

Comment on "Fire-Derived Charcoal Causes Loss of Forest Humus"

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Wardle *et al.* (Brevia, 2 May 2008, p. 629) reported that fire-derived charcoal can promote loss of forest humus and belowground carbon (C). However, C loss from charcoal-humus mixtures can be explained not only by accelerated loss of humus but also by loss of charcoal. It is also unclear whether such loss is related to mineralization to carbon dioxide or to physical export.

Wardle *et al.* (1) investigated the influence of fire-derived charcoal on the decomposition of soil organic matter in boreal forests and reported that charcoal mixed with forest humus shows greater mass loss than is suggested by the sum of mass loss determined for pure humus or pure charcoal alone. The 10-year experiment expands upon incubation studies elsewhere that have reported the same phenomenon using a simpler organic molecule, glucose (2), than the chemically more complex humus used by Wardle *et al.* However, the sole interpretation that humus decomposition was accelerated by the presence of charcoal is not well founded. Indeed, Hamer *et al.* (2) already demonstrated not only that mineralization of glucose increases by charcoal addition but also that mineralization of charcoal increases in the presence of easily decomposed carbohydrates. The same cannot be excluded in the study by Wardle *et al.* Indeed, the fact that the divergence between the calculated and experimentally determined mass loss of the humus-charcoal mixture occurred mainly before the first sampling suggests the priming to be short term. This hints toward a transient phenomenon involving oxidation of some comparatively labile component of fresh charcoal (3), rather than mineralization of humus.

If the dominant process were to be an increase of humus mineralization by charcoal through the mechanism proposed by Wardle *et al.* (1), we would expect continuing divergence of the expected and measured mass loss in the humus-charcoal mixture. Substrate-induced respiration remained higher in the mixture than the calculated sum after the first year, even though the difference in mass loss did not widen further. In addition, the argument that charcoal could not have mineralized in the mixture may not be valid without direct proof. As pointed out above, charcoal can be oxidized in the short term and can contain substantial amounts of labile compounds that disappear after a short period of weeks to months (3). The proportion of such compounds will depend on the formation of the charcoal and the type of organic matter it is generated from (4, 5) and would need to be directly determined for the charcoal used in the present experiment. Without the unambiguous proof provided by isotope tracing techniques, for example, it remains a challenge to draw conclusions about the direction in which priming occurred.

Whether charcoal enhanced humus loss or humus enhanced the loss of charcoal (or a combination of the two), the greater mass loss of the mixture at first glance questions whether accumulation of charcoal through natural fires (6) or deliberate application of biochar (7) will increase soil C. It seems relevant that Wardle *et al.* quantified the decline of mass or amounts of carbon in only one part of the system: within their buried mesh bags. Two important ques-

tions emerge for future studies: (i) was the decline in carbon mass really a consequence of carbon mineralization and hence a net loss of belowground carbon, or could it be explained by physical export of humified, dissolved, or colloidal organic carbon through the mesh and (ii) would such exported material have been stabilized upon contact with mineral soil? Soil minerals are known to have extraordinary ability to sequester carbon (8), and dissolved organic matter originating from humus layers is typically percolating in large quantities into the mineral horizon (9). This dissolved carbon can be stabilized on clay minerals for the long term (10). Including the underlying mineral soil into an analysis or possibly examining the effects of charcoal directly applied to mineral soil offers, then, exciting prospects. In the presence of mineral surfaces, greater microbial activity combined with more rapid processing of humus could result in a very different carbon dynamic than observations of the humus layer alone would allow. Such an approach could possibly even show greater ecosystem carbon stabilization in the presence of charcoal and hence turn the conclusion of the paper on its head. The answer to the broader question of what influence charcoal has on soil ecosystem carbon storage remains open and proves highly intriguing to follow.

References

1. D. A. Wardle, M.-C. Nilsson, O. Zackrisson, *Science* **320**, 629 (2008).
2. U. Hamer, B. Marschner, S. Brodowski, W. Amelung, *Org. Geochem.* **35**, 823 (2004).
3. C. H. Cheng, J. Lehmann, J. E. Thies, S. D. Burton, M. H. Engelhard, *Org. Geochem.* **37**, 1477 (2006).
4. J. C. C. Freitas, T. J. Bonugamba, F. G. Emmerich, *Carbon* **39**, 535 (2001).
5. C. I. Czimczik, C. M. Preston, M. W. I. Schmidt, R. A. Werner, E.-D. Schulze, *Org. Geochem.* **33**, 1207 (2002).
6. C. M. Preston, M. W. I. Schmidt, *Biogeosciences* **3**, 397 (2006).
7. J. Lehmann, *Nature* **447**, 143 (2007).
8. M. S. Torn, S. E. Trumbore, O. A. Chadwick, P. M. Vitousek, D. M. Hendricks, *Nature* **389**, 170 (1997).
9. C. S. Cronan, G. R. Aiken, *Geochim. Cosmochim. Acta* **49**, 1697 (1985).
10. K. Kaiser, G. Guggenberger, *Org. Geochem.* **31**, 711 (2000).

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