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Carbon Use Efficiency and Turnover of Microbial Communities: Concepts and Emerging Techniques

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Microbial element use efficiencies are fundamental for understanding organic matter decomposition and ecosystem carbon and nutrient storage. Terrestrial decomposer communities thrive on a wide range of organic substrates, which rarely ever meet their elemental demands. One of the most important mechanisms by which microbes are able to maintain their elemental homeostasis is the release of the elements in excess by regulation of the respective element use efficiencies. Microbial carbon use efficiency (CUE), also termed growth efficiency, is defined as the allocation of consumed organic carbon to growth and is thus an integrated representation of microbial metabolism. Microbial CUE is thought to decrease in response to climate warming, although this has recently been questioned. If CUE decreased, more carbon would actually be released to the atmosphere per unit of carbon consumed in a future climate, with strong repercussions on the storage of organic matter in soils, including possible positive feedbacks to climate warming. The fate of carbon, however, may also depend on the turnover rate of the microbial community, which is also thought to increase by warming, but has rarely ever been measured. It is thus of utmost importance to be able to precisely measure both CUE and turnover rates of microbial communities. So far the analysis of microbial CUE and turnover rates has been hampered by methodological and conceptional issues. Specifically, the widely used approach to estimate CUE by following the partitioning of 13C-labelled substrates between biomass incorporation and respiration is thought to inflate CUE estimates. We will briefly review different concepts and methods to measure CUE and show that they are neither conceptionally nor technically sufficiently well applicable for the purpose described above. To overcome these problems, we developed a novel technique to concurrently estimate both microbial CUE and turnover rates based on the incorporation of 18O from labelled water into microbial DNA to estimate gross growth rates and measurements of microbial respiration. We will present the method and demonstrate first results that show that CUE estimates by this technique are considerably lower than estimates by the 13C approach and in the range predicted by thermodynamic considerations. We will further demonstrate the applicability of the method by showing results of a long-term nutrient deficiency experiment, demonstrating that CUE positively responded to nitrogen fertilisation, but not to fertilisation with phosphorus or potassium; microbial turnover rates were not affected. Results from a natural warming experiment and a field drought experiment also demonstrate that CUE of heterotrophic microbial communities was affected by temperature but not by drought and that microbial turnover can be affected independently from CUE by climate change.