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SUSTAINABLE ALTERNATIVES TO SEQUESTRATION
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SESSION TWO
ORAL PRESENTATION A

CHARCOAL AS SOIL CONDITIONER AND NUTRIENT RETAINER – STUDIES IN THE HUMID TROPICS, AMAZÔNIA, BRAZIL

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Abstract

Agriculture in the humid tropics is mostly limited by low soil fertility and invasion of weeds. The nutrient retention capacity of most soils is low and applied mineral fertilizers are rapidly leached into subsoil. Small farmers can not afford continuous mineral fertilizer input to compensate for the losses. Hence the dominating agricultural praxis is shifting cultivation accompanied with slash and burn agriculture. Slash and burn agriculture is practiced by about 300 to 500 million people, affecting almost one third of the planet's 1500 million ha of arable land. The most commonly observed change in soil following slash-and- burn clearing of tropical forest is a short-term increase in nutrient availability due to ash deposition, rise in pH and soil heating. But a large proportion of nutrients is lost during combustion of biomass. After a few cropping cycles the land is abandoned due to nutrient depletion and weed invasion. The contribution of tropical rainforest burning to global warming is significant and the subsequent loss of soil organic matter causes nutrient depletion and further CO_2 emissions.

In the Brazilian Legal Amazon a hint to sustainable permanent agriculture might exist. This is the so-called Terra Preta de Indio or Amazonian Dark Earth (ADE). The sustained fertility in charcoal-containing ADE and the frequent use of charcoal as soil conditioner in Brazil and other parts of the world (mainly Japan) provided the incentive to study the effects of charcoal application to a highly weathered soil. For many small land owners in the vicinity of Manaus charcoal production provides a significant proportion of the family income. To carbonize the woody biomass (slash and char) instead of burning it (slash and burn) would sequester CO_2 if regrowing resources are used and maintain high SOM contents. On that score the authors described slash and char as a reasonable alternative to the widely practiced slash and burn agriculture. Soil charcoal additions were described to stimulate microbial activity and reduce leaching of nitrogen fertilizer. Microbial immobilization is an important nutrient retention mechanism in those soils highly affected by leaching. We suppose that microbial immobilization of easily leached nutrients (such as nitrogen) and solubilizing of mineral-bound phosphate could be further mechanism besides an increase in CEC and nutrient sorption how charcoal amendments improve nutrition of crop plants.

In a series of experiments, we are studying the use of charcoal in agricultural management of a highly weathered Xanthic Ferralsol on *terra firme* north of Manaus. In a randomized complete block design with five

replicates, 15 organic amendment combinations (compost, chicken manure, litter and charcoal) were established and plant growth of sorghum (*Sorghum bicolor*) was observed for 4 cropping cycles. Plots fertilized with mineral fertilizer (NPK and lime) and additional charcoal application showed a 40% increase in plant growth and 50% increase in yield as plots mineral fertilized alone. A maximum yield increase of more than 800% to due charcoal application was obtained in the second growing season without new fertilization. Charcoal amendments alone had no effect on plant growth. These results are evidence of charcoal's nutrient retention and/or sorption capacity and its positive effect on crop productivity. Additionally we measured soil nutrient content, pH, CEC, soil physical parameters and microbial biomass and activity.

The microbial population growth rate after addition of an easily degradable substrate (glucose) reflected the soil fertility and plant biomass production very well and the difference in charcoal amended and fertilized plots and fertilized plots without charcoal amendments was significant. The influence of charcoal to the microbial community and nutrient dynamics was studied in further experiments. Soil charcoal amendments increased the microbial activity and decreased losses of nutrients.

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SESSION ONE
ORAL PRESENTATION B

THE LINK BETWEEN TERRA PRETA DE ÍNDIO AND THE USE OF CHARCOAL TO IMPROVE SOIL QUALITY

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Amazonian Dark Earth – Terra Preta de Índio - Characterization

The Amazonian Dark Earth (ADE) or Terra Preta de Índio shows normally a plaggic, terric or hortic horizons. These horizons are identified by the dark matrix colors of the top layers, and presence of ceramics and charcoal pieces. The more widely accepted theory about the origin of these epipedons is that they were improved by Amerindian populations in Pre Colombian Indian settlements. The tophorizons on ADE sites show some differences on soil chemical, physical and hydraulic properties compared to the adjacent soils in the region. The tophorizon shows typically high amounts of P, calcium (Ca), magnesium (Mg) relative to the surrounding soils.

The high amounts of soil organic matter (SOM) and black carbon strongly influence the color, the structure and the hydraulic properties. The texture is lighter and the workability of the ADE is easier, and the drainage is, habitually, very good. Because of their easy workability and longer lasting in relation to surrounding soils, the local population intensively uses those sites. ADE sites seem to be a very resilient soil type to keep their good soil physical qualities as when submitted to an intensive soil management. In this paper we discuss some investigations concerning a better characterization and expansion of the knowledge of ADE sites. Moreover the approach to reproduce those soils using as key component charcoal residues are also reviewed and discussed.

Terra Preta reproduction

Many experiment, monitoring and modeling of the dynamic of the water, nutrients and soil organic matter in soil with addition of charcoal are on ongoing research in Manaus. The first experiment at field conditions, investigating the effect of a combination of mineral fertilizers and charcoal as a mean of reducing nutrient leaching tested anual crops in a randomized complete block design with 15 treatments with five replication including organic amendment combinations with and without fertilization (compost, chicken manure, litter and charcoal). Plots fertilized with NPK and lime + charcoal application showed better plant growth as plots fertilized alone. Our first experiment with Banana showed some better mineral nutrition for N in the plants growing on plots were charcoal were applied. A second experiment with Banana at Embrapa

research station is going for the third harvest. It has an experimental design with a 3^3 confounded factorial scheme. Three dosages of charcoal were tested (0, 13336 and 26672 L ha^{-1}), as well as three dosages of phosphorous (33.4, 66.8 and 113.6 kg P_2O_5 ha^{-1}), and three dosages of nitrogen (0, 90 and 180 kg N ha^{-1}) per cycle. The mineral sources used were residues of charcoal, simple superphosphate and urea, respectively. The results of the first cycle show significant effects of charcoal applications in the weight of the bunch, the number of fruits per bunch, diameter of the fruit and diameter of the pulp. In two cycles, the weight of the bunch was not statistically significantly changed by the applications of charcoal, phosphorous and nitrogen. In spite of this, with a larger charcoal application to the soil, the second cycle showed an approximate harvest of three tones of banana per hectare. In the second cycle, a decrease in the quantity of Mn was observed along with an increase in the amount of charcoal in the soil, which could be the result of the low solubility of Mn as a function of an increase in the pH level of the soil. A new experiment with the Brazilian plant Guaraná (*Paullinia cupana*). Guaraná when cultivated adopts a shrubby habit, growing two to three m in height. It's cultivation dates to pre-columbian times. The Guaraná consists of a crystallizable principle, called guaranine, identical with caffeine, which exists in the seeds. The powder is widely available and can be mixed with water or fruit juice and some sugar in the same way. This experiment has also 3^3 confounded factorial scheme. The treatments are: charcoal, chicken manure and bones meal. This experiment started last year and the first harvest is projected to be done next year. At this experiment in addition of the traditional agronomic parameters (survival rates, growth, harvest), soil nutrient and carbon dynamics, soil water content and the effect of soil covered by charcoal in the soil temperature were monitored. As preliminary results, the soil covered with charcoal showed a temperature variation similar to soil covered with grasses and lower than the bare soil.

Charcoal and pyroligenous acid are among the growing media available in the Central Amazon region, and are subproducts of the charcoal production process, and considered as stimulants of plants especially when applied together. A experiment was conducted using a medicinal plants native to the Amazonian region, the Crajiru (*Arrabidaea chica* Verlot). Crajiru belonging to the Bignoniaceae family, is currently extracted from the forest due to specially its anti-inflammatory and astringent properties. The objective of this research was to study the development of Crajiru in the following growing media: Plantmax® (commercial growing media) ; charcoal + chicken manure; sand; sand + charcoal and soil + chicken manure. In combination with and without application of pyroligenous acid. from the evaluated parameters, it was observed that charcoal could substitute the Plantmax growing medium with similar results, since it shows the same advantages of easy access and low costs.

We are also studying the socio-economic aspects for a future proposal concerning the feasibility of “slash-and-char” as an alternative to the “slash-and-burn” land clearing method and discusses opportunities for carbon sequestration through charcoal additions to the soil under this new praxis. Moreover some challengers and topics of research are reviewed and discussed.