Geophysical Research Abstracts
Vol. 15, EGU2013-13272, 2013
EGU General Assembly 2013

Can biochar serve as a toop to reduce soil GHG costs of agricultural production in the long term?

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With a growing world population and growing demands for bioenergy there is an urgent need to improve the greenhouse gas (GHG) emission-to-yield ratio of agricultural production. 'Young, production-fresh biochar has repeatedly been observed to reduce N2O emissions in a variety of agricultural soils, but it is unknown how long initial N2O-reducing effects will persist. Biochar-amended soils may even develop a potential for higher N2O emissions decades after Biochar application due to the formation of higher soil organic matter stocks when mineral N is applied. Unfortunately the longest-running field trials are not older than a few years, thus our ability for predictions is rather limited.

To investigate the long-term effect that Biochar addition to soils may have on soil GHG emissions we conducted three different laboratory incubation studies with potential 'long-term analogs' that may offer insights: (I) N-rich Biochar-manure compost, versus pure manure-compost, or manure-compost were the same amount of untreated, fresh Biochar was added; (II) temperate soil from a 100-year old charcoal making (kiln) site in Germany compared to the original adjacent forest soil; and (III) two tropical Terra preta soils (secondary forest and cultivation) compared to their respective adjacent ferralsols. None of the studies indicated that old, "aged" Biochar in soils or substrates will increase the risk for N2O losses. The Biochar-compost (I) still had significantly reduced N2O emissions, or was the same as the control. However, its biological activity (respiration) was significantly increased (122% of ctrl). In contrast, the fresh Biochar addition significantly reduced N2O emissions to 39% of the control, accompanied by significantly reduced respiration rates (50% of ctrl.). The kiln-area soil (II), compared to the corresponding adjacent forest soil (both at 60% of their respective WHCmax), did not exhibit higher N2O emissions after N-fertilization over the course of one month. The kiln soils' NH4+ concentration, net nitrification and respiration, and also its methane consumption activity were all significantly increased but the labile organic-C content was reduced. The overall N2O+CH4 greenhouse gas balance of the kiln soil (expressed in CO_2 equivalents) was significantly improved over that of the adjacent forest soil. Terra preta soils (III) did not show an increased potential for N2O formation before or after $NH4NO_3$ application. Only the adjacent secondary-forest soil exhibited a sharp but quickly declining N2O emission peak. Here, again, the biological activity of the Terra preta soils was always greater than those of the corresponding adjacent ferralsols.

We therefore conclude that, although the initial N2O-emission reducing capability of (untreated) biochar additions will not last forever, the danger of accelerated N2O formation in Biochar-amended soils will likely not be large in the long run. Moreover, the improved CO_2-to-N2O emission-ratios (soil respiration, as an indicator for soil fertility) observed throughout the investigated analogs in space and time provide room for careful optimism that biochar may indeed be a suitable management tool to improve GHG-emission-to-yield ratios of agricultural production in the long run.