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Former charcoal kiln sites where forest was cleared for cultivation: a case study of old biochar in cropland

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The use of biochar as a soil amendment is being increasingly investigated as a win-win solution for mitigating the anthropic CO_2 emissions and improving soil fertility. However, data on the long term impact of chars on soil properties are scarce, although they are crucial for better understanding the implications of large scale application of highly persistent biochars to soil. In Wallonia (Belgium), old charcoal kilns are found in most of the area that was forested in the late 18th century. Since then, a non-negligible part of the forest has been cleared for cultivation. Today, old charcoal-making platforms can be seen on bare soils as circular or elliptic black spots due to charcoal enrichment. In order to assess the long-term (>200 years) effects of biochar on soil chemical properties, seventeen kiln sites were chosen in several cropland areas of Wallonia on loessic luvisols (14) and loamy cambisols (3). Composite samples were taken in the ploughing layer (0 – 25 cm) and the underlying horizon (35 – 50 cm) in and out the kiln sites. The pH, total carbon (C) and nitrogen (N) contents, oxidizable carbon (CW&B), available phosphorus (Pav), cation exchange capacity at pH 7 (CEC), exchangeable cations content (Ca++, Mg++, K+, Na+) and loss on ignition at 550°C (LI550) were measured. In order to assess the impact of cultivation on charcoal aging, we also sampled four kiln sites on loessic luvisols under forest.
Here, we show that charcoal, diluted laterally by successive tillage, acts as a carbon surplus in the topsoil layer of the black spots. The charcoal-enriched horizon is characterized by higher CEC, C/N and C/LI550 ratio compared to the reference soil. Cultivation of former forest soils accelerates charcoal aging, likely due to a combined effect of mechanical (tillage splits charcoal fragments in smaller pieces and increases soil aeration) and biological actions (promoted by improved trophic conditions due to application of amendments and fertilizers over many decades). This is supported by (i) a decrease of charcoal C/N and C/LI550 ratios, (ii) a sharp increase in the CEC value per carbon unit (485 cmolc/kgC) and (iii) a greater ability to be oxidized by a K2Cr2O7 treatment as compared to forest sites. Additionally, we observe identical Pav contents in and out the charcoal kiln sites which may indicate that Pav is governed only by the native humic substance content. Exchangeable Ca++ and, to a lesser extent Mg++ are higher than in the reference soil, whereas the content of K+ is comparable. Considering the percentage of these cations on the CEC, we propose that the exchange complex of charcoal has a higher selectivity for Ca++ and Mg++, and a lower selectivity for K+ relative to that of native humic substances.
Our results provide new insights into the long-term impact of biochar on soil properties in cropland subject to intense cultivation in temperate climate.