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Converting Agro-Waste into Biochar: Improving Soil Fertility and Productivity in ASAL Ecosystems

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Key Messages

- *Recycling rice-husk waste into biochar may increase soil nitrogen and phosphorus availability*
- *Biochar has the potential to improve soil productivity and agronomic yield and nutritional quality of* D. lablab *in rotational farming with cereals in Mwea and Bura.*
- *Biochar may reduce salt-toxicity as proved with Bura soil*

Context

The prevalent constrain of food insecurity in the arid and semi-arid lands (ASALs) continue to worsen due to deteriorating soil health and increasing rate of population growth (Bai and Dent, 2006). The economic contribution of the ASAL's agricultural sector has continued to fall from 30 per cent to 20 per cent of the national Gross Domestic Product (GDP) primarily due to soil degradation. In Mwea, this is due to intensive and continuous cereal mono-cropping with minimal organic inputs; while in Bura, it is as a result of salinization (Muchena, 2008, GoK, 2009, 2012). Also, the feed value chain supports only 0.28 per cent of the GDP and its production continues to decline due to the slow growth rate of the feed production industry estimated at 300 thousand metric tonnes (MT) in 2003 growing to only 570 thousand MT in 2018, low germplasm of drought-tolerant crops, and limited crop farming due to extended drought under erratic low rainfall. This has resulted in reduced livestock population head in the ASALs from 75 per cent to 60 per cent of national livestock between 2009 and 2019.

Following the Maputo Declaration 2006, Malabo Declaration 2014 and the publishing of Kenya's Vision 2030, and the United Nations Sustainable Development Goals, Kenya is expected to achieve an agricultural growth rate of 6 per cent per annum through an increase in the utilization of land, water resources, and in the rate of fertilizer application from 8 kilogrammes per hectare (Kg/Ha) to 50 Kg/Ha, including use of organic fertilizers. Negative environmental impacts associated with chemical fertilizers, however, remain a problem due to groundwater pollution by nitrate fertilizers and low germplasm of drought-tolerant legumes. An innovative upgraded technology for production of biochar, a carbonized form of organic waste generated by recycling in limited oxygen and heat, for soil amendment to improve soil health (nutrient stock and flows) in addition to the cultivation of locally available germplasm with traits for drought tolerance, can effectively address the constraints of food production in degraded soils resulting in a substantial increase in yield and nutritional quality improvement.

Approach and Results

In line with the Comprehensive Africa Agricultural Development Programme (Africa's policy framework for agricultural transformation, wealth creation, food security and nutrition, economic growth and

Plate 1: Rice Husks (Photo: Tim Mcdonnell)

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prosperity for all) to improve research, technology, and adoption, biochar was generated from the traditional kiln and a fabricated up-scaled carbonizer. Their qualities were compared to select superior biochar for soil amendment. *Dolichos lablab* Rongai (Bura ecotype) was cultivated in the amended soils of arid and semi-arid agro-ecosystems of Bura and Mwea.

The study was carried out in a greenhouse at the University of Nairobi and in open field research fields in Mwea and Bura belonging to National Irrigation Board for three years. The overall objective was to determine physical and chemical characteristics of biochar generated from the two technologies and select biochar with suitable quality to improve soil physical, chemical, and biological properties; and to assess the effect of biochar on crop yield and water use efficiency on a selected legume (*D. lablab* Rongai Bura ecotype) upon amendment in Mwea and Bura soils.

Domesticated and wild forage legumes (*Dolichos lablab cv Highworth, V. anguiculata, Arachis hypogea, Glycin max, Phaseolus vulgaris*, and *D. lablab* Rongai Bura ecotype) were collected from Mwea and Bura and three exotic pasture-legumes of *Stylosanthes* were evaluated for drought tolerance under Mwea and Bura ecosystems using the following criteria: dry matter production, grain yield, herbage biomass at maturity, water use efficiency, soil water retention, bulk density physical and chemical properties, promiscuity of the legumes to nodulation by rhizobia, and salt tolerance. Note that nodulation is the interaction between bacteria found in the soil and their plant hosts. It is very important for plants enabling them to access nitrogen, made available by the bacteria, from the air. The studies were carried out in field research stations of National Irrigation Board in Mwea and Bura, greenhouse and soil laboratories at the University of Nairobi between 2013 to 2017 (Ouna, 2019).

Effect of biochar on soil properties. Biochar generated amended in Mwea soils cultivated with *D. lablab* raised soil pH from 6.3 to 6.8, available phosphorus increased from 52 to 78 parts per million (ppm), and total mineralized soil nitrogen increased from 0.106 per cent to 0.276 per cent. Therefore it is extremely likely that biochar will raise pH in low fertile soil which has turned acidic towards neutral, increase the concentration of soil available phosphorus fertilizer and increase soil nitrogen. Also, under cultivation with *D. lablab* Rongai, while in Saline soils of Bura, biochar reduced salinity from 6.46 to 5.72 deciSiemens per metre (dS/m). dS/m is a measure of salinity based on electrical conductivity. This resulted in a significant increase in yield compared to crops grown in non-amended control in both Mwea and Bura soil.

Effect of biochar on soil biological property. Biochar increased the population of Rhizobia from 100 thousand cells /gram(g) to 5.9 billion in the soil of Mwea and from 1 thousand cells/g to 0.58 million cells/g in Bura soil; enhanced nodulation effectiveness from 11 to 33 nodules/plant in Mwea soil and 3 to 18 nodules/plant in Bura soils; and increased nitrogen fixation efficiency in *D. lablab* Rongai. Therefore, biochar did affect soil health as soil fertility and ecosystem functions increased in amended soils.

Water retention capacity and water use efficiency. Biochar improved soil water retention from a volumetric water content of 3.7 cm3/cm3 in control to 7.5 cm3/cm3 at 10 tonnes/ha and water use efficiency at 4.99 kg/ha/mm compared to control at 2.2 kg/ha/mm.

Legume yield. Optimum seed biomass of *D. lablab cv.* Rongai increased to 1,680 kg/ha from 877 kg/ha in control while herbage biomass at 50 per cent flowering was at 2016 kg/ha against 907 kg/ha in control. During seasons of low rainfall or extended drought, it seems likely that plants grown in soils amended with biochar at 10 tonnes/ha will have higher biomass production than control. Amendments with biochar had an impact on legume crop yield in Mwea soil.

Policy Recommendations

Short-Term

- The practice of soil amendment with biochar should be included in the management of ASAL soils, and over-cultivated cereal growing zones where soils are acidic and of low fertility for sustainable soil fertility management to increase crop production.
- Improve benefit sharing of technology with local communities in the ASALs by planning to expand existing technology for production and distribution of biochar, for amendment of Mwea or Bura soil through stakeholder training and capacity development with relevant authorities to improve soil productivity.

Medium-Term

- Expand ecological niche of *D. lablab* Rongai, Bura ecotype to semi-arid (Mwea) and as a pulse forage crop, in arid feedlots (Bura) under biochar farming to improve the production of herbage and seed and quality for livestock and human nutrition in the ASALs.

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Plate 2: Dolichos lablab Rongai (Bura ecotype) (Photo: Authors)

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