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Optimal thermolysis condition for soil C storage upon plant residue burning

KAJIURA, Masako[1*] ; WAGAI, Rota[1] ; HAYASHI, Kentaro[1]

[1]National Institute for Agro-Environmental Sciences

Crop residues are often burned in the field and mixed into soil. Yet the impact of this agricultural practice on soil carbon (C) sequestration remains unclear due to the heterogeneity in burning condition and the difficulty in monitoring the biodegradation of burned residues that include char in fields. Thus, identifying the quantitative relationship among burning condition, residue chemistry, and biodegradability is a critical first step. The residue burnt at higher temperature reduces greater mass yet the remaining residue becomes more recalcitrant via carbonization. The residue burnt at low temperature, on the other hand, maintain greater mass which experiences faster biodegradation due to its lability. A corollary to the trade-off relationship is the presence of threshold temperature range above and below which the residue carbon remained after experiencing both thermal decomposition and subsequent biodegradation is strongly reduced. To test the idea, we thermolyzed residues (rice straw and husk) at different temperatures (200-600 ℃) under two oxygen availability, and measured the changes in thermal C loss and the biodegradability of thermally-altered residues by laboratory aerobic incubation. The empirical model accounting for the both decomposition processes showed the emergence of threshold temperature range (330-400 ℃ at 10^2-10^3 year time scale) due to the expected trade-off relationship. This temperature range corresponded to the major loss of O-alkyl-C (cellulose and hemicellulose) and increase in aromatic-C. These findings show that the thermally-altered residues formed by the threshold range contributes the most to the long-term soil C storage in fire-prone ecosystems and may help to develop C sequestration strategy which takes advantage of field biomass burning, a widespread land practice in many parts of the world.

Keywords: black carbon, 13C NMR spectroscopy, rice residues, oxygen concentration, pyrolysis