# Biochar and Other Organic Amendments Improve the Physicochemical Properties of Soil in Highly Degraded Habitat

Alemayehu Getahun, Diriba Muleta, Fassil Assefa, Solomon Kiros, and Mariangela Hungria

***Abstract*—Land degradation is an endless challenge in the world. Thus, rehabilitation with organic amendments (OAs) is an urgent priority issue. The purpose of this study is to assess the effect of biochar and other OAs application on soil physicochemical properties and growth parameters of cover crops in greenhouse. Biochar, compost and manure were used as OAs. Soil samples were collected from nine random corners of 30 cm depth and composited. In each experiment, five treatments were considered (biochar, compost, manure, mixed and control) at 1:1 ratio of OAs and soil in a pot, with completely randomized design arrangement in triplicate. The field experiment was made on completely randomized block design and each block contained five 41 x 4 m plots assigned at random within the block and separated by 1 m walkways. OAs additions increased soil pH (5.69-8.13), cation exchange capacity (43.78-49.98 cmolc/kg), organic carbon (1.41-2.46%), organic matter (2.43-3.91%), total nitrogen (0.13-0.76%), available P (18.89-28.53 ppm) and (iron, Fe, manganese, Mn, copper, Cu and zinc, Zn) in comparison to non-treated soil. Tripartite treatments had the largest effect on the biomass of cover crops with 3.43 g fivefold of the control (0.7 g) in alfalfa and 4.54 g twofold of the control (2.07 g) in grass pea $p \leq 0.05$. Both in field and greenhouse experiments combination of biochar and other OAs showed a better soil fertility increment and plant growth parameters. The study concluded that there is a synergistic effect in OAs on the soil fertility restoration and plant growth performance.**

***Index Terms*—Cover Crops, Coffee Husk, Land Degradation, Rehabilitation.**

## I. Introduction

Soil fertility is the vital ecological elements for the survival of biota and environmental services to play role in the conservation of biodiversity [1]. Global land assets are severely threatened due to degradation and unsustainable land use practices that need urgent calls to curb the increasing land deterioration. Rehabilitating degraded land is highly essential for regaining ecosystem services such as biodiversity renovation that ensures perpetuation of future generations [2]. The aggravation of land degradation (LD) and restoration to its original state is one of the pronounced and growing concern in the world [3].

LD is a single largest 21$^{st}$ century threat to soil productivity [4]. It takes place in all parts of the terrestrial world and leads to a reduction in productivity and quality of the land [5]. Degraded lands are the center of attention as the world demands for food, feed and fuel, whilst the agricultural land base needed for production is shrinking [6]. It has been estimated that LD is severely affecting ~1.5 billion humans and ~12.2 billion hectares of total lands [7]. Soil fertility degradation is certainly a constraint in Sub-Sahara African countries [8]. Highland places are characterized by a high population, high rainfall, sloppy and fragile ecology. It is estimated that ~1 billion tons of topsoil is lost annually in Ethiopia due to soil erosion [9]. In Ethiopia, the annual costs of LD associated to soil erosion and nutrients loss from agricultural and grazing lands are estimated at about $106 million (about 3% of agricultural GDP) from soil and nutrient losses [10, 11]. All these translate to an annual total loss of about $139 million (about 4% of GDP).

Land restoration efforts is underway in Ethiopia since 1970s and dedicated to restoring 15 million hectares in 2030 [12]. Degraded soils regularly contain lower OM, nutrients and microbial activity and unsuccessful for plant establishment [13]. Maintenance and enhancement of the quality of degraded lands are dependent on the improvement of physical, chemical and biological properties [14]. OAs application to degraded soils improves deficiencies in nutrients and OM, alters soil porosity and microbial biomass to recover plant establishment [15, 16]. Manure, biochar or compost can have a positive effect on soil microbial communities, nutrient supply for sustainable ecosystems' functions Kennedy and Smith [17] that ultimately contribute much to the restoration of soil fertility of a given habitat [18].

There is increasing interest in amending degraded soils with biochar, compost and manure receiving attention in restoring disturbed soils [19]. The effect of biochar and other OAs on soil properties, growth and activity of soil biota has not been sufficiently evaluated with field trials. To overcome problem of LD and deforestation Ethiopian government have attempted to implement different conservation activities. Those are physical structure (terraces, soil bund, water ways and check dams). There is also plantation through trial and error which is not suitable to the environmental conditions. Hence, the results are very scant due to poor management practices and implementation is not well studied as for rehabilitation. It is hypothesized that, biochar and other OAs on degraded habitat, are an inexpensive solution to increase soil function and accelerate re-vegetation. Therefore**,** the purposes of this study was to

Published on March 19, 2020.
A. Getahun, D. Muleta, and F. Assefa are with College of Natural Sciences, Addis Ababa University, Addis Ababa, Ethiopia (alemayehug2007@gmail.com, dmuleta@gmail.com, asefafasil2013@gmail.com).
S. Kiros are with Addis Ababa Institute of Technology, Addis Ababa University, Addis Ababa, Ethiopia (selamawitsole@yahoo.com).
M. Hungria Embrapa Soja, C.P. 231, Londrina, PR 86001-970, Brazil (mariangela.hungria@embrapa.br).

evaluate the effect of different OAs on the physicochemical properties of degraded soil and to assess also the growth of alfalfa (*Medicago sativa*) and grass pea (*Lathyrus sativus*) on organically amended soils under greenhouse conditions.

## II. MATERIAL AND METHODS

### *A. Description of the Study Area*

The study was carried out on degraded soils of Central Highlands of North Shewa Zone, Ethiopia from September 2016 to May 2018. It is located at 9° 45' 57'' N and 38° 42' 06" E. The soil is characterized as indicated in (Table I). More than 65% of the area is characterized by steep-slopes, a mountainous topography, valleys and gorges. Its altitude extends from 1000 to 3500 m.a.s.l. [20]. The average rainfall of the Woreda is about 1200 mm. Temperature ranges from11.5°C to 35°C with average relative humidity 62%. About 8 percent of land is unusable (abandoned) land.

### *B. Soil and OAs Collection*

Four kilograms of soil samples were taken randomly from nine corners from a depth of 30 cm and stored at room temperature. Mixed well, analyzed following standard procedure [21]. Biochar (coffee husk), compost (recycled floriculture) and manure (farmyard manure) are used as OAs. The biochar was prepared by means of slow pyrolysis of coffee husk in a biochar kiln operating at a temperature of 350°C. The properties of soil samples and OAs are listed in (Table I and II).

TABLE I. PHYSICOCHEMICAL PROPERTIES OF SOIL BEFORE ORGANIC AMENDMENTS

| Property | Mean Value | Property | Mean value |
|---|---|---|---|
| Moisture (%) | 9.2 | Ex. Na ($cmol_c$/Kg) | 0.18 |
| Depth (cm) | 30 | Ex. K ($cmol_c$/Kg) | 0.18 |
| Altitude (m) | 3114 | Ex. C ($cmol_c$/Kg) | 25.26 |
| **Texture** | | Ex. Mg ($cmol_c$/Kg) | 12.63 |
| Clay (%) | 31 | Av. K (meq/100g) | 0.14 |
| Silt (%) | 21 | TN (%) | 0.13 |
| Sand (%) | 49 | OM (%) | 2.43 |
| Soil class | SCL | C:N - | 10.92 |
| pH($H_2O$) | 5.69 | Cu (mg/Kg) | 2.52 |
| pH(CaCl2) | 5.14 | Fe (mg/Kg) | 38.62 |
| EC (dS/m) | 0.25 | Zn (mg/Kg) | 0.59 |
| Av. P (ppm) | 18.9 | Mn (mg/Kg) | 4.08 |
| OC (%) | 1.4 | CEC (cmolc/Kg) | 43.78 |

EC= electrical conductivity, TN = total nitrogen, TOC=total organic carbon, CEC= cation exchange capacity. SLM= sandy clay Loam.

TABLE II: AVERAGE PHYSICAL AND CHEMICAL PROPERTIES OF APPLIED BIOCHAR, COMPOST AND MANURE (MEANS ± STANDARD DEVIATION, N=2)

| Parameters | Biochar | Compost | Manure |
|---|---|---|---|
| Moisture | 2.19$^b$ (0.16) | 3.13$^c$ (0.12) | 5.13$^a$ (0.18) |
| pH (H2O) | 8.66$^b$ (0.41) | 8.45$^a$ (0.41) | 8.47$^b$ (0.35) |
| EC | 4.95$^b$ (0.21) | 1.95$^a$ (0.58) | 4.94$^a$ (0.43) |
| Na % | 1.74$^b$ (0.09) | 1.81$^b$ (0.09) | 1.985$^a$ (0.05) |
| K % | 0.05$^a$ (0.01) | 0.09$^a$ (0.01) | 0.12$^a$ (0.12) |
| Ca % | 3.39$^a$ (0.19) | 1.56$^a$ (0.16) | 2.36$^a$ (0.08) |
| Mg % | 1.35$^c$ (0.1) | 0.79$^b$ (0.09) | 2.24$^a$ (0.10) |
| K (cmolc/kg) | 30.7$^c$ (1.13) | 25.6$^b$ (1.74) | 37.6$^a$ (1.56) |
| TN % | 1.2$^a$ (0.18) | 1.63$^b$ (0.19) | 1.15$^b$ (0.05) |
| TOC | 47.98$^a$ (3.9) | 22.57$^c$ (1.22) | 30.97$^b$ (1.99) |
| P mg/kg | 1425.4$^c$ (17) | 3238.4$^b$ (28) | 5625.12$^a$ (14.8) |
| Cu mg/kg | 11.35$^b$ (0.54) | 16.65$^c$ (0.44) | 30.11$^a$ (1.04) |
| Fe mg/kg | 2102$^a$ (56.9) | 1998$^a$ (54.9) | 1290.05$^b$ (2.19) |
| Zn mg/kg | 102.61$^c$ (0.8) | 82.99$^b$ (0.61) | 161.1$^a$ (0.34) |

Means with the same letter are not significantly different at $p \leq 0.05$ with Duncan grouping using (mean ± SD)

### *C. Soil and OAs Analysis*

The composite soil samples and OAs were air dried, ground and sieved over 2 mm mesh used for soil physicochemical analysis. Soil pH and electrical conductivity (EC) were measured in soil: water suspension (1:2.5) ratio [22]. Cation exchange capacity (CEC) was determined by Sodium equivalent by Flame Emission Spectrophotometer (FES) [26]. Ammonium acetate (pH=7) was used to extract the exchangeable cations (Ca, Mg, K, and Na). Exchangeable Ca and Mg were measured by EDTA titrimetric method and exchangeable K and Na by Flame Emission Spectrophotometer [23].

Plant available K was determined by the ammonium acetate (CH3COONH4) method Bashour and Sayegh [24]; whilst available P was extracted by sodium bicarbonate solution as described before ISO. [25]. Soil organic carbon (OC) and total N (TN) content were determined by dry combustion methods based on [25]. Soil organic matter (OM) was calculated by multiplying soil OC by 1.724 assuming average C concentration of OM of 58%, (%OM = %OC x 1.724). Micronutrients (Cu, Fe, Mn, and Zn) were extracted with ammonium bicarbonate di-ethylene tri-amine penta-acetic acid (DTPA), as described before [26].

### *D. Greenhouse Experiments*

The performance of OAs on growth of alfalfa and grass pea was carried out. All experiments were done in triplicate and the pots 3.5 L capacity were arranged in a RCBD in greenhouse, 12 h photoperiod, day 25±2°C and night temperature 17±3°C. The treatments are biochar, compost, manure, biochar + compost, biochar + manure, compost + manure, biochar + compost + manure, and control. All the treatments were applied at 50:50 ratio of OAs and soil per pot. In each pot, 5 surfaces sterilized seeds of the alfalfa and grass pea were sown separately followed by a reduction to three plants 10 days later. Each pot was watered daily with tap water for a period of 30 days. Shoot height (SH), shoot dry weight (SDW), root dry weight (RDW), shoot fresh weight (SFW), nodule number (NN), nodule fresh weight (NFW) and nodule dry weight (NDW) were measured.

### *E. Statistical Analysis*

Mean separation was done using the Duncan multiple grouping of means at 5 % probability level when the ANOVA showed significant effects. The values were presented as means ± standard deviation (SD), where $p \leq 0.05$ was considered to be statistically significant. All statistical analyses were performed using SAS software package (version 9.0).

## III. RESULTS AND DISCUSSION

### *A. Effects of OAs on Soil Physicochemical Properties*

The amendments with biochar, compost, manure alone or in combination had affected the physicochemical properties of soil differently compared to the control (Table III). Soil pH was dramatically increased (8.4) with the application of

DOI: http://dx.doi.org/10.24018/ejers.2020.5.3.1735

the selected OAs ($p \leq 0.05$) compared to the control (5.68). Among the four amendments, BAS (biochar amended soil) had the greatest impact on pH (8.4) followed by BCMAS (biochar +compost + manure amended soil) (8.15). BAS, CAS (compost amended soil), MAS (manure amended soil), and BCMAS increased the soil pH by 1.72, 1.13, 1.27, and 1.47 units, respectively. The present result indicated that the addition of OAs could increase soil pH. Similar to the current finding, application of biochar from rice husk, sorghum silage, and sawdust increased the soil pH by 0.76, 1.17, and 1.68 units, respectively [27]. Soil pH increase was in the order of BAS > BCMAS >CAS > MAS compared to the control. The increases in soil pH due to sole application of biochar could be attributed to the high pH of the biochar used in the experiment since it contains a large amount of ash with alkaline nature that can enhance the soil pH. Soil pH increase from 7.27 to 7.85 after biochar amendment was reported due to the aforementioned reasons [28]. However, Mukherjee, et al. [29] have conducted a two-year study with 0.5% biochar by weight as a soil amendment and observed no significant increase $p \geq 0.05$ in soil pH. This is consistent with the results that OAs application can significantly increase soil pH [30, 31]. Decarboxylation of organic anions due to decomposition, complexation of free $H^+$ and $Al^{3+}$ ions with organic ligands and increased saturation of soil CEC by $Ca^{2+}$, $Mg^{2+}$ $Na^+$, and $K^+$ added by the wastes are other possible explanations for soil pH changes [32]. Moreover, green waste compost, biochar, and sedge peat application could increase saline soil pH (6.23 to 6.77), and this may be in accordance with a high content of basic cations of these amendments [33, 34]. In line to the present outcome, the application of biosolids such as animal manure and compost on acid soils increases the soil pH appreciably from 4.68 to 7.19 [35].

Compared to the control, OAs increased the total Nitrogen (TN) content in the soil. The largest increase was observed in BAS (0.98%) followed by BCMAS (0.86%), CAS (0.66%) and MAS (0.55%) amended plots (Table III). The increased TN content with manure (0.36%), liquid humus (0.31%) and compost (0.31%) amendments were noted in the previous studies [36]. Moreover, there is a TN increase in biochar (1.6 g/kg) and cattle manure (11.6 g/kg) when treated sandy soil compared to control group (0.18 g/kg) [37]. But in the present finding the high TN content was observed in BAS. The increase in TN of the soil after amendments is closely related to the build-up of OM in the soil. Similar effects were shown by Mantovi, et al. [38] in a 12-year experiments with biosolids and compost. Furthermore, it has been reported that addition of manures (i.e., cow, sheep, and poultry) increased net N released by 42, 25, and 43%, respectively over the control [39]. However, the effects of OAs on nutrient availability depend on their chemical composition and decomposition rates [40]. According to Wu, et al. [41], the application of OAs increased the N content is because of the greater N and OC concentration in the amendments.

The available P content in the soil increased in each amended soil and the highest was found in BCMAS (28.53 ppm), whilst the highest available K content was recorded in MAS (2.16 meq/100) after one year amendment (Table III). The results show a significant increase in physicochemical properties in all amended soil samples compared to the control ($p \leq 0.05$). The increased P and K contents observed in the soil were also related to the amendments chemical composition. Thus, OAs can apparently supply P and K to the soil as reported by Reynolds, et al. [42], who have evaluated municipal waste compost and observed an increase in the P and K concentrations. The increased in P and K is might be due to the negative charges in the functional groups of the OM that compete with P and K for adsorption sites and complex Fe and Al ions thereby increasing P and K activity in the soil solution [43]. For example, manure, compost and biochar can provide these nutrients to crops on organic farms [44]. The application of OAs may increase P availability, either directly from the decomposition of OM and release of P or indirectly by increasing the amount of soluble organic acids that increase the rate of desorption of phosphate [45]. The increase in available P after OAs might be due to high microbial activity induced by the addition of OAs which increased P cycling [46]. Moreover, P can be adsorbed by soil colloids, and the mixed OAs are able to bind large quantities of macronutrients and thereby to reduce their removal from soil by leaching [47].

### *B. Effects of OAs on CEC and Exchangeable Cations*

The CEC of this study was higher in all amended plots than the control and significantly ($p \leq 0.05$) different among the amended plots. Soil CEC was found to be higher in BAS (53.55 cmolc/kg) followed by BCMAS (50.82 cmolc/kg) compared to control (43.78 cmoc/kg) (Table III). Earlier studies proved that biochar resulted in higher soil CEC (29 cmolc $kg^{-1}$) than the control (25.6 cmolc $kg^{-1}$) [48]. The reason for high CEC in BAS is due to an increase in the surface area and charge density on the surface. Biochar from woody materials typically enhances the pH, soil water relations and CEC and ultimately results in improved soil fertility [49]. Applications of composts and manures increase soil fertility and the increase is short term [50]. But, application of biochar to infertile soil has provide long-lasting improvements in soil fertility [51, 52]. Because of the continuous oxidation of surfaces, and the adsorption of organic acids by biochar, CEC is expected to increase further with time [53]. In agreement to the present result, Cheng, et al. [53] have reported that the incubation of biochar during one year raised its CEC from 1.7 to 71 mmol/ kg. Likewise, according to Chan, et al. [54], biochar addition promotes positive changes in soil quality, such as acidity correction, increased CEC, and an improved environment for root growth.

Compared to the control, application of OAs alone or in combination increased the exchangeable Ca, Mg, K, and Na contents in the soil. Compared to the biochar, the compost used had greater proportions of exchangeable Ca and Mg, 33.37 and 16.49 cmolc/kg, respectively. The highest exchangeable K and Na content were found in the combined treatment (0.42, 0.97 cmolc/kg, respectively), while the least was found in the control (0.18 cmolc/kg). Inline to this finding, the compost used had greater proportions of exchangeable Ca and Mg, 162.7 and 22.7 cmolc $kg^{-1}$, respectively [55]. According to Fischer and Glaser [56], compost application alone has a liming effect due to its richness in alkaline cations such as Ca, Mg, and K, which are liberated from organic matter due to mineralization. The increase in the exchangeable bases is as a result of the presence of ash in the biochar which helps in the immediate release of mineral nutrients like Ca and K for crop use [57]. The treatment of OAs increased exchangeable $Ca^{2+}$ contents of soil, which may increase the replacement of $Na^{+}$ from the exchange sites, thus improving the remediation efficiency of soil. It has been reported that soil structure could be improved by $Ca^{2+}$ through the formation of cationic bridges between soil organic matter and clay particles [58]. For soluble salts, the addition of OAs had a significant influence on $K^{+}$ (Table III). In this finding, the highest increase in exchangeable $K^{+}$ was observed in MAS and BCMAS as verified by other investigators Walker and Bernal [59], who observed the treatment of exhausted soil with compost and poultry manure that resulted in significantly increased soil soluble $K^{+}$ and the increase probably related to the application of OAs. Among the OAs, biochar and compost had the lowest value in soil exchangeable $Na^{+}$ and $Mg^{2+}$ compared to other amendments. The increase in Ca and Mg with OAs may be due to the release of organic forms of these elements in the organic residues [60]. As reported by Qadir and Oster [61], an increase in Ca concentration in the soil solution results in the replacement of Na by Ca at the cation exchange sites on the soil particles. If the soil turns into a sodium saturated and forms Na-clay, the soil becomes less fertile.

TABLE III: THE EFFECT OF THE DIFFERENT OAS ON DEGRADED SOIL PHYSICOCHEMICAL PROPERTIES (MEANS ± STANDARD DEVIATION, N = 2)

| Property | Unit | BAS | CAS | MAS | BCMAS | Control |
|---|---|---|---|---|---|---|
| Moisture | % | 12.05 ± 0.92$^{b}$ | 12.29 ± 0.72$^{b}$ | 12.64 ± 0.75$^{ab}$ | 15.15 ± 0.38$^{a}$ | 9.2 ± 1.41$^{c}$ |
| EC | dS/m | 0.58 ± 0.03$^{c}$ | 1.24 ± 0.17$^{b}$ | 1.48 ± 0.06$^{ab}$ | 1.24 ± 0.06$^{a}$ | 0.25 ± 0.07$^{d}$ |
| pH(H2O) | - | 8.4 ± 0.33$^{a}$ | 7.99 ± 0.15$^{a}$ | 7.96 ± 0.37$^{a}$ | 8.15 ± 0.55$^{a}$ | 5.69 ± 0.16$^{b}$ |
| Av. P | Ppm | 26.33 ± 0.51$^{a}$ | 24.68 ± 0.47$^{ab}$ | 25.71 ± 0.74$^{ab}$ | 28.53 ±1.07$^{a}$ | 18.89 ± 2.9 6$^{b}$ |
| CEC | cmolc/Kg | 53.55 ± 0.89$^{a}$ | 46.86 ± 0.61$^{cd}$ | 48. 69 ± 0.62$^{bc}$ | 50.82 ± 1.89$^{ab}$ | 43.78 ± 1.19$^{d}$ |
| Ex. Na | cmolc/Kg | 0.59 ± 0.11$^{b}$ | 0.44 ± 0.06$^{b}$ | 0.89 ± 0.03$^{a}$ | 0.97 ± 0.12$^{a}$ | 0.18 ± 0.05$^{c}$ |
| Ex. K | cmolc/Kg | 0.37 ± 0.06$^{a}$ | 0.22 ± 0.04$^{b}$ | 0.41 ± 0.03$^{a}$ | 0.42 ± 0.05$^{a}$ | 0.18 ± 0.06$^{b}$ |
| Ex. Ca | cmolc/Kg | 27.66 ± 1.11$^{a}$ | 33.37 ± 0.66$^{b}$ | 30.06 ± 0.86$^{a}$ | 31.65 ± 0.95$^{a}$ | 25.26 ± 1.36$^{b}$ |
| Ex. Mg | cmolc/Kg | 13.16 ± 0.56$^{c}$ | 16.49 ± 0.93$^{b}$ | 19.61 ± 0.98$^{a}$ | 20.21 ± 1.24$^{a}$ | 12.63 ± 1.17$^{c}$ |
| Av. K | meq/100g | 0.84 ± 0.33$^{b}$ | 1.11 ± 0.18$^{b}$ | 2.16 ± 0.09$^{a}$ | 2.13 ± 0.22$^{a}$ | 0.14 ± 0.05$^{c}$ |
| TN | % | 0.98 ± 0.12$^{a}$ | 0.66 ± 0.13$^{ab}$ | 0.55 ± 0.11$^{b}$ | 0.86 ± 0.19$^{ab}$ | 0.13 ± 0.02$^{c}$ |
| C:N | - | 14.93 ± 0.38$^{a}$ | 11.85 ± 0.82$^{a}$ | 13.9 ± 0.17$^{a}$ | 13.32 ± 1.24$^{a}$ | 10.92 ± 3.75$^{a}$ |

Means with the same letter are not significantly different at $p \leq 0.05$ with Duncan grouping using (mean ± SD).

The addition of biochar, compost and manure increased Cu, Fe, Zn and Mn concentration, as did the BCMAS. The concentration of micronutrients was found to be in the order of Fe >Mn> Cu > Zn in almost all the amended soil of the study site (Fig. 1). The micronutrient availability is more pronounced in the BCMAS which might be due to their synergistic activities as noted in the previous studies [62]. These trace metals are essential elements to promote plant growth and required for metabolic functions, gene regulation, and reproduction [63]. In other finding, soil amended with biochar, compost and cattle manure significantly increased the availability of these trace elements in the range of 6.1- 460 mg/kg [64]. Moreover, both manure and biochar application could increase the concentration of Zn, Mn and Cu (0.5-2.7, 0.8-2.6, 3.5-4.6 and 0.5-2.3, 0.8-2.4 and 3.5-4.8) respectively [65]. There is a significant decreases were observed in plant-available Fe content of soil following the application of manure and biochar (2.5-2 and 2.5-1.7) respectively [65]. The increments are because of manure and biochar acts as a nutrient source, increases in nutrient availability [66, 67]. Iron availability decreases have been reported by Lentz and Ippolito [66] after the biochar application to soil.

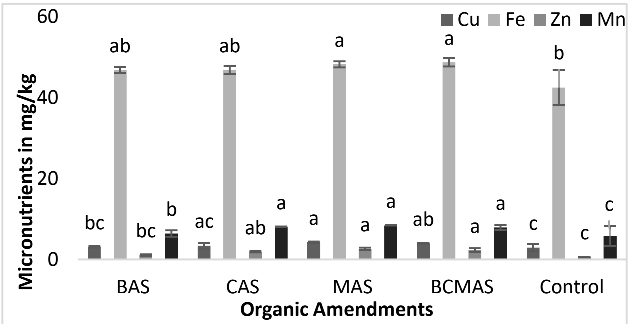


Fig. 1. The effect of different OAs on contents of micronutrients of the degraded soil. Means with the same letter are not significantly different at $p \leq 0.05$ with Duncan grouping using (mean ± SD).

### *C. Effects of OAs on Soil Organic Matter and Organic Carbon*

Soil OM significantly ($p \leq 0.05$) increased with the treatment of OAs where 2.69% in CAS and 4.86% in BCMAS compared to control 2.43%. The OM content increments were 2.28%, 0.26%, 0.96% and 2.43% in BAS, CAS, MAS and BCMAS, separately. Similarly, OC was 1.63 and 3.075% in CAS and BCMAS, respectively compared to the control (1.405%; Fig. 2). Soil OM contents of < 2.0% is low; 2.1-3.0% is medium and > 3.1% is high as reported by [35]. Our results indicate that OAs significantly increased OM and OC contents as revealed in the earlier studies [30, 31, 68]. The increase was more evident in BAS. The application of OAs clearly increased the levels of OM compared to non-treated soils which is in agreement with another study [69]. In line to the finding, Tejada and Gonzalez [70] have concluded that the chemical property of the OAs decided the effect of amendments on soil OM and

DOI: http://dx.doi.org/10.24018/ejers.2020.5.3.1735

OC. The increase in soil OC has previously attributed to the continuous addition of C [71]. Many studies have shown that an increase in OC with OAs applications [72, 73]. The effect of OAs on soil organic carbon depend on the chemical nature of the amendments [70]. Evidently, application of farmyard manure visibly enhanced the soil OC content in various cropping systems [74].

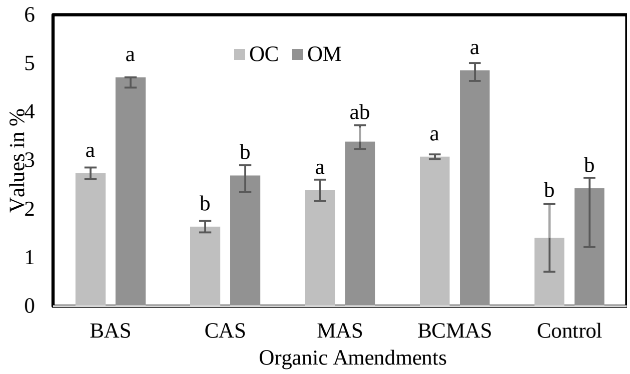


Fig. 2. The status of OC and OM of the soil after organic amendments. BAS= biochar amended soil. Means with the same letter are not significantly different at $p \leq 0.05$ with Duncan grouping using (mean ± SD).

### D. *Effects of OAs on Plant Biomass under Greenhouse*

In our study, the highest nodule number per plant was measured from BCMAS (118, 111/plant) in alfalfa and grass pea compared to the control (50, 58/plant, respectively; (Fig. 3). Moreover, BAS had the higher nodule numbers (91 and 93) both in alfalfa and grass pea compared to CAS (77, 69) and MAS (84, 88) in both alfalfa and grass pea, respectively. A similar study from greenhouse experiment confirmed that biochar increased nodule biomass and numbers in legume plants [75]. Mia, et al. [76] have stated biochar considerably increased the number of plant root nodules in red clover (*Trifolium pratense* L.). In contrast, Quilliam, et al. [77] have reported that aged biochar did not increase the number of root nodules in clover (*Trifolium repens* L.). According to Rondon, et al. [78], the basic reason for the higher root nodule numbers in legumes in the presence of biochar is attributed to increased availability of the trace nutrients such as boron and molybdenum. As shown by Harter, et al. [79], the high C: N ratio of biochar and the formation of anoxic microsites might favor the growth of free-living as well as plant associated nitrogen-fixing microorganisms. Alfalfa and grass pea plants receiving biochar, manure or compost produced more aerial fresh biomass compared to the control. Plants in BCMAS produced 25% and 29% higher fresh biomass in alfalfa and grass pea, respectively than the control. A relatively similar finding (21 and 19%) from fresh biomass of alfalfa was reported in compost and manure-amended soil, respectively [80]. Many organic wastes represent an important source of N, P, Ca, and others such as Zn, Cu, and Mg that are essential to plant growth [81]. Hence, as many scholars demonstrated, organic fertilizer has a great impact on soil fertility which is essential for good plant growth [82].

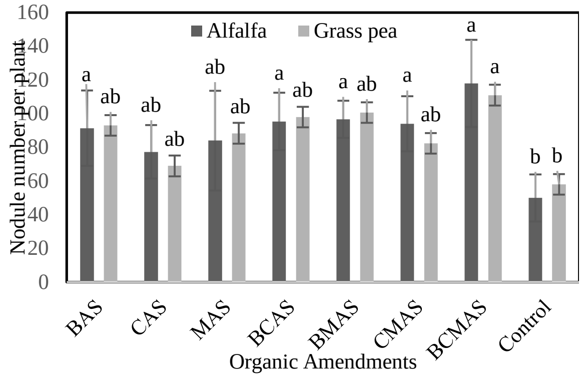


Fig. 3. Comparison of nodule numbers per plant of alfalfa and grass pea on organic amended soil. Means with the same letter are not significantly different at $p \leq 0.05$ with Duncan grouping using (mean ± SD).

The OAs application significantly ($p \leq 0.05$) increased the biomass of alfalfa and grass pea. The significant increments were shown in response to the combined application of the amendments (Fig. 4, Table IV and V). Among eight amendments, the triple treatments had the largest effect on the biomass, reaching 3.43 g fivefold of the control (0.7 g) in alfalfa and 4.54 g twofold of the control (2.07 g) in grass pea ($p \leq 0.05$). The dry weight of the plants significantly increased in soil applied with OAs, which is comparable to the previous studies [83, 84]. A similar (1.31, 1.37 and 1.49 folds increase) in rapeseed meal, manure and biochar-amended soil was report compared to the control in wheat biomass [85]. This is attributed to the active role of OAs on soil biota (enzyme activities) and chemical properties (pH) that would result in the release of nutrients from OAs. The growing biomass of soil organisms may be caused by OAs themselves and improve plant health through the decomposition of OM, nutrient cycling, and the improvement of the soil structure [86, 87]. Members of the genus *Lathyrus* include food and fodder crops, ornamentals, soil nitrifiers, dune stabilizers, important agricultural weeds, and model organisms for genetic and ecological research [88].

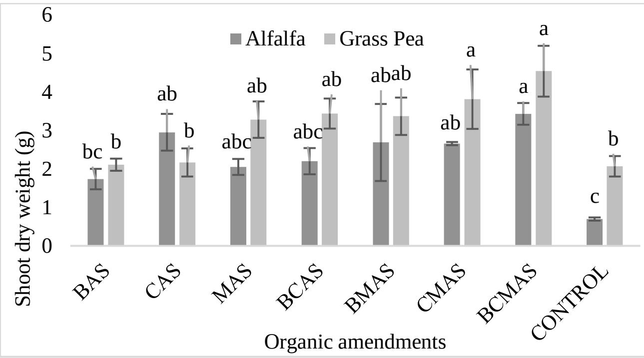


Fig. 4. The effect of OAs on the shoot dry weight of alfalfa and grass pea. Means with the same letter are not significantly different at $p \leq 0.05$ with Duncan grouping using (mean ± SD).

TABLE IV. GROWTH PERFORMANCE OF ALFALFA ON ORGANIC AMENDED SOILS UNDER GREENHOUSE TRIALS NFW- NODULE FRESH WEIGHT, NDW- NODULE DRY WEIGHT, SH- SHOOT HEIGHT, SFH- SHOOT FRESH WEIGHT, RFW- ROOT FRESH WEIGHT, RDW- ROOT DRY WEIGHT

DOI: http://dx.doi.org/10.24018/ejers.2020.5.3.1735 

| Factor | BAS | CAS | MAS | BCAS | BMAS | CMAS | BCMAS | CONT. |
|---|---|---|---|---|---|---|---|---|
| NFW | $0.73 \pm 0.09^{b}$ | $0.83 \pm 0.07^{b}$ | $0.7 \pm 0.17^{b}$ | $0.86 \pm 0.11^{b}$ | $0.88 \pm 0.02^{b}$ | $0.86 \pm 0.11^{b}$ | $1.23 \pm 0.12^{a}$ | $0.49 \pm 0.0^{c}$ |
| NDW | $0.08 \pm 0.01^{b}$ | $0.09 \pm 0.02^{b}$ | $0.08 \pm 0.03^{b}$ | $0.1 \pm 0.03^{b}$ | $0.09 \pm 0.03^{b}$ | $0.12 \pm 0.08^{b}$ | $0.29 \pm 0.07^{a}$ | $0.05 \pm 0.01^{b}$ |
| SH | $72.7 \pm 10.78^{ab}$ | $60 \pm 7.8^{bcd}$ | $53 \pm 12.77^{cd}$ | $69.67 \pm 7.4^{abc}$ | $67 \pm 4.36^{abc}$ | $53.33 \pm 5.51^{cd}$ | $81.67 \pm 11.9^{a}$ | $47 \pm 3.61^{d}$ |
| SFW | $6.30 \pm 1.58^{ab}$ | $10.14 \pm 2.60^{a}$ | $5.26 \pm 1.47^{ab}$ | $8.29 \pm 0.39^{a}$ | $8.74 \pm 6.77^{a}$ | $9.59 \pm 0.75^{a}$ | $10.27 \pm 2.88^{a}$ | $2.46 \pm 0.2^{b}$ |
| RFW | $0.69 \pm 0.19^{bc}$ | $1.33 \pm 0.55^{a}$ | $0.38 \pm 0.14^{c}$ | $0.58 \pm 0.07^{bc}$ | $0.29 \pm 0.16^{c}$ | $0.76 \pm 0.40^{abc}$ | $1.05 \pm 0.42^{ab}$ | $0.28 \pm 0.0^{c}$ |
| RDW | $0.23 \pm 0.06^{ab}$ | $0.25 \pm 0.10^{a}$ | $0.26 \pm 0.07^{a}$ | $0.22 \pm 0.03^{ab}$ | $0.23 \pm 0.1^{ab}$ | $0.29 \pm 0.13^{a}$ | $0.35 \pm 0.09^{a}$ | $0.1 \pm 0.03^{b}$ |

Means with the same letter are not significantly different at $p \leq 0.05$ with Duncan grouping using (mean ± SD)

TABLE V: GROWTH PERFORMANCE OF GRASS PEA ON ORGANIC AMENDED SOILS UNDER GREENHOUSE TRIALS NFW- NODULE FRESH WEIGHT, NDW- NODULE DRY WEIGHT, SH- SHOOT HEIGHT, SFH- SHOOT FRESH WEIGHT, RFW- ROOT FRESH WEIGHT, RDW- ROOT DRY WEIGHT

| Factor | BAS | CAS | MAS | BCAS | BMAS | CMAS | BCMAS | CONT. |
|---|---|---|---|---|---|---|---|---|
| NFW | $0.61 \pm 0.09^{cd}$ | $0.75 \pm 0.08^{bc}$ | $0.61 \pm 0.1^{cd}$ | $0.83 \pm 0.09^{b}$ | $0.77 \pm 0.1^{bc}$ | $0.83 \pm 0.15^{b}$ | $1.11 \pm 0.14^{a}$ | $0.45 \pm 0.07^{d}$ |
| NDW | $0.07 \pm 0.01^{b}$ | $0.08 \pm 0.02^{b}$ | $0.07 \pm 0.03^{b}$ | $0.12 \pm 0.07^{b}$ | $0.07 \pm 0.03^{b}$ | $0.12 \pm 0.09^{b}$ | $0.28 \pm 0.07^{a}$ | $0.04 \pm 0.02^{ab}$ |
| SH | $83.67 \pm 3.8^{ab}$ | $96.33 \pm 2.89^{a}$ | $96 \pm 11.27^{a}$ | $91.67 \pm 10^{a}$ | $98 \pm 28.67^{a}$ | $96 \pm 19.08^{a}$ | $107.8 \pm 10^{a}$ | $65.67 \pm 4.04^{b}$ |
| SFW | $6.08 \pm 0.66^{bc}$ | $5.53 \pm 2.20^{c}$ | $6.99 \pm 2.1^{abc}$ | $7.44 \pm 1.23^{abc}$ | $8.31 \pm 0.49^{ab}$ | $8.89 \pm 1.05^{a}$ | $9.64 \pm 1.37^{a}$ | $2.89 \pm 0.56^{d}$ |
| RFW | $0.15 \pm 0.05^{b}$ | $0.14 \pm 0.01^{b}$ | $0.13 \pm 0.03^{b}$ | $0.17 \pm 0.05^{b}$ | $0.19 \pm 0.06^{b}$ | $0.16 \pm 0.04^{b}$ | $0.4 \pm 0.24^{a}$ | $0.11 \pm 0.002^{b}$ |
| RDW | $0.07 \pm 0.02^{b}$ | $0.06 \pm 0.03^{b}$ | $0.07 \pm 0.02^{b}$ | $0.08 \pm 0.02^{ab}$ | $0.08 \pm 0.02^{ab}$ | $0.05 \pm 0.0^{b}$ | $0.12 \pm 0.05^{a}$ | $0.03 \pm 0.02^{b}$ |

Means with the same letter are not significantly different at $p \leq 0.05$ with Duncan grouping using (mean ± SD)

The effect of single and combined OAs on the growth of alfalfa and grass pea were indicated in (Fig. 5) as compared to control treatment. The figures realized that combined application of biochar and other organic amendments showed better growth performance followed by single application as compared to the non-amended soil.


Fig. 5. The effect of single and combined organic amendments on the growth of alfalfa and grass pea crop compared to the control

## IV. CONCLUSION

The application of biochar and other organic amendments can recover soil fertility of degraded land. This study suggests that the utilization of easily available bio-waste for degraded land restoration to benefit the ecosystem and the community.

## ACKNOWLEDGMENT

The authors thank Addis Ababa University for financial support from Thematic Research Grant No. (TR-6223). Moreover, Microbial, Cellular and Molecular Biology Department of Addis Ababa University was highly acknowledged for administrative and financial support.

Competing Interests

We confirm that none of the authors have any competing interest in the manuscript.

## REFERENCES

[1] P. A. Lone, A. K. Bhardwaj, K. W. Shah, and F. A. Bahar, "Assessment of Soil Macronutrient Status of Some Threatened Medicinal Plants of Kashmir Himalaya, India," *Res. J. Bot.*, vol. 11, pp. 18-24, 2016.

[2] V. Tripathi, S. A. Edrisi, B. Chen, V. K. Gupta, R. Vilu, N. Gathergood, *et al.*, "Biotechnological Advances for Restoring Degraded Land for Sustainable Development," *Trends in biotechnology*, vol. 35, pp. 847-859, 2017.

[3] M. Tejada, I. Gómez, T. Hernández, and C. García, "Utilization of vermicomposts in soil restoration: effects on soil biological properties," *Soil Science Society of America Journal*, vol. 74, pp. 525-532, 2010.

[4] I. O. Utuk and E. E. Daniel, "Land degradation: a threat to food security: a global assessment," *J Environ Earth Sci*, vol. 5, pp. 13-21, 2015.

[5] A. Naseer and P. Pandey, "Assessment and monitoring of land degradation using geospatial technology in Bathinda district, Punjab, India," *Solid Earth*, vol. 9, p. 75, 2018.

[6] E. F. Lambin and P. Meyfroidt, "Global land use change, economic globalization, and the looming land scarcity," *Proceedings of the National Academy of Sciences*, vol. 108, pp. 3465-3472, 2011.

[7] P. Abhilash, V. Tripathi, S. A. Edrisi, R. K. Dubey, M. Bakshi, P. K. Dubey, *et al.*, "Sustainability of crop production from polluted lands," *Energy, Ecology and Environment*, vol. 1, pp. 54-65, 2016.

[8] L. V. Verchot, M. Van Noordwijk, S. Kandji, T. Tomich, C. Ong, A. Albrecht, *et al.*, "Climate change: linking adaptation and mitigation through agroforestry," *Mitig. Adapt. Atrat. GL.*, vol. 12, pp. 901-918, 2007.

[9] O. Kirui and A. Mirzabaev, "Costs of land degradation in Eastern Africa," in *International Conference of Agricultural Economists, with the theme of Agriculture in an Interconnected World, 29th August*, 2015.

[10] O. Kirui and A. Mirzabaev, "Cost of land degradation and improvement in Eastern Africa," in *2016 AAAE Fifth International Conference, September 23-26, 2016, Addis Ababa, Ethiopia*, 2016.

[11] M. Yesuf, S. Di Falco, T. Deressa, C. Ringler, and G. Kohlin, *The impact of climate change and adaptation on food production in low-income countries: evidence from the Nile Basin, Ethiopia*: Intl Food Policy Res Inst, 2008.

[12] T. Pistorius, S. Carodenuto, and G. Wathum, "Implementing forest landscape restoration in Ethiopia," *Forests*, vol. 8, p. 61, 2017.

[13] M. Wong, "Ecological restoration of mine degraded soils, with emphasis on metal contaminated soils," *Chemosphere*, vol. 50, pp. 775-780, 2003.

[14] C. Barrow, "Biochar: potential for countering land degradation and for improving agriculture," *Appl. Geogr.*, vol. 34, pp. 21-28, 2012.

[15] S. Steinbeiss, G. Gleixner, and M. Antonietti, "Effect of biochar amendment on soil carbon balance and soil microbial activity," *Soil Biology and Biochemistry*, vol. 41, pp. 1301-1310, 2009.

[16] S. P. Sohi, E. Krull, E. Lopez-Capel, and R. Bol, "A review of biochar and its use and function in soil," in *Advances in agronomy*. vol. 105, ed: Elsevier, 2010, pp. 47-82.

[17] A. C. Kennedy and K. Smith, "Soil microbial diversity and the sustainability of agricultural soils," *Plant and soil*, vol. 170, pp. 75-86, 1995.

[18] D. N. Suprapta, "Potential of microbial antagonists as biocontrol agents against plant fungal pathogens," *J ISSAAS*, vol. 18, pp. 1-8, 2012.

[19] C. G. Cogger, "Potential compost benefits for restoration of soils disturbed by urban development," *Compost science & utilization*, vol. 13, pp. 243-251, 2005.

[20] Meskerem Abi and Degefa Tolossa, "Household food security status and its determinants in girar jarso woreda, north Shewa zone of

oromia region, Ethiopia," *J. Sustain. Dev. Afr,* vol. 17, pp. 118-137, 2015.
[21] R. Margesin and F. Schinner, *Manual for soil analysis-monitoring and assessing soil bioremediation* vol. 5. SBerlin, Heidelberg: Springer Science & Business Media, 2005.
[22] V. D. Joshi, N. N. Palei, and P. R. Rachh, "Physico-chemical properties of four farm site soils in area surrounding Rajkot, Gujarat, India," *Int. J. Chem.Tech. Res.,* vol. 1, pp. 709-713, 2009.
[23] S. Sertsu and T. Bekele, "Procedures for soil and plant analysis," *Ethiopian Agricultural Reaserch organization, Addis Ababa, Ethiopia,* 2000.
[24] I. I. Bashour and A. H. Sayegh, *Methods of analysis for soils of arid and semi-arid regions*: FAO, 2007.
[25] ISO, "11261 Soil quality—Determination of total nitrogen—Modified Kjeldahl method," *Geneva, Switzerland: ISO,* p. 4, 1995.
[26] K. Tan, "Measurement of field capacity water," *Soil sampling, preparation, and analysis. Marcel Dekker, Inc., New York,* pp. 67-68, 1996.
[27] I. C. B. d. Silva, J. J. N. Basílio, L. A. Fernandes, F. Colen, R. A. Sampaio, and L. A. Frazão, "Biochar from different residues on soil properties and common bean production," *Scientia Agricola,* vol. 74, pp. 378-382, 2017.
[28] S. Tasneem and S. Zahir, "Soil respiration, pH and EC as influenced by biochar," *Soil Environ.,* vol. 36, pp. 77-83, 2017.
[29] A. Mukherjee, R. Lal, and A. Zimmerman, "Effects of biochar and other amendments on the physical properties and greenhouse gas emissions of an artificially degraded soil," *Science of the Total Environment,* vol. 487, pp. 26-36, 2014.
[30] A. Amusan, M. Adetunji, J. Azeez, and J. Bodunde, "Effect of the integrated use of legume residue, poultry manure and inorganic fertilizers on maize yield, nutrient uptake and soil properties," *Nutr. Cycl. Agroecosys.,* vol. 90, pp. 321-330, 2011.
[31] P. Trivedi, K. Singh, U. Pankaj, S. K. Verma, R. K. Verma, and D. Patra, "Effect of organic amendments and microbial application on sodic soil properties and growth of an aromatic crop," *Ecological engineering,* vol. 102, pp. 127-136, 2017.
[32] P. S. Pavinato and C. A. Rosolem, "Disponibilidade de nutrientes no solo: decomposição e liberação de compostos orgânicos de resíduos vegetais," *Rev. Bras. Ciênc. Solo.,* vol. 32, pp. 911-920, 2008.
[33] J. Chen, S. Li, C. Liang, Q. Xu, Y. Li, H. Qin*, et al.*, "Response of microbial community structure and function to short-term biochar amendment in an intensively managed bamboo (Phyllostachys praecox) plantation soil: effect of particle size and addition rate," *Science of the Total Environment*, vol. 574, pp. 24-33, 2017.
[34] V. Šimanský and A. Klimaj, "How Does Biochar and Biochar With Nitrogen Fertilization Influence Soil Reaction?," *J. Ecol. Eng.,* vol. 18, 2017.
[35] S. Odoemelam and O. Ajunwa, "Heavy metal status and physicochemical properties of agricultural soil amended by short term applicaton of animal manure," *Curr. World Environ.,* vol. 3, 2017.
[36] M. I. Saldaña, R. Gómez-Álvarez, M. d. C. Rivera-Cruz, J. D. Álvarez-Solís, J. M. Pat-Fernández, and C. F. Ortiz-García, "The influence of organic fertilizers on the chemical properties of soil and the production of Alpinia purpurata," *Cienc. Investig. Agrar.,* vol. 41, pp. 215-224, 2014.
[37] D. E. Dodor, Y. J. Amanor, F. T. Attor, T. A. Adjadeh, D. Neina, and M. Miyittah, "Co-application of biochar and cattle manure counteract positive priming of carbon mineralization in a sandy soil," *Environ. Syst Res.,* vol. 7, p. 5, 2018.
[38] P. Mantovi, G. Baldoni, and G. Toderi, "Reuse of liquid, dewatered, and composted sewage sludge on agricultural land: effects of long-term application on soil and crop," *Water research,* vol. 39, pp. 289-296, 2005.
[39] M. Abbasi, M. Hina, A. Khalique, and S. Razaq Khan, "Mineralization of three organic manures used as nitrogen source in a soil incubated under laboratory conditions," *Communications in Soil Science and Plant Analysis,* vol. 38, pp. 1691-1711, 2007.
[40] G. Clark, N. Dodgshun, P. Sale, and C. Tang, "Changes in chemical and biological properties of a sodic clay subsoil with addition of organic amendments," *Soil Biology and Biochemistry,* vol. 39, pp. 2806-2817, 2007.
[41] S. Wu, Z. Cao, Z. Li, K. Cheung, and M. Wong, "Effects of biofertilizer containing N-fixer, P and K solubilizers and AM fungi on maize growth: a greenhouse trial," *Geoderma,* vol. 125, pp. 155-166, 2005.
[42] C. J. Reynolds, J. Piantadosi, and J. Boland, "Rescuing food from the organics waste stream to feed the food insecure: an economic and environmental assessment of Australian food rescue operations using environmentally extended waste input-output analysis," *Sustainability,* vol. 7, pp. 4707-4726, 2015.
[43] S. S. Malhi, S. A. Brandt, R. Zentner, J. Knight, K. S. Gill, T. S. Sahota*, et al.*, "Management strategies and practices for preventing nutrient deficiencies in organic crop production," in *Soils and Crops Workshop*, 2008.
[44] J. Schoenau, "The value of manure," in *Proceedings of the Manure Management 2000 Conference*, 2000, pp. 2-5.
[45] G. Nziguheba, C. A. Palm, R. J. Buresh, and P. C. Smithson, "Soil phosphorus fractions and adsorption as affected by organic and inorganic sources," *Plant and soil,* vol. 198, pp. 159-168, 1998.
[46] S. Melero, E. Madejón, J. C. Ruiz, and J. F. Herencia, "Chemical and biochemical properties of a clay soil under dryland agriculture system as affected by organic fertilization," *Eur. J. Agron.,* vol. 26, pp. 327-334, 2007.
[47] P. J. Withers, B. Ulén, C. Stamm, and M. Bechmann, "Incidental phosphorus losses–are they significant and can they be predicted?," *Journal of Plant Nutrition and Soil Science,* vol. 166, pp. 459-468, 2003.
[48] B. T. Nguyen, N. N. Trinh, C. M. T. Le, T. T. Nguyen, T. V. Tran, B. V. Thai*, et al.*, "The interactive effects of biochar and cow manure on rice growth and selected properties of salt-affected soil," *Arch. Agron. Soil Sci.,* pp. 1-15, 2018.
[49] K. Uzoma, M. Inoue, H. Andry, H. Fujimaki, A. Zahoor, and E. Nishihara, "Effect of cow manure biochar on maize productivity under sandy soil condition," *Soil Use. Manag.,* vol. 27, pp. 205-212, 2011.
[50] H. Tiessen, E. Cuevas, and P. Chacon, "The role of soil organic matter in sustaining soil fertility," *Nature,* vol. 371, pp. 783-785, 1994.
[51] B. Glaser, J. Lehmann, and W. Zech, "Ameliorating physical and chemical properties of highly weathered soils in the tropics with charcoal–a review," *Biology and fertility of soils,* vol. 35, pp. 219-230, 2002.
[52] C. Steiner, W. G. Teixeira, J. Lehmann, T. Nehls, J. L. V. de Macêdo, W. E. Blum*, et al.*, "Long term effects of manure, charcoal and mineral fertilization on crop production and fertility on a highly weathered Central Amazonian upland soil," *Plant and soil,* vol. 291, pp. 275-290, 2007.
[53] C.-H. Cheng, J. Lehmann, and M. H. Engelhard, "Natural oxidation of black carbon in soils: changes in molecular form and surface charge along a climosequence," *Geochimica et Cosmochimica Acta,* vol. 72, pp. 1598-1610, 2008.
[54] K. Y. Chan, L. Van Zwieten, I. Meszaros, A. Downie, and S. Joseph, "Agronomic values of greenwaste biochar as a soil amendment," *Soil. Res.,* vol. 45, pp. 629-634, 2008.
[55] A. K. Mensah and K. A. Frimpong, "Biochar and/or compost applications improve soil properties, growth, and yield of maize grown in acidic rainforest and coastal savannah soils in Ghana," *Int. J. Agron,* vol. 2018, 2018.
[56] D. Fischer and B. Glaser, "Synergisms between compost and biochar for sustainable soil amelioration," in *Manag. org. waste.*, ed: InTech, 2012, pp. 168-197.
[57] Abebe Nigussie, Endalkachew Kissi, Mastawesha Misganaw, and Gebermedihin Ambaw, "Effect of biochar application on soil properties and nutrient uptake of lettuces (Lactuca sativa) grown in chromium polluted soils," *Am. Eurasian. J. Agric. Environ. Sci.,* vol. 12, pp. 369-376, 2012.
[58] R. David and P. Dimitrios, "Diffusion and cation exchange during the reclamation of saline-structured soils," *Geoderma,* vol. 107, pp. 271-279, 2002.
[59] D. J. Walker and M. P. Bernal, "The effects of olive mill waste compost and poultry manure on the availability and plant uptake of nutrients in a highly saline soil," *Bioresource technology,* vol. 99, pp. 396-403, 2008.
[60] E. Ogbodo, "Effect of crop residue on soil chemical properties and rice yields on an ultisol at Abakaliki, Southeastern Nigeria," *Am. Eurasian. J. Sustain. Agric.,* vol. 3, pp. 442-447, 2009.
[61] M. Qadir and J. Oster, "Crop and irrigation management strategies for saline-sodic soils and waters aimed at environmentally sustainable agriculture," *Science of the total environment,* vol. 323, pp. 1-19, 2004.
[62] M. Mohammed, K. Kibebew, and M. Tekalign, "Fertility mapping of some micronutrients in soils of Cheha District, Gurage Zone, Southern Ethiopia," *Afr J Soil Sci,* vol. 4, pp. 313-320, 2016.
[63] C. A. Hebbern, K. H. Laursen, A. H. Ladegaard, S. B. Schmidt, P. Pedas, D. Bruhn*, et al.*, "Latent manganese deficiency increases transpiration in barley (Hordeum vulgare)," *Physiologia plantarum,* vol. 135, pp. 307-316, 2009.
[64] D. L. d. Carmo, L. B. d. Lima, and C. A. Silva, "Soil fertility and electrical conductivity affected by organic waste rates and nutrient inputs," *Rev. Bras. Ciênc. Solo.,* vol. 40, 2016.

[65] A. Inal, A. Gunes, O. Sahin, M. Taskin, and E. Kaya, "Impacts of biochar and processed poultry manure, applied to a calcareous soil, on the growth of bean and maize," *Soil Use. Manag.*, vol. 31, pp. 106-113, 2015.
[66] R. Lentz and J. Ippolito, "Biochar and manure affect calcareous soil and corn silage nutrient concentrations and uptake," *Journal of environmental quality*, vol. 41, pp. 1033-1043, 2012.
[67] J. Gartler, B. Robinson, K. Burton, and L. Clucas, "Carbonaceous soil amendments to biofortify crop plants with zinc," *Science of the Total Environment*, vol. 465, pp. 308-313, 2013.
[68] A. Maltas, H. Kebli, H. R. Oberholzer, P. Weisskopf, and S. Sinaj, "The effects of organic and mineral fertilizers on carbon sequestration, soil properties, and crop yields from a long-term field experiment under a Swiss conventional farming system," *Land Degrad. Dev.*, vol. 29, pp. 926-938, 2018.
[69] S. González-Ubierna, I. Jorge-Mardomingo, B. Carrero-González, M. T. de la Cruz, and M. Á. Casermeiro, "Soil organic matter evolution after the application of high doses of organic amendments in a Mediterranean calcareous soil," *Journal of Soils and Sediments*, vol. 12, pp. 1257-1268, 2012.
[70] M. Tejada and J. Gonzalez, "The relationships between erodibility and erosion in a soil treated with two organic amendments," *Soil. Till. Res.*, vol. 91, pp. 186-198, 2006.
[71] R. B. Bhattacharjee, A. Singh, and S. Mukhopadhyay, "Use of nitrogen-fixing bacteria as biofertiliser for non-legumes: prospects and challenges," *Applied microbiology and biotechnology*, vol. 80, pp. 199-209, 2008.
[72] F. Rezig, A. Mubarak, and E. Ehadi, "Impact of organic residues and mineral fertilizer application on soil–crop system: II soil attributes," *Arch. Agron. Soil Sci.*, vol. 59, pp. 1245-1261, 2013.
[73] E. Elhadi, A. Mubarak, and F. Rezig, "Effects of organic amendments on sand dune fixation," *Int. J. Recycl. Org. Waste Agric.*, vol. 5, pp. 1-8, 2016.
[74] M. Iqbal, A. G. Khan, and M. Amjad, "Soil Physical Health Indices, Soil Organic Carbon, Nitrate Contents and Wheat Growth as Influenced by Irrigation and Nitrogen Rates," *International Journal of Agriculture & Biology*, vol. 14, 2012.
[75] D. T. Güereña, J. Lehmann, J. E. Thies, A. Enders, N. Karanja, and H. Neufeldt, "Partitioning the contributions of biochar properties to enhanced biological nitrogen fixation in common bean (Phaseolus vulgaris)," *Biology and fertility of soils*, vol. 51, pp. 479-491, 2015.
[76] S. Mia, J. Van Groenigen, T. Van de Voorde, N. Oram, T. Bezemer, L. Mommer, *et al.*, "Biochar application rate affects biological nitrogen fixation in red clover conditional on potassium availability," *Agriculture, ecosystems & environment*, vol. 191, pp. 83-91, 2014.
[77] R. S. Quilliam, T. H. DeLuca, and D. L. Jones, "Biochar application reduces nodulation but increases nitrogenase activity in clover," *Plant and soil*, vol. 366, pp. 83-92, 2013.
[78] M. A. Rondon, J. Lehmann, J. Ramírez, and M. Hurtado, "Biological nitrogen fixation by common beans (Phaseolus vulgaris L.) increases with bio-char additions," *Biology and fertility of soils*, vol. 43, pp. 699-708, 2007.
[79] J. Harter, H.-M. Krause, S. Schuettler, R. Ruser, M. Fromme, T. Scholten, *et al.*, "Linking N 2 O emissions from biochar-amended soil to the structure and function of the N-cycling microbial community," *ISME J.*, vol. 8, p. 660, 2014.
[80] M. A. Benabderrahim, W. Elfalleh, H. Belayadi, and M. Haddad, "Effect of date palm waste compost on forage alfalfa growth, yield, seed yield and minerals uptake," *Int. J. Recyc. Org. Waste Agric.*, vol. 7, pp. 1-9, 2018.
[81] C. F. Tester, "Organic amendment effects on physical and chemical properties of a sandy soil," *Soil Science Society of America Journal*, vol. 54, pp. 827-831, 1990.
[82] M. Renčo, "Organic amendments of soil as useful tools of plant parasitic nematodes control," *Helminthologia*, vol. 50, pp. 3-14, 2013.
[83] Y. Bai, C. Zang, M. Gu, C. Gu, H. Shao, Y. Guan, *et al.*, "Sewage sludge as an initial fertility driver for rapid improvement of mudflat salt-soils," *Science of the Total Environment*, vol. 578, pp. 47-55, 2017.
[84] T. Mitran, P. K. Mani, N. Basak, S. Biswas, and B. Mandal, "Organic amendments influence on soil biological indices and yield in rice-based cropping system in coastal sundarbans of India," *Communications in soil science and plant analysis*, vol. 48, pp. 170-185, 2017.
[85] L. Yang, X. Bian, R. Yang, C. Zhou, and B. Tang, "Assessment of organic amendments for improving coastal saline soil," *Land Degrad. Dev.*, vol. 29, pp. 3204-3211, 2018.
[86] Y. Wu, Y. Li, C. Zheng, Y. Zhang, and Z. Sun, "Organic amendment application influence soil organism abundance in saline alkali soil," *European journal of soil biology*, vol. 54, pp. 32-40, 2013.
[87] V. N. Chaganti and D. M. Crohn, "Evaluating the relative contribution of physiochemical and biological factors in ameliorating a saline–sodic soil amended with composts and biochar and leached with reclaimed water," *Geoderma*, vol. 259, pp. 45-55, 2015.
[88] G. J. Kenicer, T. Kajita, R. T. Pennington, and J. Murata, "Systematics and biogeography of Lathyrus (Leguminosae) based on internal transcribed spacer and cpDNA sequence data," *American Journal of Botany*, vol. 92, pp. 1199-1209, 2005.

**Alemayehu Getahun Kassa,** Place of birth: Arsi Robe, Ethiopia, Birth date: 18/08/1989. Graduated in Biology- Wollega University, Ethiopia (2009), Master in Applied Microbiology-Bahir Dar University, Ethiopia 2011, PhD candidate Addis Ababa University, Ethiopia. Lecturer and researcher at Wachemo University. He has got an internship at Federal University of Londrina, Brazil. Mr. Alemayehu has 6 publications (Articles, Book chapters and Seminars). A Member of different associations

**Diriba Muleta Yadetie,** Place of birth: Wollega, Ethiopia, Date of birth: 25/06/1969. Graduated in Biology- Asmara University, Eritrea (1989). Master in Applied Microbiology- Addis Ababa University, Ethiopia (1999), PhD and Postdoc fellowships in Microbiology- Swedish University of Agricultural Sciences, Sweden (2007). Assistant editor, Leader to Sub-Projects, Reviewer to various local and international Journals. Associate Prof of Applied Microbiology. Dr. Diriba has over 100 publications (papers, books, book chapters, technical reports) and is also member of different associations and Vice President**.**

**Fassil Assefa Tuji,** Place of birth: Addis Ababa, Ethiopia, Date of birth (1955). Graduated in Biology- Addis Ababa University, Ethiopia (1979), Master in Zoology- Addis Ababa University, Ethiopia (1983), PhD in Microbiology- University of Bayreuth, Germany (1993). Works at different Positions. Associate Professor of Applied Microbiology. Dr. Fassil has over 150 publications (papers, books, book chapters, technical reports) and is a member of different academic associatis.

**Solomon Kiros Fantaye,** Place of birth: Mekelle, Ethiopia, date of birth: 14/01/1978. Graduated in Animal and Range Science- Mekelle University (1998), Master in Biological Environment- Nagasaki University, Japan (2008) and PhD in Applied Biotechnology- Nagasaki University, Japan (2012). Instructor and researcher at Addis Ababa Institute of Technology. Dr Solomon has over 30 publication (papers, books, book chapters, technical reports). He is the project leader and member of various associations..

**Mariangela Hungria da Cunha,** Place of birth Sao Paulo, Birth date: 06/02/1958. Graduated in Agronomy – USP, Sao Paulo, Brazil (1979), Master in Soils and Plant Nutrition - USP, Sao Paulo, Brazil (1981), Ph.D. in Agronomy (Soil Science) by Federal Rural University of Rio de Janeiro, Brazil (1985), post-doc at Cornell University (1989), University of California - Davis (1991), and University of Seville (1998). Professor Mariangela has over 700 publications (papers, books, book chapters, technical reports). Member of editorial boards of international journals, different associations and Vice-president and president. Professor, received the Medal of Merit by the Administrative Council of Agronomists of Paraná.