Estimating soil feedbacks to climate change

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General circulation models are increasingly being used to predict climate change. Whilst the land surface was previously seen as a static part of the climate system, feedbacks from the land surface are now increasingly being taken into account (Meir et al., 2006). These feedbacks include effects of changed climate and CO_2 concentration on plant growth and water use. At present the land surface and oceans take up about half the CO_2 emitted to the atmosphere, but it is uncertain if that will continue in the future (Houghton, 2003). Particularly it is uncertain how soil carbon storage will be affected. Increased CO_2 may increase plant production and thereby carbon input to the soil, but increased temperature may increase carbon loss through respiration (Rustad et al., 2001). Plant litter grown under increased CO_2 may also be less decomposable, and so increase the amount of carbon bound up in the litter pool (Körner, 2000). The increase in plant productivity may not be sustained over time because nutrients, usually nitrogen become limiting (Nowak et al., 2004). The best estimate at present is that the net uptake of CO_2 will peak before mid-century and then weaken and even reverse, thus amplifying climate change (IPCC, 2007).

The effect of increased CO_2 on plants can be described quite mechanistically using physically based equations for photosynthesis (Cox et al., 1999). The effect of changes in temperature and water availability can also be inferred from plant physiology. The effect of climate change on soils is much harder to predict, because there is little mechanistic knowledge available (Grace, 2004). Whilst most warming experiments show increased release of CO_2 (Couteaux et al., 2001; Pendal et al., 2004), it is uncertain how long this will continue. Furthermore, most decomposition experiments are performed with plant litter, even less is known about how soil organic matter will respond. Soils incubated at the mean annual temperature where they had developed showed no effect of temperature (Giardina and Ryan, 2000). This seems to suggest that that during warming, soils will release a lot of carbon in the beginning, but after a while at the new temperature they will come to a new equilibrium (Ågren and Bosatta, 2002). However, we do not know how long it will take before this new equilibrium is reached.

Most soil carbon models divide the carbon into several (2-5) conceptual pools of litter and soil organic matter with different turnover times (Parton et al., 1987; Jenkinson et al., 1987; Bradbury et al., 1993; Li, 2000; Hansen et al., 1993). Although there are probably a lot more different fractions in real soils, 2-5 pools gives enough degrees of freedom to describe CO_2 evolution during decomposition mathematically. The models usually use first order rate constants that can be modified by climatic factors (temperature and moisture). However, different models use different modifier functions, often with little experimental support. This will influence how the model predicts carbon storage in soils to change with climate change. Another question is if all pools of carbon (stable and labile) will respond equally to climate change. The general opinion seems to be that at least temperature affects all pools equally (Fang et al., 2005; Conen et al., 2006), although that is not always found (Waldrop and Firestone, 2004). Even less is known about the response to changes in soil moisture, although that could be a just as important effect of climate change.

Current work on the Hadley Centre general circulation model includes extending the soil carbon from a single pool model to multiple pool model, and introducing a nitrogen cycle to constrain the response of the carbon cycle to increased CO_2. However, it appears that more mechanistic studies on soil responses to climate are required to better constrain model responses.

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