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Survival of pyrogenic organic carbon in Brazilian grassland soils

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Introduction: Annual burning of grasslands is a common practice to remove old vegetation and to stimulate regrowth of the vegetation. This practice is often criticized for accelerating soil degradation, losses of soil organic matter (SOM) and increasing C-emission and air-pollution. On the other hand, a part of the released carbon will return to the biosphere by rain and increased photosynthetic activity. Additionally, as charcoal accumulating in and on the soil after incomplete combustion represents one of the most resistant forms of reduced organic matter, burning is assumed to increase the slow-cycling SOM pool. But, recently it was shown that with prolonged recovery time after ceasing annual burning in grassland soils the typical char pattern .....(Golchin et al., 1997) is lost for the A horizon within the first 20 to 30 years.

In search for answers concerning the stability and fate of pyrogenic organic carbon (PyOC) in natural systems and the impact of frequent fires on the respective SOM pools, soils from a chronosequence with increasing time span after ceasing annual burning (1 to 22 years) from a Campo region in the highlands of Rio Grande do Sul, Southern Brazil, were characterized by solid-state ^{13}C NMR spectroscopy. Its PyOM contents were determined as a function of soil depth and recovery time using a simplified method that is based on the combination of chemical oxidation with acid potassium dichromate and NMR spectroscopy.

Result: Increasing the time after stopping annual burning resulted in a decrease of the organic C and N concentration at all soil layers. The ^{13}CNMR spectra of the top 5

cm of all soils, however, show comparable but relative low aromatic C contribution of only 17% of total organic C and the respective ^{15}N NMR spectra identify the organic N as mainly derived from fire-unaffected organic residues. Characterizing the residue after chemical oxidation with dichromate assigns only 1 to 2% of their total organic C to aromatic chemical oxidation resistant elemental carbon (COREC). Accounting for a loss of 40% aromatic PyOC determined to occur during the chemical oxidation of grass-derived char, this attributes to a approximate PyOC contribution to the total soil organic carbon of 8% and 5% after 1 and 22 years of ceasing burning. This corresponds to 12 and 5 mg g^{-1} soil. Interestingly, with depth, the calculated relative PyOC contributions to the total organic C rise to 17% (1 year) and 8% (22 years), accounting to 7 and 3 mg g^{-1} soil in the region between 30-45 cm, respectively.

Conclusions: Ceasing frequent burning resulted in a SOM decline that is most tentatively caused by the reduction of the amount of decaying roots, remaining in the soil after combustion of the aboveground vegetation. At least in the top layers, the increase of biomass production due the fertilizing effect of burning seems to have a higher relevance with respect to C sequestration than the actual PyOC input.

In particular in the top layers, the PyOC contents were unexpectedly low, considering that in this region annual burning was applied since the arrival of the first Europeans. Possibly the high combustibility of grass prevented the accumulation of decent amounts of charred residues and as indicated by the decline of PyOC content with increasing recovery time, the humid climatic conditions fostered their fast degradation. The relative contribution of PyOC to SOM increased with depth, most likely due to transportation with leaching soil water. This observation points to the conclusion that transport of PyOC within the soil may be of higher importance than commonly assumed and has to be considered if the role of charcoal as a C sink in soils is elucidated.

References

.Golchin, A., Clarke, P., Baldock, J.A., Higashi, T., Skjemstad, J.O., Oades, J.M., 1997. Geoderma, 76, 155-174.