# Conclusion

In this research, I have explored how three possible land use scenarios could affect the carbon balance of the agricultural Midwest. In each chapter I focused on a different aspect of belowground C flow, but I have tried to show how each study contributes toward reducing uncertainty about the C-cycling consequences of management decisions.

The business as usual scenario paints a grim picture: Higher temperatures increased microbial breakdown of soil organic matter, and higher soil C inputs under eCO2 appeared to prime further heat-related respiratory losses rather than offset them. Modeling the biogeochemical feedbacks of this whole process, I found that higher temperature and CO2 are likely to lead to profound losses of soil organic matter if continued for decades with conventional tillage and cropping rotations.

The high-intensity bioenergy cropping scenario looks more sustainable: Once established, high-yielding perennial grasses require little tillage, allocate tremendous amounts of C into the soil layers most likely to store them for long timescales, and still also produce an energy crop that can offset fossil fuel emissions. By correcting for an artifact of the minirhizotron imaging method, I produced good agreement between core-based and image-based estimates of root volume, opening the possibility of tracking whole root profiles at much higher temporal resolution than is possible with direct coring.

Prairie grasses, although lower-yielding than *Miscanthus* or switchgrass, also require little management input and would be likely to build soil C and support greatly increased biodiversity—but perhaps no profit—for any landowner who planted them. By high-throughput sequencing of root *ITS* regions, I showed that grasses tend to occur deeper in the soil than forbs, suggesting a degree of niche partitioning. Since grass roots often show lower decomposition rates than those of forbs, this suggests a possible further enhancement of C storage through enriching the deep soil layers in better-protected C while forbs maintain faster-cycling tissue near the surface.

Although these findings are informative, several key uncertainties remain. Climate change provided the motivating context for this project, but only maize and soybean were measured under climate-change conditions. Since the crops under consideration in the high-yielding scenario were all C4 grasses, I do not expect them to show dramatic CO2 responses, but water availability under high temperatures may have the potential to limit their growth. Fortunately the same deep rooting habits that make *Miscanthus* and switchgrass attractive C sinks are likely to also help them maintain resilience to limited water supplies; their apparent resilience to the dry summer of 2012 appears to confirm this. The prairie system, with a mix of C4 grasses and C3 forbs and legumes, may respond unpredictably; if the legumes in the prairie mix respond to heat and CO2 in the same way soybeans do, it is possible that prairie soils too could lose C to a CO2 priming effect.

An additional uncertainty is hidden in the phrase “once established” above: Perennials may well be more resilient to individual extreme events and be highly profitable once mature, but the grass systems I describe here require a 3-5 year establishment phase to reach maximum yield, and must continue growing for many years beyond that to build any substantial amount of soil C. This implies that any individual landowner who plants perennials is making a many-year commitment and needs assurance against crop failure or policy changes during the lag phase before production begins. Long-term carbon storage will require long-term cooperation from land owners and policies should be constructed to promote this. I hope this dissertation research has offered some small measure of help toward making those policies.