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Synergy in soil organic amendments production and use for carbon sequestration and sustainable drylands agriculture

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Abstract

The potentials of biodegradable wastes conversion to soil amendments to improve soil condition and sequester carbon, in Kano, Nigeria was investigated. Kano was divided into four residential patterns based on GIS image. Wastes were collected from bins in ten random households in each segment bi-weekly. The wastes were segregated into biodegradable and non-biodegradable. Similar wastes were sourced from other locations and transformed into compost and biochar and added to maize fields with and without fertilizer. 60% of the wastes were found to be biodegradable. Biochar and compost were found to be light (0.21 and 0.31 g/cm3) and porous (87.54 and 69.09%) respectively. More recalcitrant materials (82.50%) and organic carbon (75.30%) were obtained in biochar. Organically amended soils were found to have higher organic carbon (7.36 and 6.54 g/kg) compared to sole inorganic fertilizer (6.34 g/kg) and the control (6.05 g/kg). A synergistic approach to the production and utilization of these products was proposed based on the conclusion that the use of organic amendments can improve carbon sequestration.

Keywords: Organic Amendments, Nigeria, Drylands

Introduction

There is low level of awareness among farmers about the benefits of organic soil amendments in Nigeria's drier areas. Excessive wastes generated in municipalities (Butu and Mshelia, 2014) as well as immeasurable amounts of rural agricultural wastes however present a potential for amendments production and use. Wastes has largely been managed in landfills across Nigeria, despite their tendency to contribute to greenhouse gases (GHGs) emissions (USEPA, 2007).

In addition to improving the declining fertility of dryland soils, organic amendments hold potential for boosting the carbon levels of such soils. A major problem associated with the use of such materials, especially in the drylands of Nigeria is however, the near total lack of empirical evidences on their impact on local crops and soils. Some literature exists on compost production and use (Lawal et al., 2007), but hardly any on biochar. This study was initiated to evaluate organic wastes generation pattern in metropolitan Kano, processing and conversion methods; including composting, anaerobic digestion and biochar production. It also evaluated impact of some of the products on some soil properties, especially organic carbon for its value in sequestering carbon. It finally proposed a synergistic method of production that can facilitate production and create awareness of use potentials among farmers.

Methodology

The study area

The study was conducted at the Faculty of Agriculture, Bayero University Kano, Nigeria. Kano lies between latitude 10 – 13^{o} N and longitude 8 – 9^{o} E within the dry, sub-humid agro-ecological zone of Nigeria.

Waste generation assessment

Kano city was segmented into four residential patterns based on housing concentration using google earth image and ground trothing. Two representative settlements were selected which included Hausawa and

Kabara; Gandu and Shagari Quarters; Gaida and Gaidar Fulani; and Gadama and Gadama Cikin Gari for very high, high, medium and low densities respectively. Waste bins were installed in ten randomly selected households in each category. Bins were evacuated bi-weekly. All synthetic materials were sorted from organic materials. Soil was sieved out from bins that had dry content and rinsed out in bins with wet content. The sorted materials were weighed separately.

Organic amendments production and use

For expediency, sorted municipal solid waste (MSW); livestock and arable farm wastes in forms of poultry litter; manure; and fresh/dried herbages and threshed maize cobs were separately sourced within the premises of the University and the faculty farm.

Anaerobic digestion

MSW was digested under anaerobic conditions in fabricated metallic and plastic anaerobic reactors for six weeks with frequent stirring. The digestion was done from August to September when temperature was sufficiently high to eliminate the need for heating.

Compost production

Compost was produced in pens by mixing the anaerobic digestate (AD) solids and leachate from the MSW digestion with dried and fresh herbages and poultry litter. The setup was moistened by applying approximately a liter of water to about 5 kg of compost material at an interval of 5 – 7 days after the first 10 days of the setup in the absence of an intervening rainfall. The setup was turned completely at an interval of 2 weeks and maintained for 2 months.

Biochar production

Biochar was produced in a fabricated metallic biochar kiln fitted with an inner cylindrical, airtight combustion chamber and an outer heater. Dried maize cobs with or without sawdust were filled to ¾ of kiln's volume and heated to about 450 - 500^{o}C for 2.30 – 3.00 hours. The system was allowed to cool overnight to prevent re-ignition.

Field trial

Field trial was conducted under irrigation with 5 tons ha^{-1} biochar: compost ratio of 100:0, 75:25, 0:100 supplemented with NPK at the rate of 60:30:30 kgha^{-1}; 100:0, 0:100 without NPK; 0:0 with NPK at 120:60:60 kgha^{-1} and a control plot that had neither biochar: compost nor NPK. The amendments were applied after land preparation before planting. Maize (EVDT 2009) was planted at inter and intra-row spacing of 75 and 25cm respectively. The plots were laid in randomized complete block design replicated three times. The gross and net plot sizes were 9 and 4.5m^{2} respectively.

Soil Sampling

Soil samples were collected between two randomly selected maize stands from two rows per plot and bulked. Soils were collected from plots with only 100% amendments, 100% NPK and the control three weeks after sowing.

Laboratory analyses

Compost and biochar were characterized before application. Soils were analyzed to evaluate potential impact of amendments on soil's properties. Biochar volatile matter, resident matter, porosity, pH and CEC were determined by the methods of McLaughlin et al. (2009); Compost and soil pH were determined in 1:2.5 material: water mixture with a pH meter; bulk density in all materials were determined by gravimetric method; N in soil, compost and biochar was determined by micro-Kjheldal technique (Adepetu et al., 2000). Organic carbon (OC) and CEC in compost and soil were respectively determined using wet oxidation and ammonium acetate saturation methods (Adepetu, 2000).

Data analyses

Simple percentage was used to estimate municipal's waste generation. Analysis of variance (ANOVA) was done using GenStat Statistical Package (Version, 2011). Carbon gain potential was estimated by projecting soil organic carbon to per hectare basis using a modification of the formula proposed by Saiz and Albrecht (2015) by multiplying organic carbon content with weight of the furrow slice to the depth of 15 cm.

Results

Waste generation pattern in Kano metropolis

The records (Table 1) showed that wastes generally increased with concentration of humans. The results further highlights the tendency for wastes across the settlements to be dominated (>60%) by biodegrable components.

Table 1: Summary of major findings

<table>
<tr><td colspan="6">Daily and monthly waste generation pattern in Kano</td></tr>
<tr><td rowspan="2">SAMPLING UNIT</td><td colspan="2">Monthly Record</td><td colspan="2">Per Visit Records</td><td rowspan="2">Average Family Size</td></tr>
<tr><td>Total waste (kg)</td><td>Biodegradable (kg)</td><td>Total waste (kg)</td><td>Biodegradable (kg)</td></tr>
<tr><td>Very high</td><td>1145.6</td><td>760.5</td><td>39.83</td><td>26.57</td><td>11.35</td></tr>
<tr><td>High</td><td>1139.7</td><td>790.8</td><td>43.46</td><td>29.58</td><td>8.7</td></tr>
<tr><td>Medium</td><td>694.6</td><td>420.9</td><td>24.3</td><td>14.77</td><td>7.5</td></tr>
<tr><td>Low</td><td>550.7</td><td>304.6</td><td>20.11</td><td>11.42</td><td>5.0</td></tr>
<tr><td>TOTAL</td><td>3550.6</td><td>2276.8</td><td>127.7</td><td>82.34</td><td></td></tr>
<tr><td>%</td><td>100</td><td>64.14</td><td>100</td><td>64.48</td><td></td></tr>
<tr><td colspan="6">Physical and chemical properties of the organic amendments</td></tr>
<tr><td colspan="2">Property</td><td colspan="2">Biochar</td><td colspan="2">Compost</td></tr>
<tr><td colspan="2">Yield/Kg Biomass (%)</td><td colspan="2">78.00</td><td colspan="2">68.107</td></tr>
<tr><td colspan="2">pH</td><td colspan="2">6.55</td><td colspan="2">7.57</td></tr>
<tr><td colspan="2">Bulk density (gcm^{-3})</td><td colspan="2">0.21</td><td colspan="2">0.31</td></tr>
<tr><td colspan="2">Porosity (%)</td><td colspan="2">87.54</td><td colspan="2">69.09</td></tr>
<tr><td colspan="2">Moisture content (%)</td><td colspan="2">1.01</td><td colspan="2">26.28</td></tr>
<tr><td colspan="2">N (gkg^{-1})</td><td colspan="2">7.70</td><td colspan="2">13.42</td></tr>
<tr><td colspan="2">CEC ($cmolkg^{-1}$)</td><td colspan="2">18.70</td><td colspan="2">23.07</td></tr>
<tr><td colspan="2">Mobile matter (%)</td><td colspan="2">15.50</td><td colspan="2">18.00</td></tr>
<tr><td colspan="2">Resident matter (%)</td><td colspan="2">82.50</td><td colspan="2">52.50</td></tr>
<tr><td colspan="2">Organic carbon (%)</td><td colspan="2">75.30</td><td colspan="2">28.80</td></tr>
<tr><td colspan="6">Effects of amendments on selected soil properties</td></tr>
<tr><td>Amendments</td><td>N gkg^{-1}</td><td>OC gkg^{-1}</td><td>CEC $cmolkg^{-1}$</td><td colspan="2">pH</td></tr>
<tr><td>100B0CNF*</td><td>0.86</td><td>7.36</td><td>7.644</td><td colspan="2">7.179</td></tr>
<tr><td>100C0BNF**</td><td>0.74</td><td>6.54</td><td>6.967</td><td colspan="2">7.190</td></tr>
<tr><td>0B0CFF***</td><td>1.01</td><td>6.34</td><td>7.956</td><td colspan="2">7.011</td></tr>
<tr><td>0B0C0F****</td><td>0.89</td><td>6.05</td><td>7.811</td><td colspan="2">7.432</td></tr>
<tr><td>SED±</td><td>0.0966</td><td>0.68</td><td>1.492</td><td colspan="2">0.1598</td></tr>
<tr><td colspan="6">Projected SOC difference between treatments</td></tr>
<tr><td>Treatment</td><td>OC gkg^{-1}</td><td>Projected value: $Mgha^{-1}$</td><td colspan="3">Difference Between highest & lowest: $Mgha^{-1}$</td></tr>
<tr><td>100B0CNF</td><td>7.36</td><td>16.56</td><td colspan="3">-</td></tr>
<tr><td>100C0BNF</td><td>6.54</td><td>14.715</td><td colspan="3">1.845</td></tr>
<tr><td>0B0CFF</td><td>6.34</td><td>14.265</td><td colspan="3">2.295</td></tr>
<tr><td>0B0C0F</td><td>6.05</td><td>13.6125</td><td colspan="3">2.9475</td></tr>
</table>

*100B0CNF = 100%Biochar:0%Compost:0%NPK **100C0BNF = 100%Compost:0%Biochar:0%NPK ***0B0CFF = 0%Biochar:0%Compost:100%NPK ****0B0C0F = 0%Biochar:0%Compost:0%NPK

Properties of compost and biochar

The results (Table 1) revealed that both materials are light and porous. There was relatively higher N and CEC in compost than biochar. There was however more recalcitrant matter and organic carbon in the biochar.

Effects of amendments on some soil properties

None of the treatments (Table 1) produced any significantly different effect on any of the properties. Compared to the control and the sole inorganic fertilizer treated soil, the organically amended soils had higher organic carbon with amount in the biochar amended field being the highest.

Proposed synergy in production and use of organic amendments

As a way forward, a synergistic approach to the production and utilization of these products is hereby proposed as depicted in Figure 1. It is a system in which output from one process serves as input into another production until the desired products are obtained.

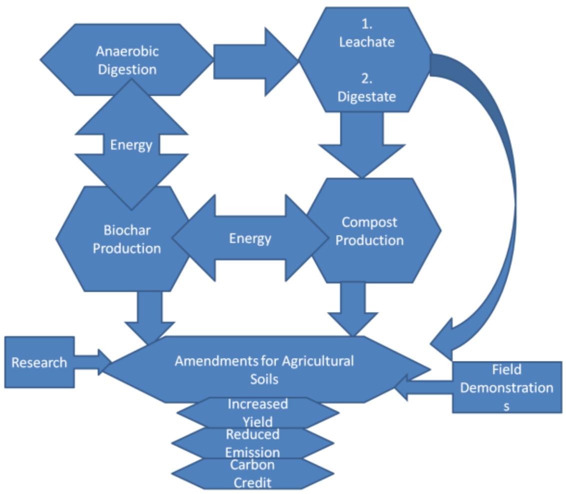

Fig. 1: Synergistic approach to soil amendments production and use

Discussion

The high levels of biodegrable wastes in the composition of the wastes heightens the fear entertained by researchers that landfills constitute major risk factors in GHG emission. The over 65% recovery potentials of the waste in the forms of the amendments is however encouraging and presents a viable option that can be exploited on a large scale basis. The higher recalcitrant and carbon content in biochar make it a better potential material for carbon sequestration. Biochar, according to Schimmelpfennig and Glaser (2012) is relatively stable against microbial decomposition due to its recalcitrance.

The lack of the significant effects of the addition of the amendments on the soil properties in the short term does not warrant any judgment on their effect. Lack of significant effect of both amendments in the short term has been highlighted by Liu et al., (2012) at field levels. The difference of about 3 Mg/ha between biochar plots and the control could make a huge impact in the soil's carbon stock especially if the extensive arable lands of the region are to be brought under similar treatment.

Conclusions

It can be concluded that the use of organic amendments in the two forms evaluated holds potentials in improving the soil carbon stock of the area. Their popularization is therefore recommended.

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