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Proposed model for impacts of woody encroachment on groundwater CO_2 and mineral weathering in grassland watersheds

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Displacement of grasses by woody plants (woody encroachment) is occurring in grasslands worldwide. Previous studies indicate that woody encroachment can alter subsurface CO_2 concentrations and mineral weathering, though these impacts are not fully understood. To address this knowledge gap, we sampled groundwater and stream water every three weeks during the 2022 water year from two watersheds at Konza Prairie Biological Station, a native tallgrass prairie underlain by limestone and mudrock units in Kansas, USA. Amounts of woody encroachment differ between the watersheds primarily because of differences in fire frequency. One watershed is burned annually (~20% woody plant coverage) whereas the other is burned every four years (~40% woody plant coverage). We expected to find higher CO_2 levels in the more encroached watershed, assuming the deeper roots of woody plants increase inputs of water and CO_2 to bedrock. However, we found the opposite. Our results indicate that groundwater from the same limestone aquifer contained 1.4 mM CO_2 in the less encroached watershed and 1.0 mM CO_2 in the more encroached watershed. Despite differences in CO_2 levels, amounts of carbonate mineral weathering per liter of groundwater differed little between watersheds. We hypothesize that these results reflect a decrease in soil water residence time in response to changes in root properties that accompany encroachment. If water passes through soils relatively quickly, such as we expect for the more encroached watershed, the CO_2 added during recharge has little time to react with soil minerals before entering the underlying bedrock. Mineral weathering in the bedrock can then draw down CO_2 concentration as the water moves along groundwater flowpaths, given that bedrock CO_2 generation is likely small compared to that in the overlying soil. In contrast, if the water moves through soils more slowly, such as in the less encroached watershed, CO_2 added during recharge can react with soil minerals and the CO_2 that is consumed can be replaced by soil CO_2 generation, resulting in a greater concentration of CO_2 carried through the subsurface. If correct, this model implies that woody encroachment mainly impacts the depth rather than the amount of weathering.