Available residues and potential utilization of biochar in farm lands for Turkey

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Torrefaction

Thermo-chemical
- Pyrolysis
- Gasification
- Combustion

Bio-chemical
- Alcohol Fermentation
- Anaerobic Fermentation

Physico-chemical
- Trans-esterification
- Pelletization

TORREFACTION
Approximately at 300°C
Torrefaction

- By-product of other thermal processes
  Drying/Grindability/Long term storage

- Soil amendment
  Useable carbon source

- Alternative fuel to coal
  %30 Higher volumetric energy density
A key technology to reach a 50% CO₂-eq. emission reduction in the energy sector by 2050 compared to 2005 levels.

Systems are carbon negative by transforming the carbon in biomass into stable carbon structures in biochar which can remain sequestered in soils for hundreds and even thousands of years.
Field Application in Australia

- Biochar produced from poultry litter at 450°C and 550°C
- Application to radish production in soil quality of a hardsetting Chromosol (Alfisol)
  ✓ The yield increased, compared with the unamended control field from 42% at 10 t/ha to 96% at 50 t/ha of biochar application

- Sweet corn 59 days after sowing (8 Feb 2008)
- Field trial growing corn in a ferrosol amended with different rates of agrichar.
  ✓ resulted in 35 tonnes of fresh corn produced, compared to 16 tonnes of fresh corn with no agrichar.

Source: Chan et al., 2008; NSW Department of Primary Industries, Best Energy
### Yield Increases Based On Different Crops

<table>
<thead>
<tr>
<th>TYPE OF CROP</th>
<th>AUTHORS</th>
<th>LOCATION</th>
<th>TYPE OF SOILS</th>
<th>QUANTITY of BIOCHAR (t/ha)</th>
<th>YIELD INCREASES (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice</td>
<td>Asai et al.</td>
<td>Houay-Khot, Nord du Laos</td>
<td>upland</td>
<td>8</td>
<td>70%</td>
</tr>
<tr>
<td>Rice</td>
<td>Steiner et al.</td>
<td>Manuas, Brésil</td>
<td>xanthic ferralsol / laterite</td>
<td>11</td>
<td>73%</td>
</tr>
<tr>
<td>Rice</td>
<td>Masulili et al.</td>
<td>Sungai Kakap, Indonesia</td>
<td>acid sulphate soil</td>
<td>10</td>
<td>93%</td>
</tr>
<tr>
<td>Sugarcane</td>
<td>Chen et al.</td>
<td>Okinawa, Japan</td>
<td>shima jiri maji (clay)</td>
<td>7,2</td>
<td>78%</td>
</tr>
<tr>
<td>Tomato</td>
<td>Effah et al.</td>
<td>Kade, Ghana</td>
<td>forest ochrosol</td>
<td>7</td>
<td>177%</td>
</tr>
<tr>
<td>Cotton</td>
<td>Reddy</td>
<td>Midjil Mandal, Andhra Pradesh, India</td>
<td>alkaline</td>
<td>3,75</td>
<td>100%</td>
</tr>
<tr>
<td>Cabbage</td>
<td>Carter et al.</td>
<td>Siam Reap, Cambodia</td>
<td>sandy acidic</td>
<td>100</td>
<td>750%</td>
</tr>
<tr>
<td>Maize</td>
<td>Major et al.</td>
<td>Llanos Orientales, Colombia</td>
<td>savanna oxisol</td>
<td>8, 20</td>
<td>71%, 140%</td>
</tr>
<tr>
<td>Maize</td>
<td>Kimetu et al.</td>
<td>Vihiga, western Kenya</td>
<td>highly degraded ultisol</td>
<td>6</td>
<td>71%</td>
</tr>
<tr>
<td>Peanut</td>
<td>Islami et al.</td>
<td>Malang, Indonesia</td>
<td>clay loam</td>
<td>15</td>
<td>54%</td>
</tr>
<tr>
<td>Cowpea</td>
<td>Tagoe et al.</td>
<td>Gifu, Japan</td>
<td>sandy loam</td>
<td>-</td>
<td>146%</td>
</tr>
<tr>
<td>Onion</td>
<td>Pro-Natura</td>
<td>Senegal</td>
<td>-</td>
<td>10</td>
<td>50%</td>
</tr>
<tr>
<td>Wheat</td>
<td>Van Zwietan</td>
<td>NSW, Australia</td>
<td>ferralsol</td>
<td>15</td>
<td>170%</td>
</tr>
<tr>
<td>Wheat</td>
<td>Vaccari et al.</td>
<td>Postoia, Italy</td>
<td>silty loam</td>
<td>30</td>
<td>33%</td>
</tr>
<tr>
<td>Canola</td>
<td>Pervej-Ahmed et al.</td>
<td>Saskatchewan, Canada</td>
<td>brown loam soil</td>
<td>1</td>
<td>20%</td>
</tr>
<tr>
<td>Barley</td>
<td>Gathorne-Hardy et al.</td>
<td>United Kingdom</td>
<td>light soil</td>
<td>20</td>
<td>43%</td>
</tr>
</tbody>
</table>

Inorganic contaminants can be absorbed to biochar surfaces because of their large surface area and cation exchange capacity.

It may cause a direct risk for soil biota.

✓ For long term use, the stability of biochar in soil must be investigated and the interactions between biochar and soil biota unambiguously identified.

Source: Beesley et al., 2011, Lehmann et al. 2011; Mynott, 2014
<table>
<thead>
<tr>
<th>Biochar Standards</th>
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</thead>
<tbody>
<tr>
<td><strong>Carbon Content</strong></td>
</tr>
<tr>
<td></td>
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<tr>
<td></td>
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<tr>
<td></td>
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<tr>
<td></td>
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<tr>
<td><strong>H/C&lt;sub&gt;org&lt;/sub&gt; and O/C&lt;sub&gt;org&lt;/sub&gt;</strong></td>
</tr>
<tr>
<td><strong>Heavy metal As, Cd, Cr, Co, Cu, Ni, Pb, Hg, Mo, Se, Zn, B [mg/kg&lt;sub&gt;db&lt;/sub&gt;]</strong></td>
</tr>
<tr>
<td><strong>PAH (EPA)</strong></td>
</tr>
<tr>
<td><strong>pH Value</strong></td>
</tr>
<tr>
<td><strong>BET Surface Area</strong></td>
</tr>
<tr>
<td><strong>PCB, Dioxins/Furans</strong></td>
</tr>
</tbody>
</table>

Total N, nutrients, electrical conductivity, Volatile matter, bulk density, moisture etc.

Source: http://www.european-biochar.org/biochar/media/doc/IBI-EBC.pdf
CO₂ eq. emissions of Turkey

### CO₂ eq. emission distribution

<table>
<thead>
<tr>
<th>Sector</th>
<th>2009</th>
<th>2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy</td>
<td>%75,3</td>
<td>%72,5</td>
</tr>
<tr>
<td>Industrial process</td>
<td>%8,6</td>
<td>%13,4</td>
</tr>
<tr>
<td>Agriculture</td>
<td>%6,9</td>
<td>%10,6</td>
</tr>
<tr>
<td>Waste</td>
<td>%9,2</td>
<td>%3,5</td>
</tr>
</tbody>
</table>

Source: Turkish Statistical Institute
In 2015, the total utilized agricultural land and forest area in Turkey was 60,244 thousand hectares.

Distribution of Agricultural Land

Source: Turkish Statistical Institute
Distribution of Crop Production

Wheat
Vicia
Medicago sativa
Sainfoin
Barley
Potato
Sunflower

Cotton
Tobacco
along the coastline

Source: Ministry of Energy and Natural Resources - Turkish Biomass Energy Potential Map
Distribution of Residues from Crop Production

Total amount of residues: 142 million ton/year in 2015

Its energy content: 669 million GJ

Wheat, Barley, Cotton stalk, Corn stalk

Residues from fruit production: 75 million GJ
56% hazelnut, 30% olive tree residues

Source: Ministry of Energy and Natural Resources - Turkish Biomass Energy Potential Map
Regional Distributions of Forest Residues

Its energy content: 35.7 million GJ

Source: Ministry of Energy and Natural Resources - Turkish Biomass Energy Potential Map
The Large Soil Groups Present

- Alfisol
- Molisol
- Aridisol
- Verdisol
- Entisol
- Histosol

Source: https://cografyabilim.wordpress.com/tag/turkiye-buyuk-toprak-gruplari-harita-resmi/
Current maps cover the large soil groups and they are not adequate for scientific studies due to their high error rate.

New maps should be created by detailed soil surveys using current technology.

Since 2002, the General Directorate of Rural Services has been conducting a project named the “Soil Database of Turkey” in order to improve the knowledge about the soil taxonomy of Turkey.

Central and eastern Black Sea region was completed.

Source: Ozyazici et al., 2013; Black Sea Directorate of Agricultural Research Institute - TAGEM
26% of the soil texture: clay loam soil

22% of it: clay soil

pH value: neutral at a rate of 30% and slightly alkaline at a rate of 24%

Medium levels of organic material were detected in soils that had lower salinity and lime contents.

The arable soils were rich in terms of nitrogen but insufficient in available phosphorus.

Other regional soil survey and mapping projects are in progress.

Source: Ozyazici et al., 2013; Black Sea Directorate of Agricultural Research Institute - TAGEM
The chemical compositions of urban, industrial, agricultural, and rural top-soils in Izmir city.

High concentrations of lead (Pb), zinc (Zn) and cadmium (Cd) in soil samples were found because of iron-steel producers situated in the north of Izmir.

Source: Yatkin and Bayram, 2011
Southwestern Anatolia region: The concentration of Cr was found to be 20 times higher than the acceptable limit for Turkey. Besides Cr, the concentrations of cobalt (Co) and Ni were also found to be higher than the acceptable limits.

Marmara region: Cd, which has high environmental risk, was much more mobile in greenhouse samples than field samples.

Source: Sungur et al., 2016; Yalcin et al., 2016
The sum of lands under permanent crops, meadows, pastures and fallow land, was higher than the total sown area. These lands should be evaluated to increase the agricultural efficiency of Turkey.

Although the arable lands of Turkey prevail in seven regions, total crop production seems to be focused in southern, western and central Anatolia.

Compared to total crop production, the ratio of field crop production was substantially higher than that of other crop types.
Potential Biochar raw materials:
- The residues of wheat, barley, corn and cotton stalk, olive tree, forest and hazelnuts
- Hazelnut residues found at the coastline of the Black Sea region
- Cotton stalk and olive tree residues in the Aegean and Mediterranean regions
- Wheat, barley, corn stalk and forest residues could be suitable in all regions as well.
- If the half of forest residues alone is used in torrefaction, 430,000 t/year biochar and its energy of 12.5 million GJ/year could be obtained approximately.
It is clear that there are different soil types in the arable lands of Turkey and therefore soil survey and mapping studies should be performed in detail using current technologies.

It is foreseen that biochar, produced from selected residues, would be able to amend the soil texture of Turkey, if used together with fertilizer.

Moreover, farmers would not need to rest the soil for a period of time before re-cultivation and consequently, the ratio of fallow lands would be reduced in Turkey.

The utilization of biochar in these soils would help to protect food crops from some pollutants (such as heavy metals).

On the other hand, biochar can be used as commercial fuel and could support farmers by providing them as an additional income.