38% for silt and 14.60 to 15.55% for clay showing that the soils used were predominantly sandy-loam. Variation in temperatures practically has no effects on the soil texture at the end of experiment.

The soil pH ranged from 7.79 to 8.10 as depicted in Figure 1, which revealed that the soil was slightly alkaline. Soil pH increased with increased in temperature. Increased pH has been linked with organic acid

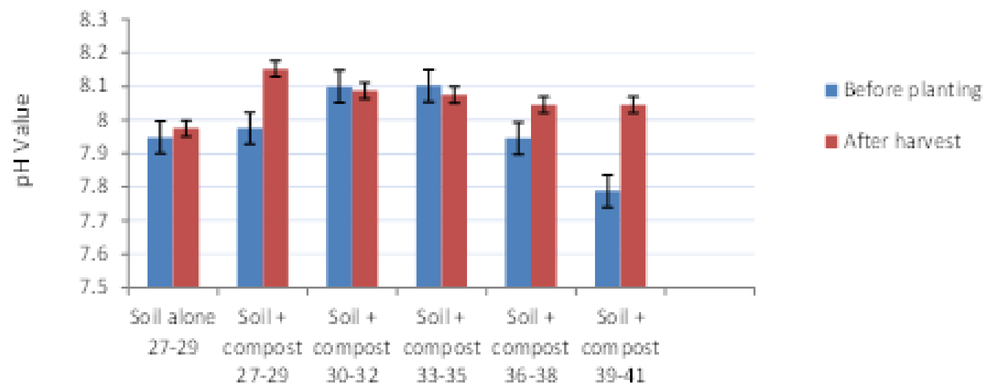

Figure 1. Variation in soil pH before and after the experiment (indicating error bars with standard error).

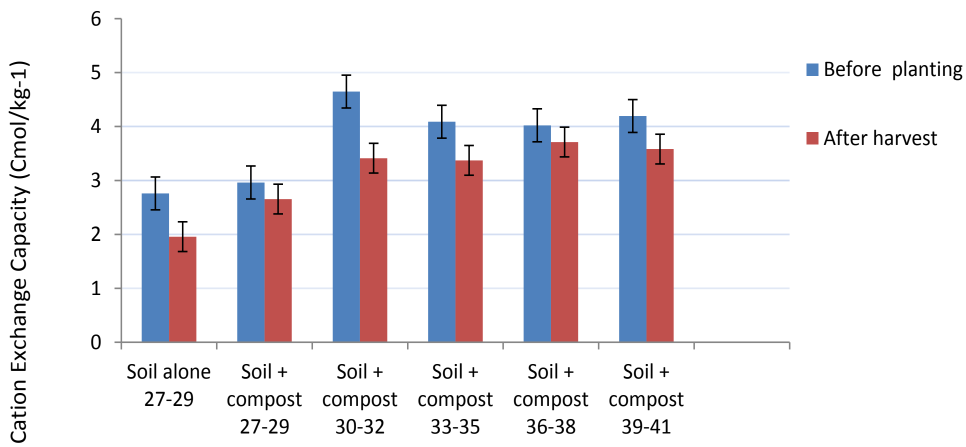

Figure 2. Variation in cation exchange capacity in the experimental soils (indicating error bars with standard error).

denaturalization which is associated with increase temperature as reported by Mensies and Gillman (2003). This further confirmed Nederlof et al. (1993) assertion that high pH could be major factors controlling heavy metals bioavailability. The mean values for the pH of the soils before and after the experiment were significant ($P \leq 0.05$). Increasing temperature from 30-35°C decrease the pH by 0.34 to 0.15 %. Anion exchange capacity of a soil has been reported to increase as soil pH decreases, thus with increasing temperature, soil anions exchange capacity may be expected to increase under this experimented condition, which can lead to improving the capacity of the soil to adsorb and exchange anions. The observed decrease in pH with increase temperature was consistent with the report of Ying et al. (2009) that with increasing temperature, soil pH decreased. However, 1.26-3.2% increase was observed at the range of 36-41°C which could be adduced to increased exchangeable cations such as potassium and calcium from composting enhanced at higher temperature. The result suggests that with increase in global temperature as simulated in this experiment, soil pH may increase resulting to soil alkalinity. This may be detrimental to crop growth, micro-organisms activities and other ecological processes.

Cation Exchange Capacity (CEC) which is a measure of the soil's ability to hold positively charged ions increased with increase temperatures as depicted in Figure 2. Result showed that the maximum and the minimum mean values were observed at the temperature range of 27-29°C and 36-38°C respectively. Significant variations ($P \leq 0.05$) were observed in the soils CEC before and after the experiment. Result of the effect of applied compost was 19.08% (29.08 to 10) increase in cation exchange capacity making such soil less

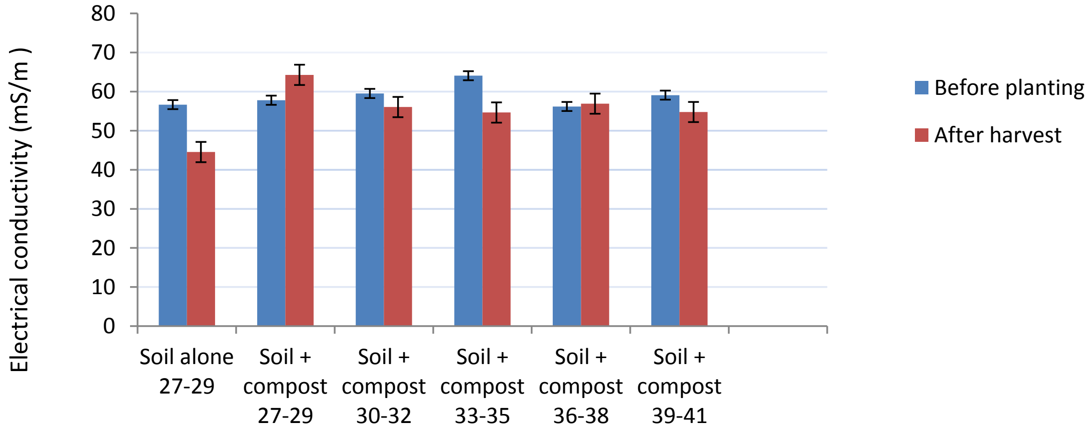

Figure 3. Variation in electrical conductivity of the soil used before planting and after harvest (indicating error bars with standard error).

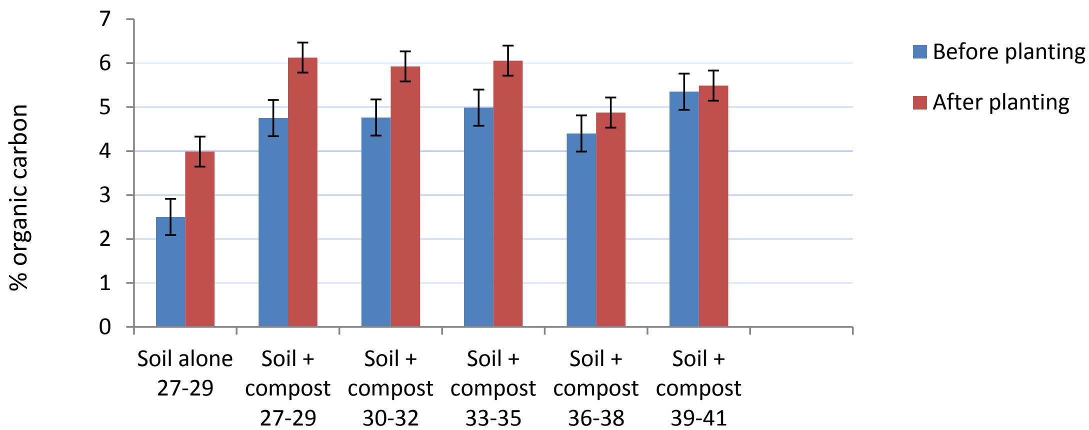

Figure 4. Variation in soil organic carbon (indicating error bars with standard error).

susceptible to leaching,since soil with high CEC soil has been reported to be less susceptible to leaching of cations, (CUCE, 2007). Increasing temperature from 30 to 41°C resulted to decrease in CEC ranged from 7.71 to 26.75%, suggesting that soil under this experimental condition may be deficient in potassium (K^+), magnesium (Mg^{2+}) and other cations as reported in CUCE (2007). Cation exchange capacity is a very important soil property influencing soil structure stability, nutrient availability, soil pH and the soil's reaction to fertilizers and other ameliorants (Hazelton and Murphy, 2007), increase temperature would not favour this soil important factor under global warming condition as revealed in this experiment. Organic matter addition cushioned the effects of increased temperature on this soil factor (CEC). In addition, the result indicated that amending the soil with compost increase soil electrical conductivity as illustrated in Figure 3. However, temperature effects from 32-41°C reduced this effect by 2%. There was a significant variation in the soil electrical conductivities ($P \leq 0.05$), showing nutrient release with increasing temperatures. This was consistent with Sakaguchi et al. (2007) report that electrical conductivities of sand decreased with increased temperature. Increased temperature adversely affects soil electrical conductivity and it could be inferred from the experiment that the use of organic fertilizer could ameliorate such impacts.

The organic carbon (OC) contents of the soil with organic compost treatments were higher than the unfertilized pots as shown in Figure 4. Organic Carbon availability in the soil decreased with increasing temperatures. This agrees with Ying et al. (2008) that increasing temperature has somewhat decreasing effects on soil organic carbon and that climate warming could

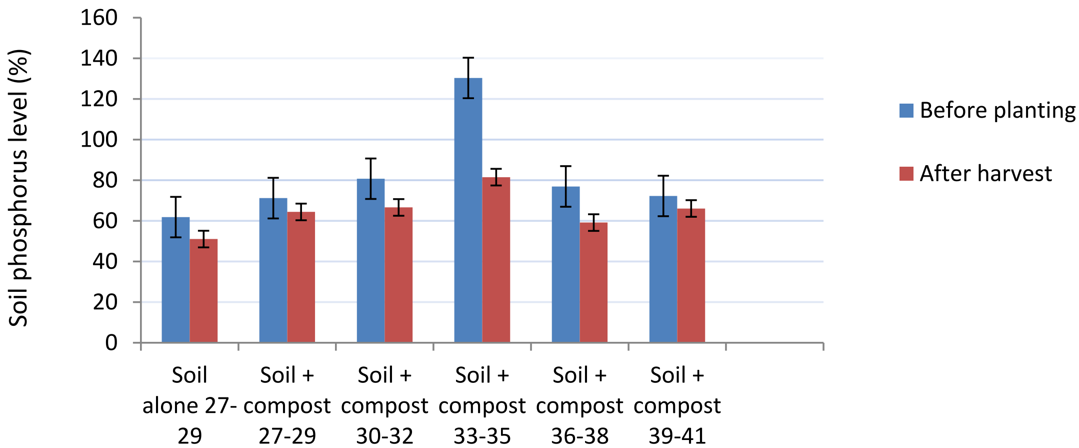

Figure 5. Variation in total phosphorus of the soil used before planting and after harvest (indicating error bars with standard error).

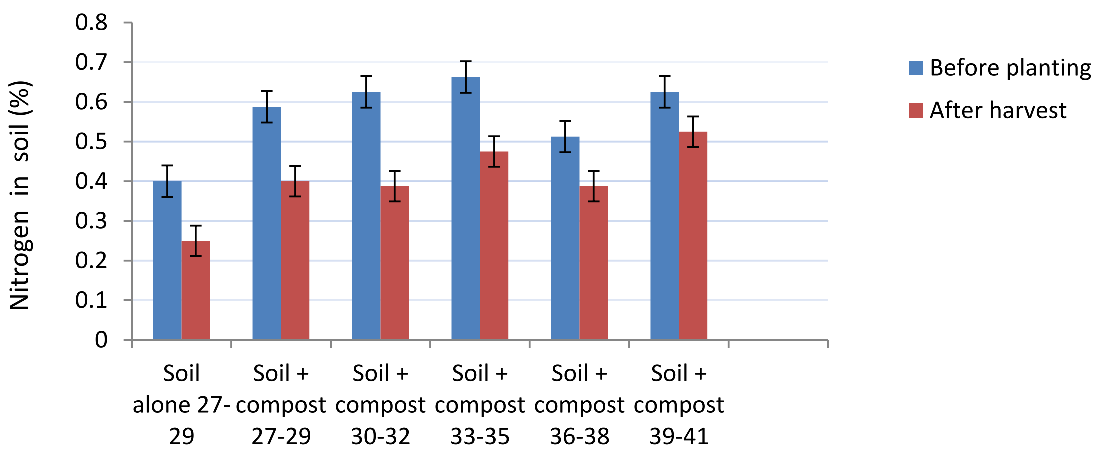

Figure 6. Variation in total nitrogen of the soil used before planting and after harvest (indicating error bars with standard error).

promote soil organic carbon degradation, thus, resulting in loss of soil organic matter which may eventually result to crop failure, loss of vegetation and increasing desertification menace. According to Brevik (2013b), organic matter is important for many soil properties, including structure formation and maintenance, water holding capacity, cation exchange capacity, and for the supply of nutrients to the soil ecosystem. Besides, soils with an adequate amount of organic matter tend to be more productive than soils that are depleted in organic matter, a decline in organic matter due to warming demand higher application of compost to cushion this effect as revealed under this experimental condition.

Result on soil total phosphorus content ranged from 0.0016 to 0.013% before planting, and 0.00051 to 0.00067% after harvest. Increasing temperature from 33^0C to 38^0C enhanced phosphorus loss by 16% to 20% but above 38^0C, soil phosphorus loss was suppressed by 1%. This result probably showed that phosphorus may become more available in soil at elevated temperature as demonstrated under this experiment condition as shown in Figure 5.

Nitrogen generally declined as a result of nutrients loss as seen in Figure 6. The nitrogen content of the experimented soil increased with organic composting in all the treatments than the unfertilized pot. Increase temperature stimulates nitrogen availability as the concentration remained high even at elevated temperature of 38 - 41°C, at the end of the experiment. This is in line with Hungate et al. (2003) who reported that increased temperatures stimulate N availability in the soil. Result showed that C/N ratio generally increased by

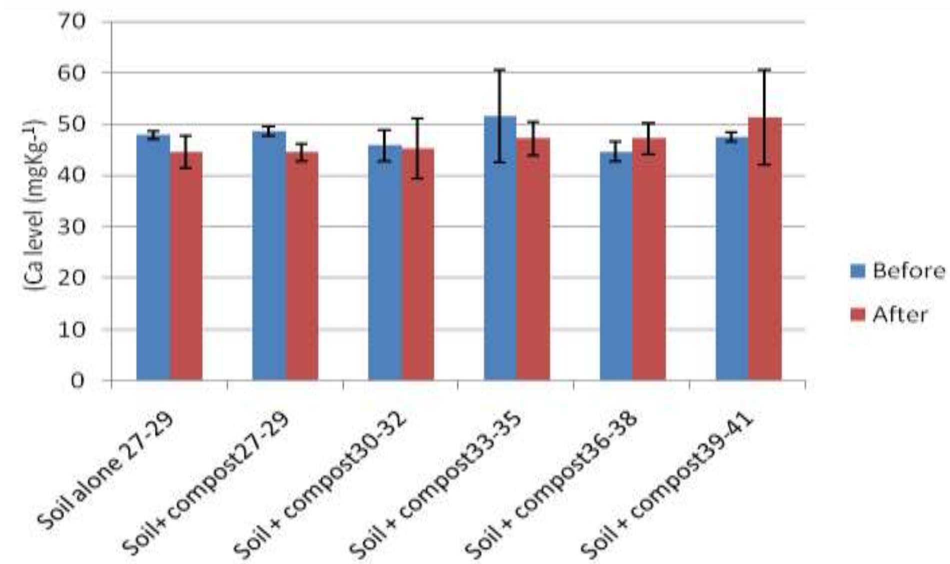

Figure 7. Variation in calcium ions in the soil used before planting and after harvest (indicating error bars with standard error).

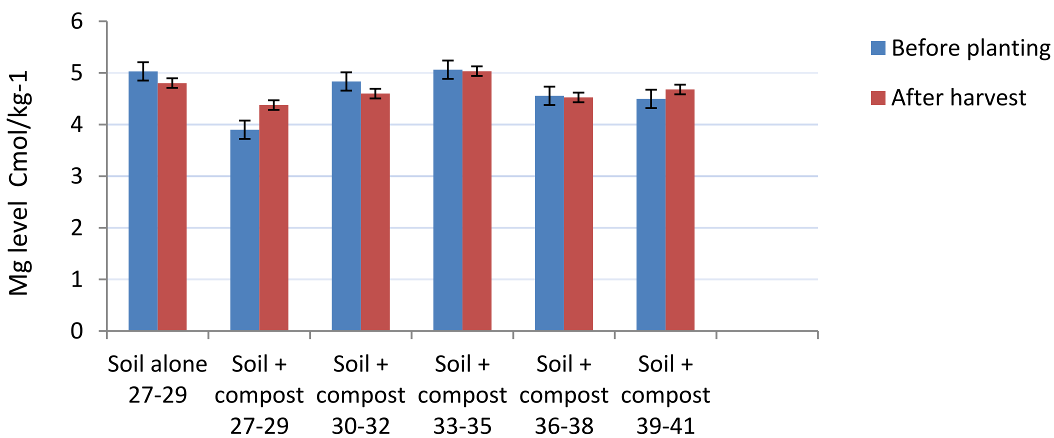

Figure 8. Variation in magnesium ions in the soil used before planting and after harvest (indicating error bars with standard error).

(3.8 to 5%) and (0.7 to 2.1%) relative to unfertilized pot (27 to 29°C) indicating that compost amendment raised carbon nitrogen status.

The carbon nitrogen ratio commonly referred to as C:N ratio declined with increasing temperature. The least values (9.29 and 10.45) were noted at temperature range of 36 - 41°C while higher values (12.15 - 15.95) were observed between 27- 35°C showing that increasing temperature adversely affected C:N ratio in the soil and thus crop performances could be adversely impacted.

Exchangeable bases of the soils (Ca, Mg, Na and K) decreased with respect to initial value probably as a result of nutrient release as shown in Figure 7 to 10 respectively. There was a significant variation in the Na and K in the soil before and after harvest ($P \leq 0.05$). Potassium concentration increased from 9 to 28.48% with increasing temperatures indicating that it desorption and solubility increased with increased temperatures. Initial observation of crops grown on soils containing high potassium has been reported to continually show poor crop yield, general chlorosis and failure to respond to fertilizer additions (Sparks and Jardine 1981), thus increase temperature with consequential increase in potassium concentration may adversely affect crop yield.

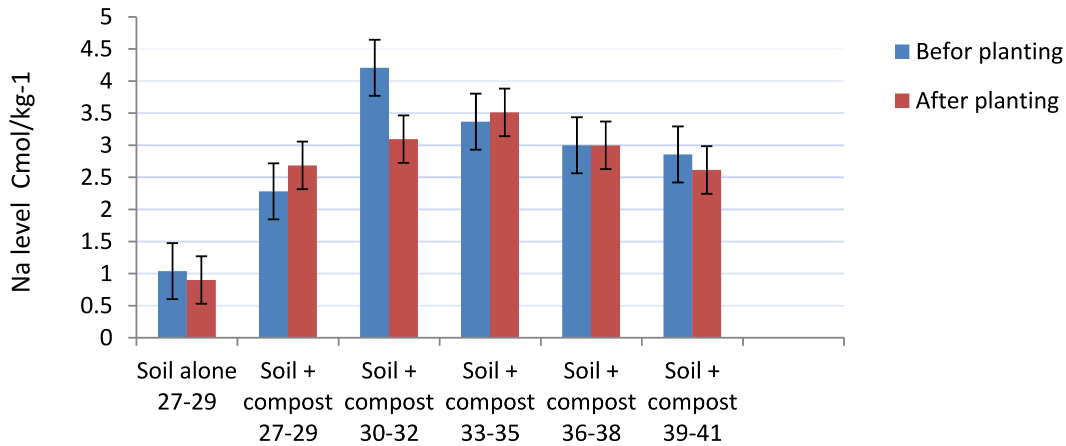

Figure 9. Variation in sodium concentrations in the soil used before planting and after harvest (indicating error bars with standard error).

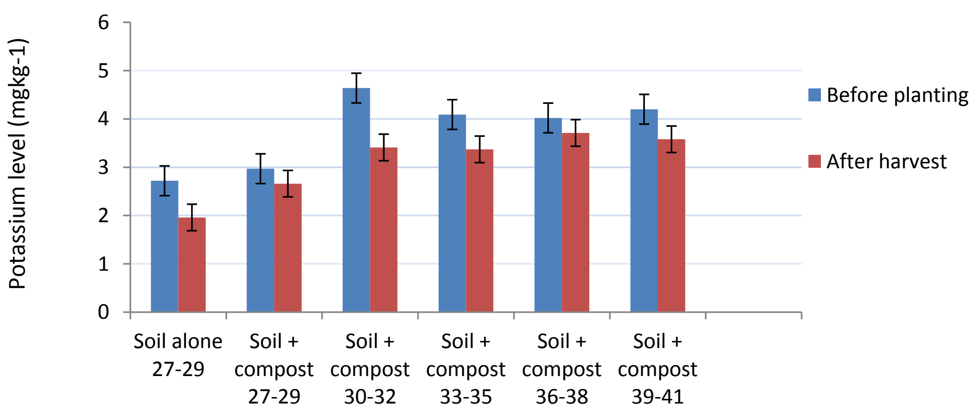

Figure 10. Variation in potassium concentrations in the soil used before planting and after harvest (indicating error bars with standard error).

In addition, high levels of one nutrient may influence uptake of another (antagonistic relationship). For example, K uptake by plants is limited by high levels of Ca in some soils. High levels of K can in turn, limit uptake of other essential mineral nutrients with increase temperature. This result agrees with the report of Sparks and Jardine (1981) that as soil temperature increased from 0 to 40°C, the amount of K adsorbed by soil decrease.

It was also noted that without the addition of compost, a decrease of 6.88% was recorded for calcium concentration in the experimented soil while on the addition of composts, soil calcium decreased by 8.65%. The effect of applied compost was therefore 1.77% decrease in soil calcium.

Calcium concentrations increased with increase temperature at the range of 1.12 to 8.4%. Applied compost cushioned temperature effect on soil calcium loss by 0.23 to 7.53%. In the absence of compost, soil magnesium decreased by 4.52%. The addition of compost resulted to 10.97% increase in Mg availability.

Increasing temperatures from 30 to 38°C led to decline in magnesium content of soil by 0.69 to 4.86%. A further increase in temperature from 39 - 41°C increased soil magnesium by 3.89% as depicted in Figure 10 showing that magnesium ion content becomes more available in soil at higher temperature. It could be inferred too that applied compost cushioned temperature effect on soil magnesium loss. Sodium concentration in the un-composted soil decreased by 13.23% at the end of the experiment but increased by 14.99% in soil treated with compost. It is then concluded that the effect of applied compost was 14.99% increase in soil sodium concentration. Applied compost increased the concentration and bioavailability of this ion. With increase in temperatures 30 to 35^{0}C, a further increase in soil sodium was obtained from 26.44 to 41.28%. However, raising the temperature from 36 to 41°C resulted into 0.83 and 4.49% decline in soil sodium. This result showed that sodium ion bio-availability could be induced under control temperature above which temperature may negatively affect it concentrations. Figure 9 gave the illustration of sodium ion variation of the experimental soils. Applied compost cushioned temperature effect on soil sodium loss.

According to Brevik, (2013b) healthy soils are important because they supply nutrients to the crops grown in those soils. Unhealthy soils, on the other hand, tend to have a lower overall nutrient status (Sanchez et al., 2005). Degraded agricultural soils will not only reduce the amount of food available for growing population but will also make the resulting crops less nutrient-rich which makes those who rely on the low nutrient soils for crop production more susceptible to disease (Brevik, 2013b). The need to incorporate greater agronomic practices to solving climate change related soil challenges cannot be over emphasized. The cushioning effect of compost on soil sustainability factors such as evaluated in this study calls for proactive use of compost materials to ameliorate the negative effects of climate change on soil factors to enhance food security.

Conclusion

The result of the experiment revealed that soil sustainability factors could be heavily impacted with increase in average global temperature. The research also indicated that addition of compost could serve as a mitigating measure against the negative impact of increasing temperatures on soil properties.

It must be noted that climate change has already caused and will continue to cause changes in global temperature and precipitation patterns as well as changes in soil sustainability factors and properties, the need for proactive measure against this cannot be over emphasized, for the purpose of enhancing food production and safe guarding food security.

Recommendations

The need for good management practices is essential in farming to ameliorating the negative effect of climate change on soil sustainability factors or properties.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Adekunle IM (2009). Temperature Effect on Water Extractability of Cadmium, Copper, Pb and Zinc from Composted Organic Solid Wastes of South-West Nigeria. International Journal of Environmental Research and Public Health 6(9):2397-2407.

Akamigbo FOR, Nnaji GU (2011). Climate Change and Nigerian Soils: Vulnerability, Impact and Adaptation. Agro-Science Journal of Tropical Agriculture, Food, Environment and Extension 10(1): 80-90.

Anderson JM, Ingram JS (1993). Tropical soil biology and fertility. A handbook of methods. Information Press Eynsham.

Bremner JM (1982). Inorganic Nitrogen, in Page AL, Miller RH, Keeney DR (edition).

Brevik EC (2013a). The potential of climate change as soil properties and processes and corresponding influence on food security. Agriculture 3:398-417.

Brevik EC (2013b). Soils and Human Health-An Overview. In Soils and Human Health; Brevik EC, Burgess LC, Eds.; CRC Press: Boca Raton, FL, USA pp. 29-56.

Brownmang O, Brown M (2018). Effects of soil temperature on some soil properties and plant growth. Advances in Plants Agriculture Research 8(1):37-41.

Buchas GD (2001). Soil temperature regime. In: Smith KA, Mullins ED (Eds.), soil and environmental analysis: physical methods. Marcel Dekker: NY, USA pp. 539-594.

Cornell University Cooperative Extension (CUCE) (2007). Cation Exchange Capacity (CEC). Agronomy Fact Series 22. Department of Crop and Soil Sciences, College of Agriculture and Life Sciences, Cornell University.

Davidson EA, Janssens IA (2006). Temperature sensitivity of soil carbon decomposition and feedbacks to climate change Nature 440(7081):0165.

Hazelton PA, Murphy BW (2007). Interpreting soil test results: what do all the numbers mean? CSIRO Publishing: Melbourne P 152.

Hungate BA, Dukes JS, Shaw MR, Luo Y, Field CB (2003). Nitrogen and climate change. Science 302:1512-1513.

Iloeje NP (2001). A new geography of Nigeria. New Revised Edition. Longman Nigeria PLC. P 200.

Intergovernmental Panel on Climate Change (IPCC) (2014). Climate Change 2014: Synthesis report. Contribution of working Groups I, II and III to the Fifth Assessment Report of t of the Intergovernmental Panel on Climate (Core writing team, Pachauri, R. K. and Meyer, L. A. (eds). IPCC, Geneva, Switzerland.

Intergovernmental Panel on Climate Change (IPCC) (2007). “Summary for Policymakers.” In Climate Change 2007: Impacts, Adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry ML, Canziani OF, Palutikot JP, van der Linden PJ, Hanson CE, eds. Cambridge, UK: Cambridge University Press.

Jarvis A, Ramirez J, Anderson B, Leibing C, Aggarwal P (2010). Scenarios of climate change within the Context of Agriculture. In Climate Change and Crop Production; Reynolds MP, Ed.; CPI Antony Rowe: Chippenham, UK pp. 9-37.

Karmakar R, Das I, Dutta D, Rakshit A (2016). Potential Effects of Climate Change on Soil Properties: A Review: Science International (4):51-71.

Link SO, Smith JL, Halverson JJ, Bolton H (2003). A reciprocal transplant experiment within a climatic gradient in a semiarid shrub-steppe ecosystem: Effects on bunchgrass growth and reproduction, soil carbon, and soil nitrogen. Global Change Biology 9:1097-1105.

MaClean EO (1982). Soil pH and lime requirement in Black CA (Ed): Methods in soil analysis chemical and microbiological properties part II- American Society of Agronomy, Maidison, Wiscousin USA pp. 927-932.

Mensies N, Gillman G (2003). Plant growth limitation and nutrient loss following piled burning in slash and burn agriculture. Nutritional Cycling in Agroecosystems 65(1):23-33.

Nederlof MM, Van Riemsdijk WH, De Haan FAM (1993). Effect of pH on the Bioavailability of Metals in Soils. In: Eijsackers HJP, Hamers T (eds) Integrated Soil and Sediment Research: A Basis for Proper Protection. Soil and Environment, vol 1. Dordrecht: Springer.

Nelson DW, Sommer LE (1982). Total Carbon, organic carbon and organic matter, in page et al ed, method of soil Analysis, part 2, 2nd (Ed) Agronomy Monograph No 9, ASA and SSSA, Madison, WI pp. 539-579.

Okalebo JR, Gathua KW, Woomer PL (2002). Laboratory methods of soil and plant analysis. A working manual, 2nd edition. Sacred Africa, Nairobi, Kenya pp. 22-77.

Oslem SR, Sommers LE (1982). Phosphorus P. 403-434. In page et al (eds), method of soil analysis, part 2, 2nd 291 ed Agronomy Monograph No 9, ASA and SSSA, Madison, WI.

Pimentel D (2006). Soil erosion: A food and environmental threat. Environment Development and Sustainability 8:119-137.

Rousk J, Brooke PC, Bååth E (2009). Contrasting Soil pH Effects on Fungal and Bacterial Growth Suggest Functional Redundancy in Carbon Mineralization. Applied Environmental Microbiology 75(6):1589-1596.

Sakaguchi I, Momose T, Kasubuchi T (2007). Decrease in thermal conductivity with increasing temperature in nearly dry sandy soil. European Journal of Soil Science 58(1):92-97.

Sanchez PA, Swaminathan MS (2005). Hunger in Africa: The link between unhealthy people and unhealthy soils. Lancet 365:442-444.

Sparks DL, Jardine PM (1981). Thermodynamics of potassium exchange in soil using a kinetics approach. Soil Science Society of American Journal 45:1094-1099.

Thomas GW (1982). Exchangeable Cation. In, AL et al (eds) methods of soil analysis. Part 2, Agronomy monograph, a second edition, pp. 159-165. ASA and SSSA, Madison, Wisconsin.

Terefe T, Mariscal SI, Peregrima F, Espejo R (2008). Influence of heating on various properties of sic Mediterranean soils. A laboratory study. Geoderma 143(3-4):273-280.

Wan Y, Lin E, Xiong W, Li Y, Guo L (2011). Modeling the impact of climate change on soil organic carbon stock in upland soils in the 21st century in China. Agriculture Ecosystems and Environment 141:23-31.

Ying Y, Sheng T, Xue B (2009). Coupling effects of temperature, moisture, and nitrogen application on greenhouse soil pH and EC. The Journal of Applied Ecology 20(5):1112-1117.

Zhang XC, Nearing MA, Garbrecht JD, Steiner JL (2004). Downscaling monthly forecasts to simulate impacts of climate change on soil erosion and wheat production. Soil Science Society of America Journal 68:1376-1385.

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Mapping soil terrain resources and descriptions of agro-ecological zone in Dawuro and Gamo Gofa zones in south-western Ethiopia

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This study aims to identify and delineate land resources including soil, water and terrain resources, and major river basins, with demographic data and agro-ecological zone classification of general climatic conditions and vegetation characteristics of Gamo Gofa and Dawuro zones in South-western Ethiopia. Metadata source and visual assessment were used for this purpose. Agroecology zone classification is based on elevation, reference length of growing period, temperature, soil type, major river basins at district level alongside their relationship and specificity in land use system. Agroecology approach is particularly useful for agrarian systems, because it provides information about their physical functioning and their spatial/temporal differences. It shows the differences that exist clearly in the structure and physical/biological functioning in agriculture- either natural resources and consumer market link or a new transition toward a more sustainable agrarian development. This work is designed to ascertain the state of natural resources to aid coherent decision making regarding resource use efficiency in rural development process.

Key words: Agroecology class, Dawuro, Gamo Gofa, river basin, spatial soil distribution.

INTRODUCTION

Landscapes that have many different uses and in a way that meet the multiple objectives supporting livelihoods, food production, and ecosystem conservation of land users have received a wider attention. Managing food, water and energy at the landscape level is key to achieving sustainable farming systems, and that has received increasing recognition over the last 10 years (Braslow et al., 2016). Changes in land, water, and other natural resources will either impact users' access to resources or require individuals or communities to adopt certain natural resource management, both of which are likely to affect users' livelihoods. For example, mountain small-scale farms are usually not the centres of national production in terms of quantity, yet small-scale farms in mountains help shape mountain landscapes, providing ecosystem services (such as provision of freshwater, disaster risk reduction, preservation of biodiversity including agro- biodiversity, and space for recreation and tourism) that

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are vital for development far beyond mountain areas (Wymann von Dach et al., 2013).

According to the United Nations Sustainable Development Solutions Network (UNSDSN, 2013), soil erosion, drought, salinization, waterlogging, desertification and other forms of land degradation have spread widely in the past 30 years, particularly threatening ecosystems and agriculture in smallholder environments. Recent land degradation associated with economic losses was estimated at 5% of total agricultural gross domestic product (UNCCD, 2013).

In the coming decades as the report indicates, less water may be available, and more droughts are expected to occur (Dai, 2013). Over 40% of the world's population may be living in river basins experiencing severe water stress by 2050 (OECD, 2012). The world food production coming from irrigated systems is 40%; only about 20% comes from the arable land area. A much higher level of food security and sovereignty without more irrigated agriculture can be unlikely achieved in Sub-Saharan Africa (UNSDSN, 2013). More investments in improving water productivity in existing schemes and safely expanding irrigated agriculture will be needed for long-term food security that should ensure maximum efficiency and protect critical freshwater resources with a strong emphasis on policies and new technologies (Rosegrant et al., 2009). The use of surface water and groundwater resources by different sectors will be a balance of integrated solution (Gleick, 2003).

Without clear metrics and well-designed research using institutional approach to make the metrics operational, efforts to evaluate the cross-sectoral performance, systems that take full advantage of new technologies, and reaching the targets for sustainable development will remain an amorphous goal.

Reversing land degradation in most cases will require investments by either outside investors or by communities and individuals. Following recently agreed voluntary guidelines for responsible governance of tenure of land, fisheries and forests (FAO, 2012), countries should craft their own policies to ensure equitable, inclusive access by the rural poor to these critical resources. The acting together now for pro-poor strategies against soil and land degradation (AGORA) seeks to facilitate a process by which farmers are empowered to work together with other stakeholders to design and implement equitable solutions to land degradation and associated development problems, for instance, in many Africa countries.

Mapping characteristic feature of spatial information will identify areas that could be targeted for natural resource management and land restoration. Any proposed changes through these management practices can have positive impacts on their livelihood and could be equitable to all potential users. The maps that result from this process can also validate previous or future suitability analysis or assumptions about land use and land cover change trajectories. The maps can also be used to target detailed biophysical data collection on current stocks of ecosystem services, which will provide an indication of whether current levels of use are sustainable that could provide the benefits on improved natural resource management. An inventory of available resources, often summarized in database formats and expert systems are the two complementary components for a system-based research strategy. With its greater emphasis on the capability of land resources to support specific types of agricultural development, the agro-ecology approach can improve the efficiency of research and the potential impact of technologies generated by research (FAO, 1994).

This approach initiated the idea to identify topography, soil type, watershed, river and to classify agro-ecological zones on general climatic condition and vegetation characteristic using metadata source together with visual assessment to map Gamo Gofa and Dawuro zones in south-western Ethiopia.

MATERIALS AND METHODS

Description of the study area and data

The areas addressed in this study are Gamo Gofa and Dawuro administration zones in South Nations, Nationalities Peoples' (SNNP) regional state in south-western Ethiopia. Gamo Gofa and Dawuro administration zones are those of the fourteen zones in SNNP region in Ethiopia suited in the south-western part of the country. It lies between 5° 34′ 16.31″ N to 7° 20′ 57.61″ N of latitude and 36° 22′ 13.04″ E to 37° 51′ 25.91″ E of longitude. The total area of the zones is about 16,530.49 km^2. The zones' location with boundary are presented in Figure 1A and B. The zones in SNNP region capture a multitude of AEZ and various diverse form of heterogeneous farming system demonstrated in the entire regions of the country. The traditional management and conservation roles of indigenous knowledge associated with biodiversity expanded biomass base are used for different purposes such as human and animal disease treatment (Andarge et al., 2015).

Taken together with obvious attractions of lakes, hydroelectric dams, and national parks would ensure long-term prospects for tourism. The scene is superb around Gibe III hydroelectric Dam over River Omo, lakes Abaya, Chamo and other small lakes, parks of Neschsar, Maze and Chabara-Churchura which rise toward the hills to over 3560 m behind villages and towns. As Makin et al. (1975) indicated the 1972 World Bank report on aviation and tourism selecting Arba Minch as a center maintains rift valley merits special tourist development.

Data

The dataset includes digital elevation model (DEM), shape, contour line and point data features of Dawuro and Gamo Gofa zones on 10 m x 10 m resolutions projected with global coordinate (GC) system derived from global mapper 8 (USGS) in area extent of 812,529 m north, 616,449 m south, 209, 664 m west and 373, 424 m east. The soil data were obtained from harmonized world soil database (HWSD) version1.2 (FAO/ IIASA/ ISRIC/ ISS-CAS/JRC, 2012). Actual decadal rainfall and Normalized Difference Vegetation Index (NDVI)are processed data for livelihood early assessment and protection (LEAP ver. 2.7) in Ethiopia (WFP/FAO, 2012; Hoefsloot and Calmanti, 2012); reference length of growing period (RLGP)

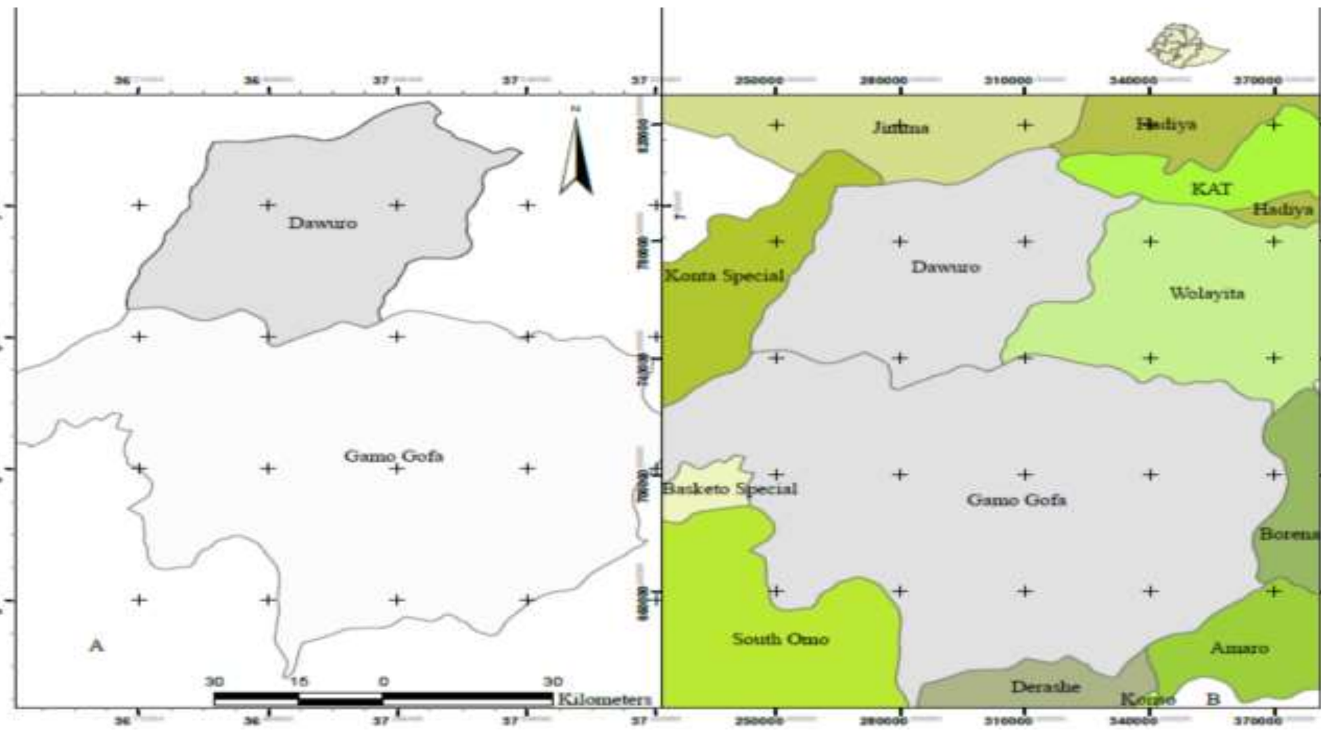

Figure 1. Location map of (A) administration zones, and (B) boundary in the direction in Gamo Gofa and Dawuro zones.

and average annual temperature data from FAO Global Agro-ecology database were obtained. Moreover, field condition observation was purposively made for 2014 to 2017 in different parts of the zones (Amejo et al., 2017; Amejo et al., 2018; Amejo et al., 2018a).

Terrain model data

The DEM of the zones was built in Arc GIS 10.2 to generate terrain dataset in different file formats. The DEM by 10 m x 10 m resolution was derived from global mapper 8. The terrain data include slope, slope direction (aspects), flow direction; and slope of flow directions was derived in the study zones by defining parameters in Arc GIS 10.2. The flow direction was used to derive watershed dataset in the zones, and water resources potential in the zones were assessed zones. The slope (%) of the topography and its area coverage were described from the output dataset in the zone. The slope direction (aspect) and hillside areas were highlighted in the zones.

Soil data

According to FAO report, HWSD is composed of a GIS raster image file linked to an attribute database and can be extracted to excel format. It is a digitized and online accessible soil information system, which aims to allow policy makers, planners and experts to overcome some of the shortfalls of data available to address the old challenges of food production and food security and plan for new challenges of climate change and accelerate natural resources degradation. Thus, the soil dataset from HWSD software was assembled to Arc GIS 10.2 with its projection in GC. The data were re-projected and extracted to point values in area extents of the zones and processed on spatial interpolation in 10 m x 10 m resolutions. The major soils were identified from the analysis, and corresponding soil properties were extracted to excel from HWSD version 1.2 before processing the original dataset and after reprocessing in Arc GIS 10.2 for the purpose of comparison. The spatial distributions of major soil (soil unit) interpolated in inverse distance weight (IDW), were mapped for the zones. The top and subsoils properties of major soils were described.

Rainfall and NDVI data

The long-term, decadal values of actual rainfall and NDVI (RF1, RF2, and ARC2), based on the range of availability were used to describe the trends and patterns of environmental responses in the zones (Amejo et al., 2018a). The actual rainfall available from 1983-1994 ARC2, 1995-2000 RF1 and 2000-2014 RF2 was used. The actual NDVI value available from 2008-2015 in FAO MODIS was used. The data value from LEAP software version 2.7 (WFP/FAO, 2012; Hoefsloot and Calmanti, 2012) was extracted to excel, and averaged to monthly scale at each district level to describe trends of vegetation growth and intra-seasonal environment response in the zones. Intra-seasonal variability on vegetation growing season was described using independent samples Kruskal Wallis test on long-term seasonal average rainfall and NDVI value in the twenty districts of the study zones.

Reference length of growing period (RLGP)

The RLGP from 1961-1990 online available on FAO global agro-ecological database (Tóth et al., 2012) was projected in the project coordination of the country; it was extracted to point values in zonal statistics in GIS 10.2 in area extents of the administrative zones. The values were used for AEZ classification and delineation in the zones.

Figure 2. Terrain map of districts in Dawuro and Gamo Gofa Zones.

Socio-demographic characteristic and water resource

Data record of population census report of 2007 (CSA, 2007) in each district *i* of the zones was used to estimate population density per km^2 as follows.

$$Population\ density = \frac{Total\ population\ in\ district\ i}{\text{Shape area of district } i} * 1{,}000{,}000$$

The river dataset with its attribute obtained from zonal agriculture and rural development office was also mapped in different forms.

Agro-ecological zone (AEZ) classification

The watershed dataset derived in terrain model from flow direction was used as a base for AEZ classification. Using elevation, river basin, resemblance to natural break and boundary share between the districts, soil type, RLGP and temperature together with visual aiding processing in Arc GIS 10.2, AEZs were classified in the zones. For the classification of AEZ an earlier classification made by Ministry of Agriculture (MoA, 2000) in Ethiopia was adopted.

RESULTS AND DISCUSSION

Terrain surface feature

An earlier study showed that Ethiopia has extremely varied topography (FAO, 1984). The complex geological history that began long ago and continues to accentuate the unevenness of the surface; a highland complex of mountains and bisected plateaux characterizes the landscape. Similarly, the terrain surface of Dawuro and Gamo Gofa is patchy mountainous fold across the AEZ (Figure 2), which may be the result of recent earth surfaces transgression. Mirab Abaya, Arba Minch, Bonke Kemba, Ubadebretsh and Ayida districts in Gamo Gofa zone are also laid in East Africa rift valley towards Lake Rudolf. In this striking landscape, the zones area covers about 8.08% above 2400 m.a.s.l. which was classified as the highland AEZs; about 10.79% within ranges of 1800-2400 m.a.s.l. was the midland AEZs and about 81.13% below 1800 m.a.s.l. was the lowland AEZs.

In northern Ethiopia, Dove (1890) described major agricultural zones more precisely as: ‘Kolla’ with altitudes below 1800 m.a.s.l., ‘Weyna Dega’ with altitudes between 1800 – 2400 m, and ‘Dega’ with areas above 2400 m. These are based on broad traditional classification; however, other sub-agroecological classifications have been done in Ethiopia. In the highlands includes the Weyna Dega, Dega, High Dega and Wurch zones; coverage of the observed landscape considerably amounts to 26% of these zones (Hurni, 1998). Assuming that the inverted cone-shaped landscape with narrow side ends in the highlands zones could probably be acceptable to the area coverage amount observed in the present analysis.

The altitude in Dawuro and Gamo Gofa zones varies from about 500 m.a.s.l. at lower valley of Omo River basin in Issara, Loma and Melekoza districts to about 3600 m.a.s.l. on highlands in Dita (Figure 3A). Issara, Loma, Gena, Mareka, and Tocha are districts in Dawuro zone presented in Figure 2 with another fifteen districts in Gamo Gofa zone. The boundary of the two zones lies at Omo River at the center to Gibe III dam between Kuch and Loma districts, and at the lower valley of the Omo River between Melekoza and Issara districts.

A varied complex setup of the land surface topography was observed in the zones through vertical gradients of the slope (%) surface measured from DEM (Figure 3B). In

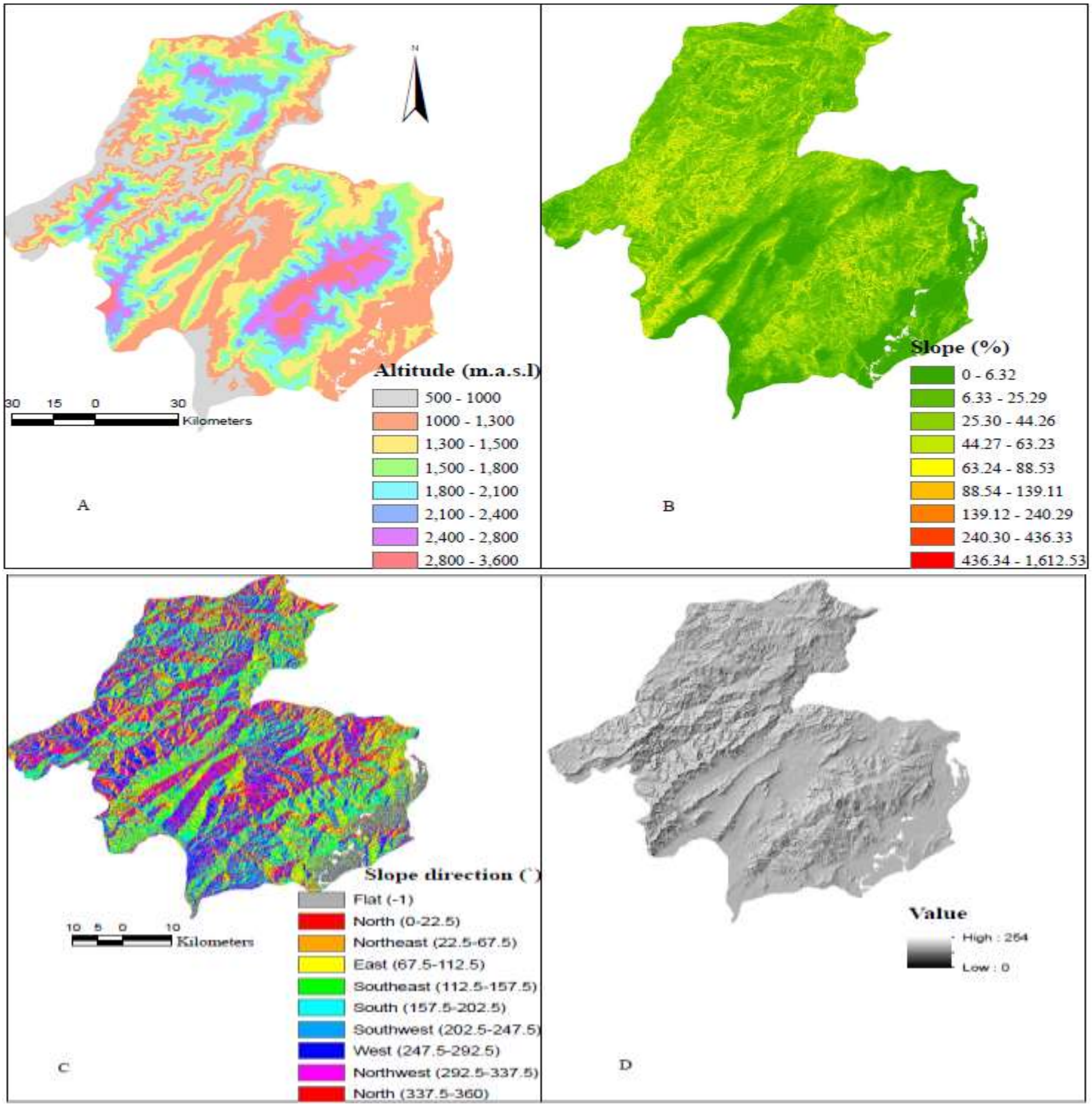

Figure 3. Terrain surface of (A) Elevation (m.a.s.l)l; (B) Slope (%); (C) Slope direction (aspect, ^{0}); and (D) Hillshade (%) in Dawuro and Gamo Gofa zones.

its natural break, the coverage area of the slope surface ranging from 0.0-6.32% is about 17.12% in the zones. This landscape is mainly situated in lowland AEZ of Mirab Abaya, Arba Minch Zuri, Zala and Boreda districts in Gamo Gofa zone. This slope ranges in the central lowlands regions, where Buka, Alee, Tone and Mansa rivers intercept Zea, Gesa, Wogayow, Yidedia, Chawa, Dibina, and the tributaries of Gojeb River from the north to northwest in Dawuro Zone (Figure 9).

Large percentage, about 40.20% area in the zones lies within 6.33-25.29% slope rise, which includes the mound (uplifted) surface scattered across the lowland and the upper highland AEZ. The slope between 25.30-44.26% accounts for about 26.22% area in the zones, marking a uniform break in the gradient upward at an altitude of about 1400 m.a.s.l. The topography lies between 44.27-63.23% slope; its coverage is about 12.14% of the area in the zones. This ranges at an altitude above about 1800 m.a.s.l. by-passing some deflated surfaces in the highland. The remaining 3.94% and 0.38% land surface lie between 63.24-90% and above 90% slope rises, respectively in the zones. The first is a long, vertical

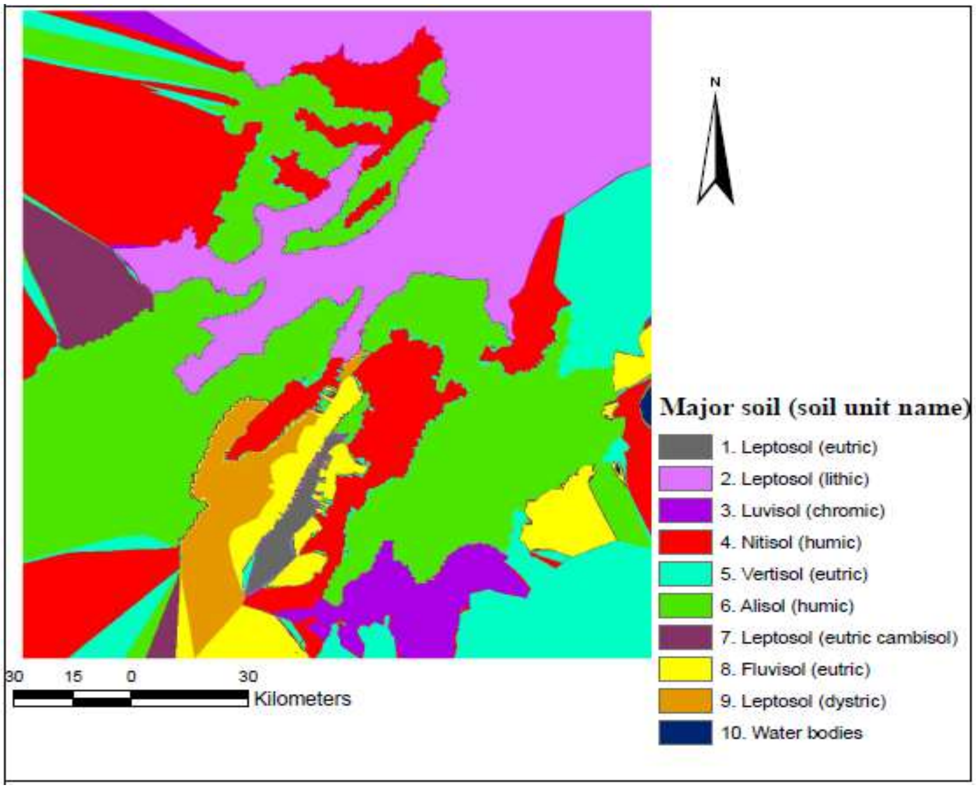

Figure 4. Spatial distribution of major soils (soil unit) from inverse distance weight interpolation on 10 m × 10 m in Arc GIS 10.2 in Gamo Gofa and Dawuro zones.

narrow ridge instituted all over the AEZs whereas the latter is the uplift of the mountainous surface in the highland regions commonly in Dita, Geze Gofa and Tocha districts (Figure 3B).

The degree measures of slope direction (aspect) in the zones are generally inclined towards south-west angle (Figure 3C) having mainly less sun illumination or are darken regions (Figure 3D).

Most of the terrain surface coverage in the zones remarkably reflects typical silvopasture agricultural system despite the varied, complex heterogeneous mixture of the crop-livestock system. The landscape below 25.29% slope could still be important for mixed farming system with its constituent assortment of multi-river channels from upstream, grasslands with diverse browsing species and a wide variety of crop types with favourable performance in wide ranges of soil properties. The existence of an expert agreement and certain characteristics of flexibility in land use system in Ethiopia were addressed by Hurni (1998).

Soil general termed as land is the only basic building blocks of livelihoods of an agrarian society.

Soil mapping

Soil general termed as land is the only basic building blocks of livelihoods of an agrarian society. From farm plot family produces crops and raises livestock; the community gathers food, feed and fiber from forests; water bodies are used for irrigation and catch fish; fibers are used to make clothes and create tools for artesian and fundamentally useful in family incomes to pay taxes, educate children and for medication in free market economy; all these are derived from soil. On top of that, about 42.68% area coverage of the zones landscape lies above 25.29% slope rise which can significantly affects agricultural production and productivity in a marginalized society. Some old church buildings and prolonged historic trends, and dense settlement pieces evidence that some highland regions have been cultivated for longer periods of time in Ethiopia. A frequent phenomenon of frost was also reported (Hurni, 1998). Within the altitudinal range of 1214-2723 m.a.s.l. in some of the present areas, a severe wet stress was also observed (Amejo et al., 2018a).

Leptosols, alisols, nitisols, vertisols, fluvisols, and luvisols are major soils in zones (Figure 4). The first four soils comprise about 91.11% area coverage of the zones. The leptosols are also include about four soil units and cover about 29.06% of zones area, which about 21.72% the lithic leptosols, 3.38% the eutric combisols, 3.15% the dystric leptosols and 0.81% the eutric leptosols unit in the zones area coverage.

The lithic leptosols soil largely occupies the stony bushland to the savannah grassland; it is dominant in lowland regions along riversides mainly where maize, sorghum, teff, groundnut, bean, zinger, taro and sweet potato grow (Figure 4).

The second most abundant soil in the zones, alisols (humic) covers about 28.60% area in the zones. Alisol soil is generally distributed all over the districts with dominant coverage in highland AEZ like Chencha, Dita, Daramalo, Melekoza, Geze Gofa in Gamo Gofa zone and one uppermost escarpment in all districts in Dawuro zone (Figure 4 and Figure 5). Nitisols (humic) soil in the zones occupies 21.23% area of soil distribution mainly in forest belt in Issara, Tocha and Ayida and savannah grasslands of Kucha, Zala, Denibu Gofa, Ubadbretshey and along the plain area in Boreda district.

Eutric vertisols covers 12.22% area of the zones, significantly the lower plains of Arba Minch Zuri, Mirab Abaya, Boreda and Kucha districts in flood running bays to Omo River direct towards the dam point at Gibe III. The eutric fluvilsols covers about 4.74% of the area, basically distributed in Mirab Abaya, Arba Minch Zuri, Boreda and at the center to the south in Zala, Denibu Gofa, Ubadbretshey and Kemba districts.

The chromic luvisols soils which are mainly distributed in Arba Minch, Bonke, Kemba and Tocha districts cover about 4.05% of the zones' area. The soils unit of eutric cambisols (leptosols) are mainly found at lower valley of Omo River basin at about 500 to 600 m.a.s.l. altitude in Melekoza and Issara districts and 600 to 1000 m.a.s.l. in Ubadeberetshey, Ayida, Geze Gofa and Denibu Gofa districts. The eutric leptosols unit occupies the floodplain areas in Zala, Kemba, and Ubadbretshey districts.

The diversity of the major soils is relatively high in plain areas of lowland AEZ. The diversity mainly mechanical results in soils and soils layers due to drainage, erosion and flooding events on upper high slope surface and high weather processes in some rift valley regions in Arba Minch Zuri, Mirab Abaya and Bonke districts. Apart from the limited information on soil, a field experiment by Mengestu (2009) demonstrated about four types of soils in 182 km^2 area of hare watershed between Chencha, Boreda, Mirab Abaya and Arba Minch Zuri districts in Gamo Gofa zones. These soils were cambisol, ferrasol, fluvisol, and regosol.

The topsoil (0-30 cm depth) properties of major soils in the zones are described in Table 1. The topsoil textural classes of major soils in its spatial distribution are mainly dominated by clay loam, light clay, loam, and sand clay loam based on USDA classification.

The topsoils organic matter content, in general, better describe the soils in the zones and particularly high for the humic alisol and humic nitisol soils unit which are the highest distribution in highland to midland AEZ in the zones (Table 1). Soil management and manure utilization condition can enrich this situation in the zones. The topsoil in the zones has traces of mainly acidic to neutral properties which are often described as the best pH for nutrient availability and suitable situations for most crops type in the essence of agronomic management, except the lithic leptosols which are low in pH.

The pedogenetic characteristics of topsoil which relates with clay fraction are mainly kaolinite to illite mixes whereas lithic leptosols are dominated by kaolinite. The total nutrient fixing capacity of topsoil of major soils in the zones is mainly above 10 cmol/kg; it indicates they have high resilience and can build up stores of nutrients. The topsoil properties of major soils identified in the zones mainly reflected saturated conditions for base saturation (Table 1).

Subsoil properties of major soils in the zones are presented in Table 2. The dominant textural classes of subsoil properties described on major soils in the zones are clay loam, heavy clay, light clay and loam-based on USDA classification. The top and subsoil properties of major soils described in Dawuro and Gamo Gofa zones are generally low in cation and salt contents. The situation there indicates that soils in the zones need activation and treatment with cation.

Climatic condition and seasonal response in vegetation

The livelihood system of the community is organized based on the environment and depends on the land size holdings, the scale of food and feed products available from the plots and socio-cultural means to sustain life across seasons in the year. Farm operation and labour productivity are further hindered by the acute seasonality of many climates, in which wide differences exist between the wet and dry seasons, or seasons with and without irrigation water (Ruthenberg, 1971) in tropics. Thus, the series of the seasons are remarkably important for production and allocations of livelihood systems.

Gamo Gofa and Dawuro zones experience dry season during winter period with short rainfall and wet season in summer and rainy period. However, often in the society the year is subdivided into four different seasons locally, namely from Sept-Nov as 'adile'; from Dec-Feb as 'boneya'; from Mar-May as 'assura' and from June-Aug as 'balegua' with respect to differences in rain and sunny condition, environment and access to and availability for livelihood options in a period of season.

The seasonal average of long-term rainfall and NDVI in the districts in Dawuro and Gamo Gofa zones is indicated in Table 3. The seasonal overall average rainfall and NDVI in drier winter season during December to February was 11% (98.79 mm) and 21% (0.23), respectively in the districts in Dawuro and Gamo Gofa zones. In wet (monsoon) winter season during March to May seasonal average land surface rainfall was 44% (410.61 mm) and NDVI was 23% (0.25) in the districts of the zones. This marginal amount of rainfall is the highest in peak bimodal rainfall distribution and more than the main rainy seasons of the year.

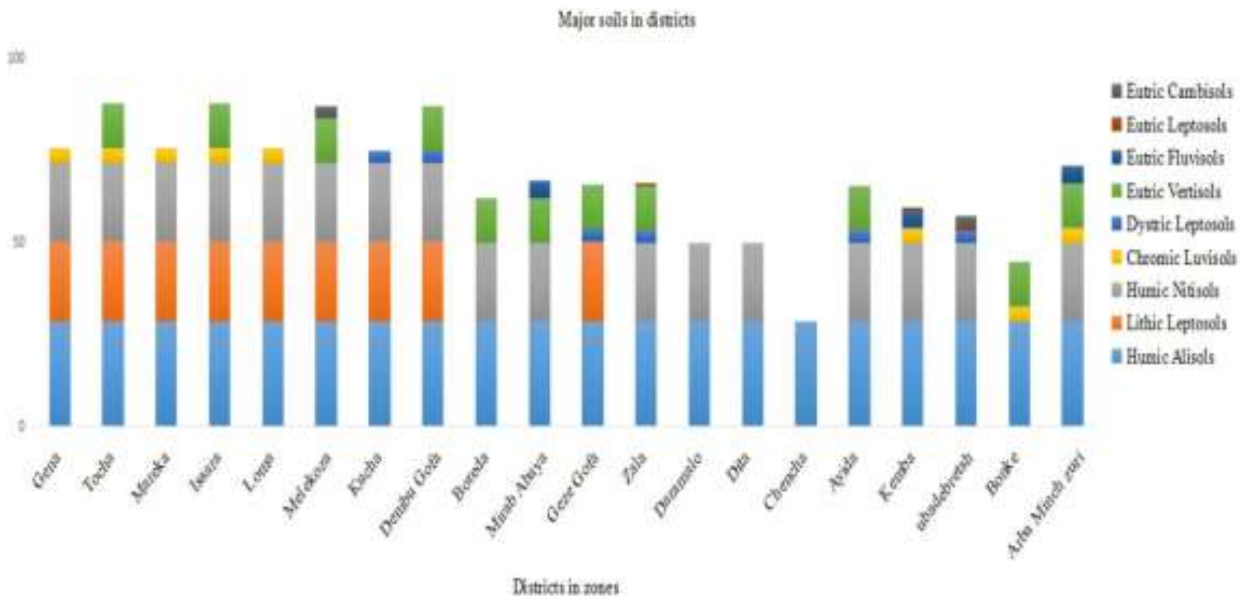

Figure 5. Major soil units extracted to point values from inverse distance weight interpolation on 10 m x 10 m in Arc GIS 10.2 in Gamo Gofa and Dawuro zones.

Table 1. Topsoil (0-30 cm depth) properties of major soils extracted from spatial interpolation on 10 m x 10 m in ArcGIS 10.2 in Dawuro and Gamo Gofa zones.

Property	ALu	NTu	LPq	CMe	LPd	LPe	VRe	FLe	LVx
Texture	M	F	M	M	M	M	F	M	M
Depth (cm)	100	100	10	100	30	30	100	100	100
Drainage (0-0.5 slope %)	MW	MW	IMF	MW	IMF	IMF	P	MW	MW
AWC (mm)[1]	150	150	15	150	50	50	125	150	150
Sand fraction (%)	39	24	43	45	53	50	21	44	51
Silt fraction (%)	29	27	29	31	26	30	25	33	22
Clay fraction (%)	32	49	28	24	21	20	54	23	27
Class	CL	LC	CL	L	SCL	L	LC	L	SCL
Bulk density (kg/dm^3)	1.19	1.18	1.31	1.38	1.45	1.35	1.51	1.33	1.45
Gravel content (%)	1	1	32	1	31	31	1	1	1
Organic carbon (% weight)	2.28	2.45	0.39	0.87	0.75	0.72	1.07	0.73	0.63
pH in water solution	5.5	5.3	7.5	6.6	5.1	6.5	6.9	7	6.4
Clay CEC (cmol/kg)[2]	33	21	51	50	15	49	68	50	31
Soil CEC (cmol/kg)[3]	19	20	16	15	6	12	40	14	10
Base saturation (%)	45	27	100	91	38	87	100	91	85
TEB (cmol/kg)[4]	8.6	5.4	16	13.7	2.3	10.4	40	12.7	8.5
Calcium carbonate (% weight)	0	0	3.1	0.3	0	0.2	0.4	0.8	0
Calcium sulfate (% weight)	0	0	0.1	0.1	0	0.1	0.1	0.1	0
Sodacity (%)	1	1	1	2	2	2	1	2	2
Salinity (dS m^{-1})	0	0	0.4	0.1	0	0.1	0.3	0.1	0

[1]Available water storage capacity (AWC), [2]Cation exchange capacity of the clay fraction (CEC), [3]Cation exchange capacity of the soil (CEC), [4]Total exchangeable bases (TEB); Medium (M), fine (F), Moderately well (MW), imperfectly (IMF), poor (P), clay loam (CL), light clay (LC), loam (L), sandy clay loam (SCL), Humic Alisols (ALu), Humic Nitisols (NTu), Lithic Leptosols (LPq), Eutric Combisols (CMe), Dystric Leptosols (LPd), Eutric Leptosols (LPe), Eutric Vertisols (VRe), Eutric Fluvisols (FLe), Chromic Luvisols (LVx).

The highest annual average (30%) in vegetation growth was achieved during September to November in the districts in zones (Table 3). The period was also the second peak for bi-modal rainfall with 24% of the annual

Table 2. Subsoils (30-100 cm depth) properties of major soils extracted from spatial interpolation on 10 m x 10 m in ArcGIS 10.2 in Dawuro and Gamo Gofa zones.

Property	Humic Alisols	Humic Nitisols	Eutric Vertisols	Eutric Fluvisols	Chromic Luvisols
Class	Clay loam	Clay (heavy)	Clay (light)	Loam	Clay loam
Sand fraction (%)	36	18	20	46	45
Silt fraction (%)	30	21	24	31	21
Clay fraction (%)	34	61	56	23	34
Bulk density (kg/dm^3)	1.35	1.25	1.58	1.4	1.5
Gravel content (%)	1	1	1	1	1
Organic carbon (% weight)	0.82	0.96	0.56	0.32	0.35
pH in water solution	5.6	5.4	7.5	7.3	6.5
Clay CEC (cmol/kg)[1]	37	16	70	49	31
Soil CEC (cmol/kg)[2]	16	20	41	13	12
Base saturation (%)	31	29	100	94	84
Total exchangeable base (cmol/kg)	5	5.8	41	12.2	10.1
Calcium carbonate (% weight)	0	0	1.4	1.8	0.1
Calcium sulfate (% weight)	0	0	0.1	0.1	0
Sodacity (%)	1	1	2	2	1
Salinity (dS/m)	0	0	0.3	0.1	0

[1]Cation exchange capacity of the clay fraction (CEC), [2]Cation exchange capacity of the soil (CEC).

Table 3. Seasonal average of long-term rainfall and NDVI in districts in Dawuro and Gamo Gofa administration zones.

District	Long-term rainfall (1983-2015) mm					NDVI (2008-2015)			
	Dec-Feb	Mar-May	June-Aug	Sept-Nov	Yearly	Dec-Feb	Mar-May	June-Aug	Sept-Nov
Issara	126.68	495.55	303.97	291.9	1218.1	0.28	0.36	0.4	0.42
Gena	106.4	437.89	313.67	291.62	1149.58	0.19	0.24	0.33	0.36
Loma	113.64	489.11	285.38	304.05	1192.18	0.21	0.28	0.35	0.37
Mareka	110.1	483.65	312.84	308.5	1215.09	0.26	0.3	0.34	0.39
Tocha	109.87	476.87	324.59	316.19	1227.51	0.31	0.35	0.37	0.42
Arba Minch Z.	71.49	333.19	112.75	167.29	684.73	0.1	0.11	0.13	0.15
Ayida	108.1	396.98	144.69	182.88	832.64	0.26	0.27	0.23	0.32
Bonke	82.61	354.62	107.38	161.43	706.03	0.25	0.25	0.25	0.32
Boreda	79.12	377.58	195.99	191.53	844.21	0.19	0.19	0.26	0.29
Chencha	75.11	340.86	155.4	185.68	757.05	0.26	0.23	0.26	0.34
Daramalo	84.27	380.85	168.28	190.16	823.57	0.21	0.22	0.29	0.32
Denibu Gofa	111.99	458.98	225.44	246.09	1042.49	0.22	0.26	0.32	0.35
Dita	75.3	353.62	159.67	180.18	768.77	0.24	0.21	0.2	0.31
Geze Gofa	118.76	446.43	202.39	228.66	996.24	0.26	0.3	0.33	0.38
Kemba	94.11	360.51	113.2	166.78	734.6	0.23	0.26	0.27	0.31
Kucha	89.52	421.44	207.81	221.08	939.85	0.19	0.22	0.29	0.32
Melekoza	122.64	462.88	250.27	252.68	1088.46	0.28	0.33	0.34	0.39
Mirab Abaya	82.01	353.57	170.45	192.1	798.13	0.11	0.11	0.14	0.17
Ubadebretsh	110.34	374.16	124.58	174.23	783.3	0.28	0.3	0.29	0.35
Zala	103.74	413.57	178.57	205.19	901.07	0.2	0.23	0.3	0.32
Total average (%)	**98.79 (11)**	**410.61 (44)**	**202.86 (22)**	**222.91 (24)**	**935.18**	**0.23 (21)**	**0.25 (23)**	**0.28 (26)**	**0.33 (30)**

amount. Vegetation was fairly accomplished and normal growth, which started in the second decade of September and reached maximum level in the first decade of November (Figure 6). This could probably be the period vegetation (crops) matures with maximum potential in zones. However, vegetation growth might end in the

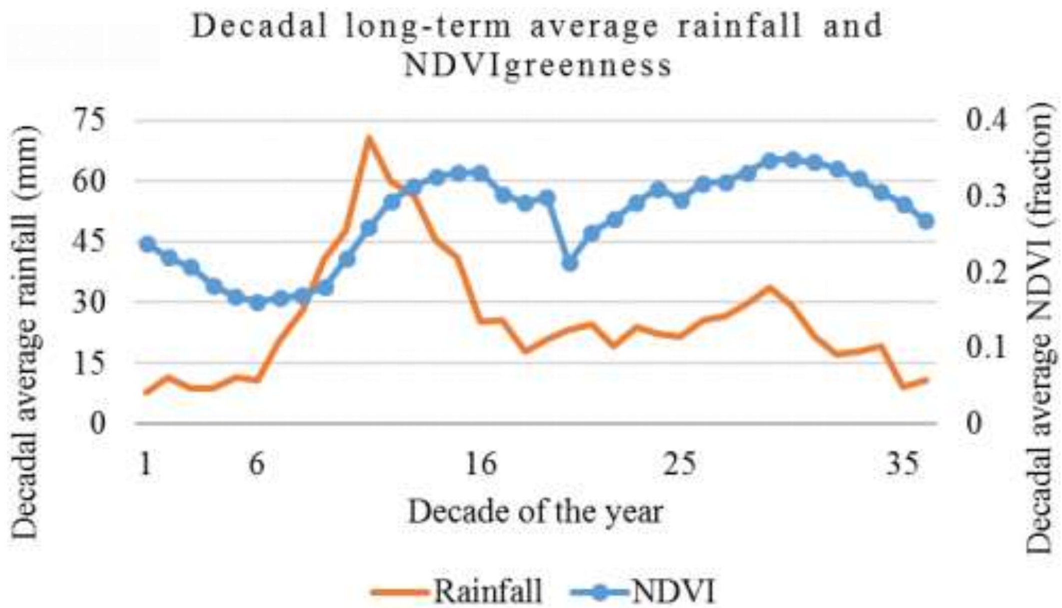

Figure 6. Yearly onset and cessation in vegetation growing season based on overall decadal average long-term rainfall and NDVI in Dawuro and Gamo Gofa zones (decade 1 start on January).

second decade of December in which overall decadal rainfall enters into lagging phase, below 10 mm in the zones.

Vegetation growth is defined in the third decade of March when the overall decadal average rainfall surpasses 33 mm (Figure 6). This persistently continued to peak in the first decade of June after 80 days during the onset of growth. The average amount of NDVI is also high in this period compared to the other seasons of the year which was accompanied by stable rainfall distribution since the onset of growth in the districts.

As Figure 6 shows the main rainy season, during June to August, the decadal overall average rainfall in the second decade of June highly fluctuated till the second decade of July; this might have a negative impact on vegetation growth in the zones. Eventually, vegetation growth retakes from third decade of July to third decade of August with a steady increase in growth curve for about 40 days (Figure 6). The optimum level of vegetation growth was observed in this season in the zones exceptional to some abrupt sunk in growth curve from fluctuation in rainfall amount in July.

A stable decade to decade rainfall amount with averages above 33 mm in each season could largely influence a maximum potential in vegetation growth in the zones. Rainfall occurs back to back period with a decadal average above 26 mm; this could maintain a sub-optimum level of vegetation growth in the regions. This should remind experts of irrigation, hydrology, etc to at least maintain the given level of soil water moisture content in some river available in AEZs in the zones.

The independent samples Kruskal Wallis test showed a significant difference (χ^2=25.55, p=0.00) on a seasonal average NDVI; similar significance difference (χ^2=65.21, p=0.00) was observed on a long-term average of seasonal rainfall in the zones. Pairwise compression of an intra-seasonal pattern of rainfall and NDVI also showed a significant difference in response to yearly periods of growing season. The response of NDVI variability significantly differred between drier winter (December-February) season and summer (June-August) season (χ^2= -20.53, p=0.01), between drier winter and spring (September-November) season (χ^2 =35.03, p=0.00), between wet dry (March-May) and spring (χ^2 =26.08, p=0.00), and between summer and spring season (χ^2 =14.50, p=0.048). Significant difference between drier winter and summer (χ^2 =-26.05, p=0.00), between drier winter and spring (χ^2 =31.25, p=0.00), between drier winter and wet dry (χ^2 =-59.10, p=0.00), between summer and wet dry (χ^2 =33.05, p=0.00) and between spring and wet dry (χ^2 =-27.85, p=0.00) were observed in intra-seasonal variability of the rainfall that induced the variability in environmental condition and growing season in the regions. The trends in the length of the growing season are the results of the differences between the trends in the onset and end of the growing season (Linderholm 2006; Høgda et al., 2013).

The reference LGP between 1961 to 1990 in Dawuro and Gamo Gofa zones isindicated in Figure 7. The reference LGP in the zone ranges from 236 to 279 days. The mean LGP is highest in Chencha 274 days with 15 days range and in Dita 272 days with 20 days range within districts. The different maximum range was in reference LGP in Kemba (43 days) and Bonke (40 days).

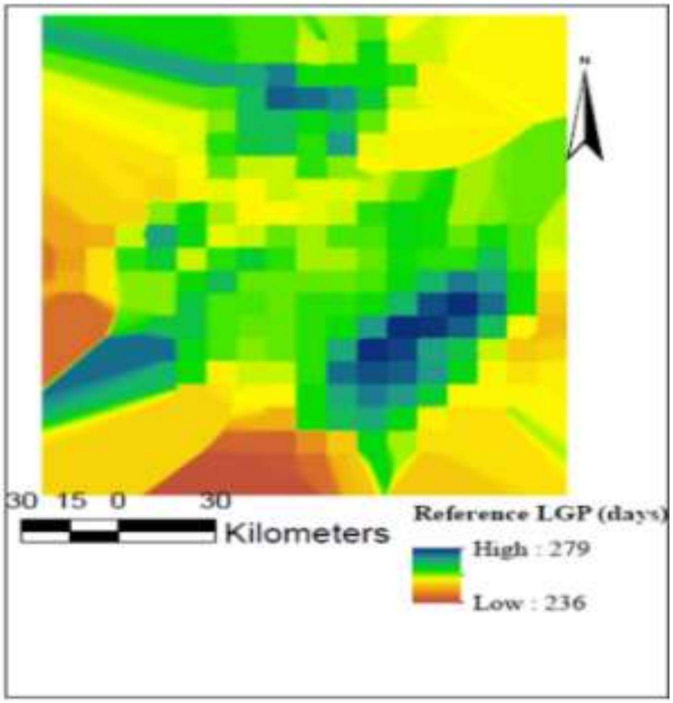

Figure 7. Average long-term (1961-1990) reference LGP (days) from IDW interpolation in Arc GIS 10.2 Gamo Gofa and Dawuro zones.

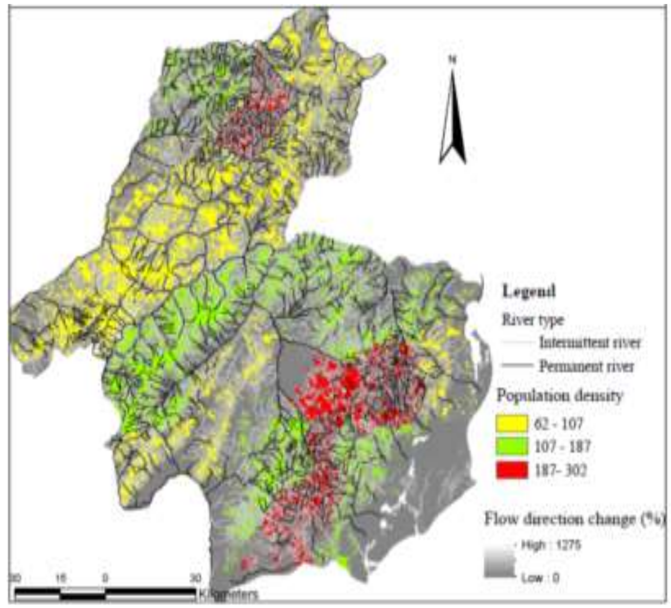

Figure 8. Population density and river types in Dawuro and Gamo Gofa zones.

Socio-demographic and water resource

The highland districts of the zones have high population density. The districts, Mareka in Dawuro zone and Daramalo, Dita, Chencha, and Bonke in Gamo Gofa zone have highest population density, which ranges from 187 to 302 person/km^2 (Figure 8). Whereas the lowest, 62 to 107 person/km^2 is found in lowland AEZ of Gena, Loma, and Issara districts of Dawuro and in Mirab Abaya, Zala, Ubadebretsh, Ayida and Melekoza in the Gamo Gofa zone.

The indicated highest population density in the highland region is probably associated with early period trends of population settlement due to environmental condition suitability to agriculture production and health. Whereas, currently population displacement and resettlement increasingly continued from highlands to lowland due to agricultural land scarcity, less produce and decreasing productivity. In the zones, the rural highland population density is nearly equal to the urban settlement in Ethiopia town. This is in eastern Ethiopia; in Dire Dawa city administration was done by 328 person per km^2 (CSA, 2007).

The zones have about 2286 counts of surface water bodies consisting of 930 intermittent and permanent 1356 rivers (Figure 8 and 9). Among the twelve major river basins in Ethiopia, Gojeb and Omo are the two found in the zones.

Agro-ecological zone (AEZ) class

The lower wet lowland AEZ mainly located below 600 m.a.s.l. in the lower valley of Omo River could probably be unique in its elevation range in Melekeza, Issara and Loma districts in the zones (Table 4). An earlier study mentioned that a wide altitudinal range within this range of AEZ (associated variation in climate), from 500 m at Chew Bahir (Makin et al., 1972) which lines in gradients up to Lake Chamo and Lake Abaya was parallel in the eastern side to the Omo River. In fact, Omo River is an upland water contributor to Lake Turkana.

The vegetation is tall grass cover of savannah type grassland. Whereas metadata analysis indicated soils are characterized by riparian type such as Eutric Combisols CMe and Lithic Leptosols LPq. The reference LGP ranged from 242-255 days and long-term average annual temperature between 22.42-25.01 C^0. This AEZ could probably be less anticipated for human settlement and cropping activity. An altitudinal range between 600-1000 m.a.s.l. is almost similar in AEZ, land use system, reference LGP and previous soil type, and exceptional to wider area coverage across districts along the lower valley from Omo to Gojeb river basins. AEZ within a similar altitudinal range around Chamo and Limo-Danigilo lakes differ in soil type, RLGP;the land use system consists of human settlement and livelihood activities alongside Bonke, Kemba, Ubadebretsh districts (Table 4). The AEZ classes could also bear difference given as lower moist lowland adopted from previous AEZ classification of MoA (2000) in Ethiopia.

The AEZ classification of MoA demonstrates that

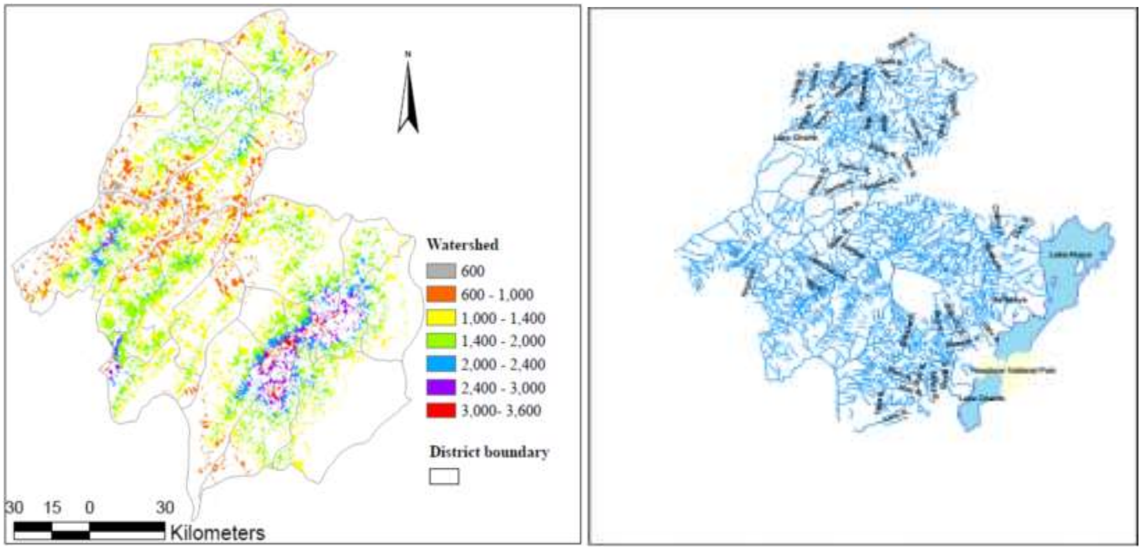

Figure 9. Major watershed within elevation range (left) and rivers, lakes and parks (right) in Gamo Gofa and Dawuro zones.

altitude ranges between 500-1500 m.a.s.l. and average annual rainfall amount is below 900 mm as dry lowland. Based on this Abaya-chamo basins from 1000-1400 m.a.s.l. alongside Arba Minch zuri, Mirab Abaya, Boreda, Chencha distincts are classified into dry lowland AEZ (Table 4). An earlier study by Makin et al. (1975), as well as current station measurement in this AEZ evidence average annual rainfall of about 800 mm. Maize in important food and cash-crop cultivated with cotton, beans and banana with or without intercropping, whereas banana growing towards specialized type farming system is the most promising cash-crop in this AEZ. The woodland opens out and decreases in height, until only well-spaced tall specimens of *Balanites aegyptiaca* and *Acacia tortilis* occur, as well as include common genera in riparian forest such as Ficus, Manilkara, Trichilia, Garcinia and Bridelia along the Culfo River between the lakes (Makin et al., 1975).

At this point, between lakes Abaya and Chamo several of the larger mammals have survived in favoured localities, and especially at Neschsar National Park. At Neschsar, Burchell's zebra, Swayne's hartebeest, Grant's gazelle, greater kudu and waterbuck all occur commonly (Makin et al., 1975). By the same authors, soil fertility, structure and drainage are generally favourable for arable use, the major constraint being low and unreliable rainfall.

The wet lowland AEZ within same altitude range often consists of areas of sparse human settlement with major livelihood activities such as maize, teff, sorghum, beans, groundnut, taro, sweet potato, cassava, sugar cane, coffee, tree fruits, etc. The common livestock are cattle and goats. This AEZ occupies substantial area of savannah grassland with sparsely distributed woody coverage; high prevalent rate of tse tse fly is also common in the dry lowland regions. The wet lowland AEZ includes all the districts in Dawuro zone. At Chabara-Chuchura National Park, mammals such as elephant, buffalo, lion, leopard, wild cat, hyaena and jackal are typical in wet lowland AEZ between districts of Issara, Tocha and Konta special. On the other hand, Swayne's hartebeest is unique feature at Maze Park, between Kucha, Zala, Dermalo districts. Likewise, the AEZ consists of several river basins (Table 4); the upland streams and rivers provide maximum potential for irrigation technology.

Mengistu (2009) highlighted the long tradition of farmers on water management in small scale agricultural use. The author mentioned that hare watershed downstream farmers extensively irrigate a command area of 2224 hectares with three different features. That was a modern diversion from traditional delivery system; a fully tradition and a modern diversion weir at water delivery structure. However, there is no substantial irrigation scheme in Dawuro zone except the failed attempt made by Derg regime during its final phase in Wini-Mawula river basins.

Upper wet lowland AEZ (1400-2000 m.a.s.l) generally lines up region in highland bamboo plantation zones. Teff is an important cash-crop at lower gradient where maize cropped twice yearly either with fresh harvest grows above the boundary of this AEZ. Ruminant livestock density probably high and family diet consists of widely milk and milk products in the advent of extensive grazing. Another AEZ with similar altitude range is upper moist AEZ (Table 4).

The typical characteristic of upper moist zone is usually the short cycle, horticulture farming practice. There is also relative variation within or between soil units (Table 4) that could reflect land use system, mainly in wet upper lowland grassland with increasing tree cover, while in moist upper

Table 4. Classification of agro-ecology zone (AEZ) in Gamo Gofa and Dawuro zones.

AEZ	Characteristics					
	Altitude (m)	Temperature (°C)	RLGP (days)	Major soil	Major river basin	Districts in AEZ belt
Lower lowland wet	< 600	22.42-25.01	242-255	CMe, LPq	Lower Omo valley	Issara, Loma, Melekoza
	600-1000	18.03-23.94	247-264	CMe, LPq	Omo-GojebValley	Issara, Melekoza, Geze Gofa, Denibu Gofa, Zala, Kucha, Loma, Gena, Mareka, Tocha
Lower lowland moist	600-1000	22.72-25.07	236-255	FLe, LVx, Ve, LPe, Nu	Chamo, Limo-Sile-Danigilo	Bonke, Kemba, Ubadebretsh
Wet lowland	1000-1400	20.50-23.43	252-260	LPq, VRe, LVx, NTu	Mansa-Wini/Shata-Wogaye	Issara, Loma, Gena, Mareka, Tocha
	1000-1400	20.03-23.28	247-260	LPq, CMe, LPe, FLe, LPd, VRe, NTu, ALu	-	Melekoza, Geze Gofa, Denibu Gofa, Kucha, Zala, Daramlo Kemba, Bonke, Ubadebretsh, Ayida
Dry lowland	1000-1400	22.06-22.52	251-254	LVx, FLe, VRe, CMe, NTu, ALu	Lake Abaya-Chamo, Sile-Culfo-Hare	Arba Minch, Mirab Abaya, Boreda, Chencha
Upper lowland wet	1400-2000	16.12-22.78	253-272	LPq, LVx, VRe, NTu, ALu	Gindera-Zea, Yideda-Wari, Chewa-Dibisa	Issara, Loma, Gena, Mareka, Tocha
	1400-2000	15.46-21.96	257-268	LPd, VRe, ALu		Melekoza, Geze Gofa, Denibu Gofa, Zala, Ubadebretsh, Ayida
	1400-2000	13.35-21.65	259-274	LVx, VRe, ALu	Sero-Kola-Beshe, Anitale-Bonge, Yamero-Chichla	Bonke, Kemba, Daramlo, Dita, Chencha, Kucha, Boreda, Mirab Abaya, Arba Minch
Sub-humid wet	2000-2400	17.60-18.31	265	ALu, NTu, VRe	Bera	Issara
	2000-2400	16.04-18.69	260-274	ALu, NTu, VRe	Koranto-Gabeno-ton-Aukma	Loma, Gena, Mareka, Tocha
	2000-2400	17.95-18.63	262	ALu	Zea	Gena
	2000-2400	18.52-21.69	255-262	ALu		Denibu Gofa,
	2000-2400	14.25-17.04	261-266	ALu		Geze Gofa, Zala, Ubadebretsh, Ayida
	2000-2400	12.16-21.59	261-278	ALu,VRe	Aniziya Hare	Arba Minch, Bonke, Kemba, Daramlo, Dita, Chencha, Kucha, Boreda, Mirab Abaya
	2000-2400			ALu		Kucha
	2000-2400	15.46	268	ALu		Melekoza
	2000-2400			ALu		Mirab Abaya
Wet highland	2400-3000	16.04-18.69	265-273	ALu, NTu, VRe	Yechi-Wata-Geda-Shepa	Tocha, Mareka, Loma, Gena,
	2400-3000	18.41-19.81	260-263	ALu		Denibu Gofa,
	2400-3000	1654-17.12	262-273	ALu		Geze Gofa, Ayida, Ubadebretsh,
	2400-3000	11.99-18.31	266-279	ALu, VRe	Baba-Beg, Fala-Hayie-Subeno, Alila-Lama	Arba Minch, Bonke, Kemba, Daramlo, Dita, Chencha, Kucha, Boreda, Mirab Abaya
	2400-3000	15.46	268	ALu		Melekoza
Wet upper highland	3000-3600	15.46	268	ALu		Melekoza
	3000-3600	11.83	273	ALu		Ayida, Ubadebretsh,
	3000-3600	12.70-13.54	275-279	ALu		Chencha, Dita

Table 4. Contd.

	3000-3600	13.54	275	ALu		Dita
	3000-3600	11.99-17.64	269-278	ALu	Beg-Kosa-Sheisha	Dita, Kemba, Daramlo, Bonke
	3000-3600	12.97-13.32	275	ALu	Chilo-Hanich	Bonke, Kemba

lowland bush/woodland there is visible bare surface. The common characteristic of upper lowland is the long mountains belt, with high slope rise in the mid-altitude of each zone.

Sub-humid wet within altitude ranges between 2000-2004 m.a.s.l. and is characterized by annual crops such as pulses, wheat, barley, etc. Typical, this AEZs are the origins of many long distance travel rivers downward the lowland AEZs. Most of the districts at this point occur independently by detaching or losing the link along the neighbouring region (Table 4). That could also differ in time and space during planning or by influencing the livelihood of the farm household themselves.

Wet highland within altitude range of 2400-3000 m.a.s.l. is characterized as having dense human population, as well as regions dense in enset, bamboo, eucalyptus/juniper tree plantation farming system. In livestock system, they are specialize in sheep and mare production. Introduction of apple fruit is a foundation stock throughout the country. Soil wet stress is considered as a common problem. Irish potato, garlic and some traditional cabbages are usually rare household income source particularly for women. In the AEZ, enset is supplemented by cabbage and mostly staple food in the household. Farm holdings are increasingly declining and there is shortage of infrastructure for marketing opportunity.

Wet upper highland with altitude range within 3000-3600 m.a.s.l. is characterized as having crops such as barley and pea. Its common vegetation includes broad leaved, short height forbs and shrubs. The supply-side challenge could be considered as high.

SCOPE FOR FUTURE OPPORTUNITY AND POSSIBILITY

Agroecology is deeply enriched by interaction and communication between disciplines and different systems of knowledge in a manner called transdisciplinarity interactive enrichment (Casado and de Molina, 2017). By the same authors, agroecosystems are ecosystems with a “purpose,” and that purpose is socially constructed and changes over time, so agroecosystems are much more than systems that produce food. All ecosystems provide environmental services for our planet (such as biodiversity conservation, soil and water protection, carbon sequestration, etc.); they must all be maintained with a high priority for their economic viability, affordability, and accessibility to all. Most importantly, the social sustainability of the food system must become a primary focus of food system change, with what we now call food justice, food security, and food sovereignty being the key goals (Casado and de Molina, 2017).

Nix (1983) asks a question, ‘how do we prescribe a technology that is appropriate to the land, labour, capital and management of resources of individual farmers? One of the first steps in classifying land utilization needs to be agroecosystems in which the strong social dynamic system is explained by the way societies interact with their agrarian environment. It can provide a conceptual framework for the integrative analysis of natural (ecological or biophysical) and social processes based on different perspectives to aid coherent decision making regarding energy use efficiency. One of the most relevant is the perspective of the agroecosystem itself, trying to measure both its efficient management and the state of health of its different components falls squarely within the realm of agroecology (Casado and de Molina, 2017). Agroecological indicators have been designed to ascertain the state of the natural resource elements of agroecosystems and, therefore, provide a very useful tool to evaluate the sustainability of agroecosystem management.

Two particular noteworthy characteristics have natural resources and assets; they process energy, materials, and information at a rate determined by their own structure; and they require periodic renewal or reproduction (Scheidel and Sorman, 2012). Given this (Giampietro et al., 2009) a part of the input flows needs to be devoted to constructing, maintaining, and reproducing the spread out energies. The boundaries of the agrarian sector signify the optimization of its possibilities by raising biomass production, otherwise limits growth rate of a given society.

The main elements of natural resource and asset the agrarian development process encompasses are agroecosystems (land in the broad sense: soil, water, biodiversity, etc.) and domesticated livestock, which, when managed by humans, process external energy, materials, and information to produce biomass that, in turn, provides a flow that feeds other dissipative structures of social metabolism (Casado and de Molina, 2017). According to Giampietro et al. (2009), capital is the set of artifacts (a preparative procedure made by an agrarian society) capable of processing energy and materials that are created by humans. The fund elements (productive resources and assets) could even be improved over time, allocating increasing amounts of energy and materials for this purpose (Casado and de Molina, 2017).

The qualitative leap in human transformation power first had impressive effects on the forms of appropriation of nature—agriculture, livestock breeding, fishing, management of water, forestry, and mining, among other sectors—that, in turn, potentiated the accelerated growth of human population, cities, and industry (Casado and de Molina, 2017). The human population living within the territorial limits of a given society should, therefore, consider the processor of the energy, materials, and information required to produce work and assets.

This current agroecology based approach provides land resources including soil resources, terrain resources, major river basin, water resources and demography. Agroecology zone classification is based on elevation, reference length of growing period, temperature, soil type, major river basins at district level with their relationship and specificity in land use system alongside. The potential of land use and farming system is derived through field experience since mid-2014. The database on soil type, terrain feature, water and river basin and the agroecology classes could have importance for various future applications such as:

i) Land use allocation;
ii) Agricultural performance and land suitability assessment;
iii) Rangeland biomass potential assessment;
iv) Hydrologic and irrigation potential analysis; and
v) Land protection status, infrastructure availability, and market access conditions by administration unit in the district level.

A new study can be established on a variety of uses, for instance, ensuring the accuracy of spatial information on soil data obtained from the most recent version of SoilGrids and comparing and estimating probability distribution on soil information by point sampling and laboratory analysis. Regarding the quality of information, further scaling up can be done at regional as well as country level. Agroecology approach is particularly useful to agrarian systems, because it provides information about their physical functioning and their spatial/temporal differences (Casado and de Molina, 2017). It enables differences to be shown with greater clarity, in terms of their structure and physical/biological functioning, between agriculture—either natural resources and consumer market link or a new transition toward a more sustainable agrarian development process.

CONFLICT OF INTERESTS

The author has not declared any conflict of interests.

REFERENCES

Amejo AG, Gebere YM, Dickoefer U, Kassa H, Tana T, Lawrence P (2017). Evaluation of livestock contribution to household income through descriptive analysis and modeling livestock performance in crop-livestock systems in Southwestern Ethiopia. Omo International Journal of Sciences 1(2):1-26.

Amejo AG, Gebere YM, Dickoefer U, Kassa H, Tana T, Lawrence P (2018). Herd dynamics and productivity performance modeling of livestock in smallholder crop-livestock systems in Southwestern Ethiopia. Journal of Veterinary Science and Animal Husbandry. 3(1):17-24.

Amejo AG, Gebere YM, Kassa H, Tana T (2018a). Comparative analysis of climate change impact on livestock in relation to biomass base feed availability using standardized precipitation index in south-western Ethiopia. International Journal of Livestock Production 9(7):184-191.

Andarge E, Shonga A, Agize M, Tora A (2015). Utilization and conservation of medicinal plants and their associated indigenous knowledge (IK) in Dawuro Zone: An ethnobotanical approach. Journal of Medicinal Plants Research *4*:330-7.

Braslow J, Cordingley J, Snyder K (2016). A guide for participatory mapping of ecosystem services in multiuse agricultural landscapes – How to conduct a rapid spatial assessment of ecosystem services. International Center for Tropical Agriculture (CIAT). Cali, Colombia. 86 p.

Casado GIG, de Molina MG (2017). Energy in Agroecosystems: A Tool for Assessing Sustainability. (Eds.), CRC Press.

CSA (2007). Population and Housing census. A. A., Ethiopia.

Dai A (2013). Increasing drought under global warming in observations and models. Nature Climate Change, 3(1):52.

Food and Agriculture Organization (FAO) (1984). Provisional Soil Map of Ethiopia. Land use Planning Project, Addis Abeba.

Food and Agriculture Organization (FAO) (1994). AEZ in Asia. Proceedings of the Regional Workshop on Agro- ecological Zones and Applications, Bangkok, Thailand, 17-23 November 1991. FAO, Rome, Italy.

Food and Agriculture Organization (FAO) (2012*).* Voluntary guidelines on the responsible governance of tenure of land, fisheries and forests in the context of national food security*.* FAO, Rome, Italy. http://www.fao.org/nr/tenure/voluntary-guidelines/en

FAO/IIASA/ISRIC/ISSCAS/JRC (2012). Harmonized world soil database (version 1.2). FAO, Rome, Italy and IIASA, Laxenburg, Austria.

Giampietro M, Mayumi K, Ramos-Martin J (2009). Multi-scale integrated analysis of societal and ecosystem metabolism (MuSIASEM): Theoretical concepts and basic rationale. Energy 34(3):313-322.

Gleick PH (2003). Water use. Annual review of environment and resources, 28(1):275-314.

Hoefsloot P, Calmanti S (2012). LEAP version 2.61 for Ethiopia.hoefsloot.com

Høgda KA, Tømmervik H, Karlsen SR (2013). Trends in the start of the growing season in Fennoscandia 1982–2011. Remote Sensing, 5(9):4304-4318.

Hurni H (1998). Agroecological belts of Ethiopia. Explanatory notes on three maps at a scale of, 1(1,000,000).

Linderholm HW (2006). Growing season changes in the last century. Agricultural and Forest Meteorology, 137(1-2):1-14.

Makin MJ, Kingham TJ, Waddams AE, Birchall CJ, Teferra T (1975). Development prospects in the Southern Rift Valley, Ethiopia. Development prospects in the Southern Rift Valley, Ethiopia (21).

Mengistu KT (2009). Watershed hydrological responses to changes in land use and land cover, and management practices at Hare Watershed, Ethiopia.

Ministry of Agriculture (MoA) (2000). Agroecological Zonations of Ethiopia. Addis Ababa, Ethiopia.

Nix HA (1983). Minimum data sets for agrotechnology transfer. In Proceedings of the International Symposium on Minimum Data Sets for Agrotechnology Transfer pp. 181-188.

Organisation for Economic Co-operation and Development (OECD) (2012). Publishing, and Organisation for Economic Co-operation and Development Staff.. Rosegrant environmental outlook to 2050: the consequences of inaction. OECD publishing.

Rosegrant MW, Ringler C, Zhu T (2009). Water for agriculture: maintaining food security under growing scarcity. Annual review of Environment and resources, 34.

Ruthenberg H (1971). Farming systems in the tropics. Oxford University: Clarendon Press.

Scheidel A, Sorman AH (2012). Energy transitions and the global land rush: Ultimate drivers and persistent consequences. Global Environmental Change, 22(3):588-595.

Tóth G, Koslowski B, Prieler S, Wiberg D (2012). Global Agro-Ecological Zones (GAEZ v3. 0). GAEZ Data Portal, User guide, Laxenburg, Austria.

United Nations Convention to Combat Desertification (UNCCD) (2013). The economics of desertification, land degradation and drought: methodologies and analysis for decision-making. Background document. UNCCD 2nd Scientific Conference. (UNCCD, Bonn). http://2sc.unccd.int

UNSDSN (2013). Solutions for Sustainable Agriculture and Food Systems. Technical report for the post-2015 development agenda (www.unsdsn.org).

WFP/FAO (2012). LEAP version 2.61 for Ethiopia. Retrieved from/Available from http://hoefsloot.com/download/leap_install.exe

Wymann von Dach S, Romeo R, Vita A, Wurzinger M, Kohler T (2013). Mountain farming is family farming: a contribution from mountain areas to the International Year of Family Farming 2014. FAO.

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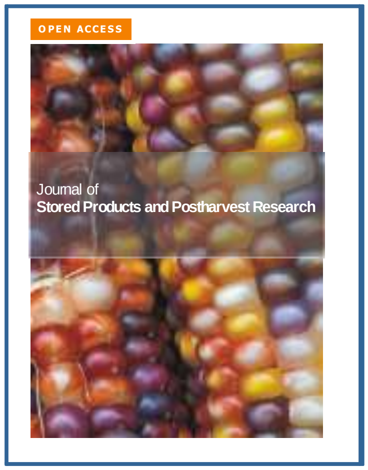

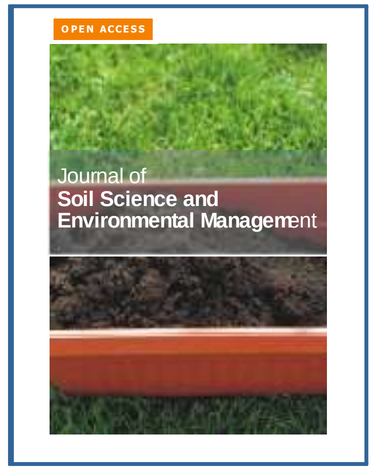

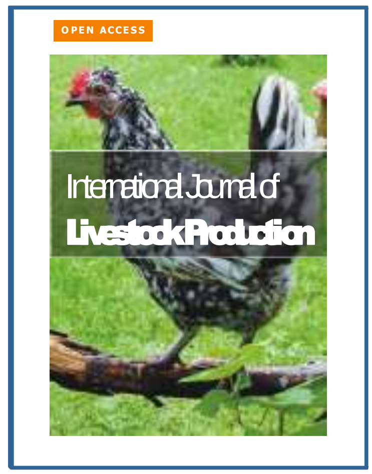

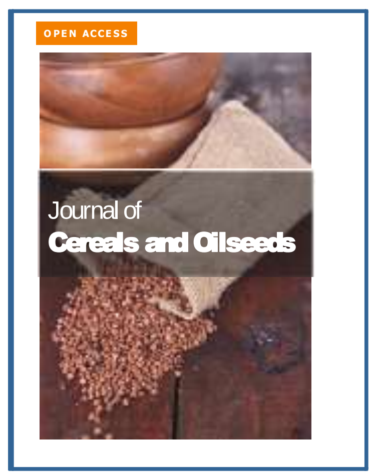

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