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Impact of ancient charcoal kilns on chemical properties of several forest soils after 2 centuries

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Pyrogenic carbon plays a major role in soil biogeochemical processes and carbon budgets. Until the early 19th century, charcoal was the unique combustible used for iron metallurgy in Wallonia (Belgium). Traditional charcoal kilns were built directly in the forest: wood logs were piled into a mound and isolated from air oxygen with a covering of vegetation residues and soil before setting fire, inducing wood pyrolysis. Nowadays, ancient wood-charring platforms are still easy to identify on the forest floor as heightened domes of 10 meters in diameter characterized by a very dark topsoil horizon containing charcoal dust and fragments. Our goal is to assess the effects of wood charring at mound kiln sites on the properties of various forest soil types in Wallonia (Belgium), after two centuries. We sampled soil by horizon in 18 ancient kiln sites to 1.20 meter depth. The adjacent charcoal-unaffected soils were sampled the same way. We also collected recent charcoal fragments and topsoil samples from a still active charcoal kiln located close to Dole (France) to apprehend the evolution of soil properties over time. The pH, total carbon (C) and nitrogen (N) content, available phosphorus (Pav), cation exchange capacity at pH 7 (CEC), exchangeable cations (Ca++, Mg++, K+, Na+) and loss on ignition at 550°C (LI550) were measured on each soil sample. We separated the soil profiles in 5 groups based on the nature of soil substrate and pedogenesis for interpretation of the results.

We show that the total carbon stock is significantly increased at kiln sites due to higher C concentrations and greater depth of the organo-mineral horizon. The C/N ratio in charcoal-enriched soil horizons is significantly higher than in the neighboring reference soils but clearly attenuated compared to pure wood-charcoal fragments.

The CEC is higher in the charcoal-enriched soil horizons, not only due to higher C concentrations but also to increased CEC by carbon unit at kiln sites. The high negative charge of charcoal results from surface oxidation processes over time. This charge varies over quite a wide range of values according to soil type, which might be explained by the nature of the charred wood.

The surface soil horizons at kiln site show a completely desaturated exchange complex, comparable to the reference soils. However, the raise of the base saturation in the underlying horizons reflects the past liming effect of ashes produced by wood charring that has been completely erased from the topsoil in 200 years.

Exchangeable K+ in the topsoil layers of kiln sites is very low, which can be related to an enhanced selectivity for Mg++ and Ca++ on the exchange complex of old charred material. Similarly, very little Pav is extracted from charcoal-enriched horizons, suggesting that Pav is either reduced in quantity or in availability.

Our data clearly highlight the long-term effect of the accumulation of charred material on the evolution of soil chemical properties due to charcoal ageing and nutrient leaching.