Optimizing for ecosystem carbon while managing for multiple goals

An informal guide for natural resource professionals, using The Nature Conservancy's Newell and Ann Meyer Nature Preserve as a case study

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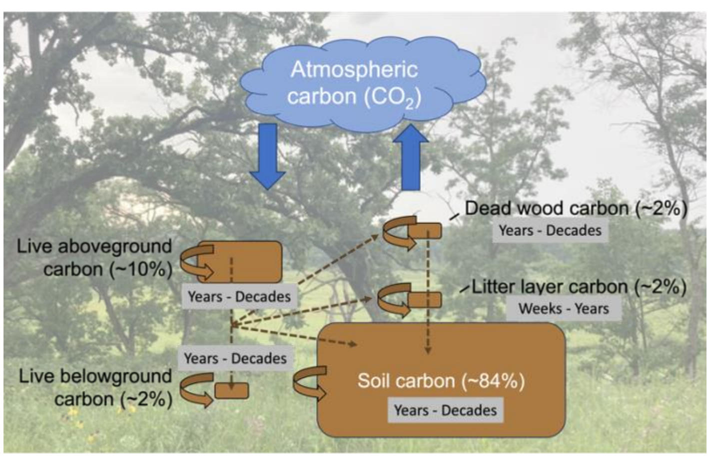
There is increasing interest from natural resource professionals to understand how carbon management aligns with other management goals. For example, at The Nature Conservancy's Newell and Ann Meyer Nature Preserve in southeastern Wisconsin, managers are considering how to restore oak savannas to support a high level of savanna-dependent plant biodiversity and maintain or increase carbon storage where feasible. Oak savannas are emblematic of how trade-offs between management goals can manifest. In these ecosystems, maximizing plant carbon storage is at odds with low canopy cover conditions that promote many native understory plant species. Here, we use the Meyer Preserve as a case study to demonstrate how land managers can consider carbon as one of multiple goals by prioritizing different goals in different patches across the landscape.

Where is carbon stored in the ecosystem?

Before diving into a conversation about managing for carbon, it is important to understand the fundamentals of carbon cycling and where carbon is stored within an ecosystem (see Figure). In terrestrial ecosystems, plants sequester carbon from the atmosphere via photosynthesis. This carbon is then stored in plants (live and dead plant tissues) and in soils. Over time, plant and soil carbon is emitted back to the atmosphere via decomposition or combustion (fire), completing the carbon cycle. The *stability* of carbon in the ecosystem refers to how long carbon persists in the ecosystem before being emitted back to the atmosphere, with greater stability providing more long-term climate mitigation benefits.

In most ecosystems, soils and live plant pools are the first and second largest pools of carbon in an ecosystem, respectively. In temperate oak savannas like the Meyer Preserve, more than 80% of total ecosystem carbon can be stored in soils. Approximately 50% of plant biomass is carbon, such that greater plant biomass means a bigger plant carbon pool. Temperate forests with closed canopies have more live plant biomass than savannas, but soils still commonly contain more than 50% of total ecosystem carbon in these ecosystems.



Distribution and movement of carbon in an oak savanna. This is an example (using a well-studied site at Cedar Creek Research Preserve in Minnesota) of the relative sizes of carbon pools in an oak savanna. Approximate mean residence times (indicating stability) are shown in grey boxes. Dotted lines indicate that carbon moves between pools before eventually being emitted back to the atmosphere. Actual carbon pool sizes and their stability vary across sites and are affected by management and disturbance.

How can management affect ecosystem carbon storage?

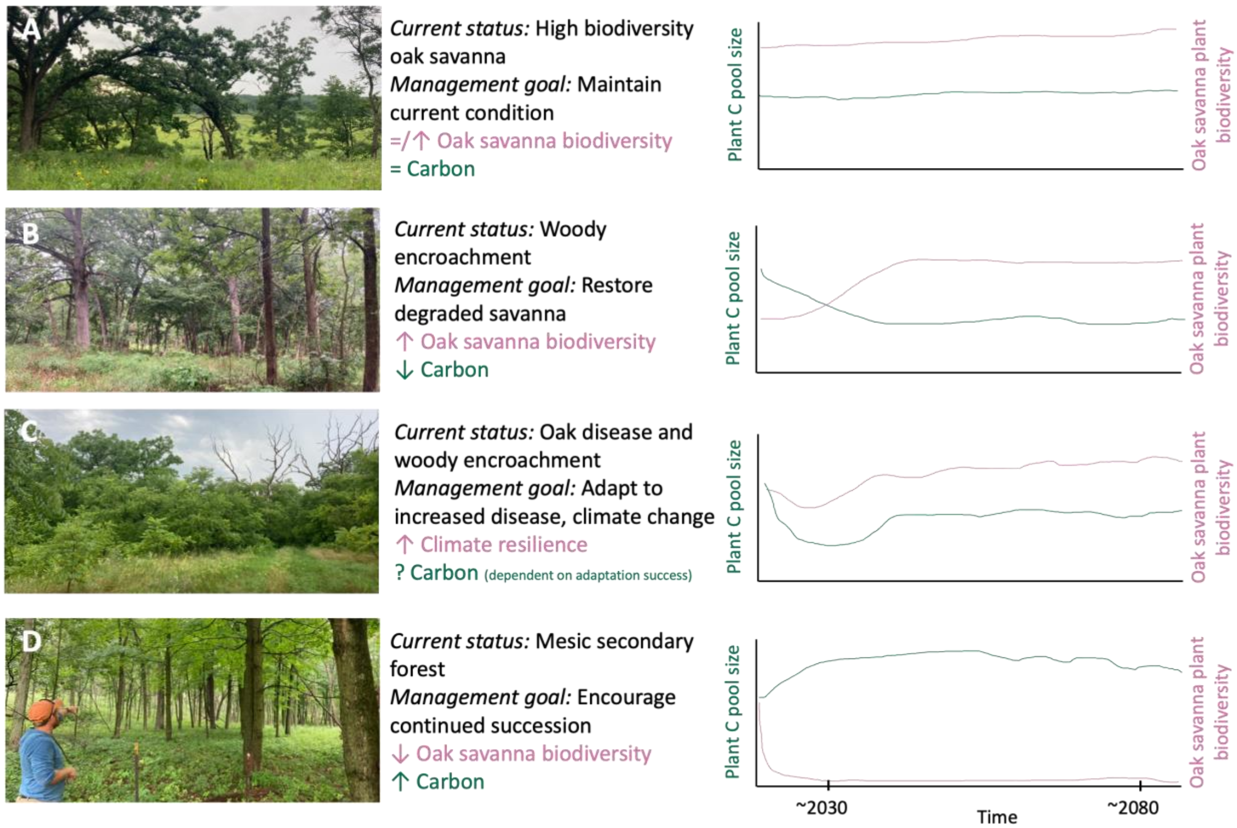
Soils are an important reservoir of long-term carbon storage. Apart from restoring highly disturbed sites, soil carbon pools cannot be quickly increased through management actions in natural systems due to the slow cycling of soil carbon. However, soil carbon pools can decrease quickly if soils are not protected. Management actions focused on carbon goals should prioritize preventing potential soil carbon losses while recognizing the limits to significantly increasing soil carbon storage in the short-term. In contrast, management actions can have significant and short-term effects (either positive or negative) on plant carbon storage. The magnitude of such effects should be evaluated by considering the relative size of plant versus soil carbon pools. For example, will there be a big effect on a small pool (e.g., burning understory vegetation at a site where understory live plant carbon represents ~5% of total ecosystem carbon?) or a big effect on a large pool (e.g., removing topsoil)? It is also important to consider the stability of the carbon pool affected by the management action. Significant changes to plant carbon pools can occur more quickly (years to decades) compared to soil carbon pools (decades to centuries), such that plant carbon pool losses can be recovered more quickly.

Using a patchwork approach to optimize for multiple goals

Considering the current status and unique management challenges of different management units across the landscape makes it possible to achieve multiple management goals despite potential inherent trade-offs between goals. For example, the Meyer Preserve and neighboring protected areas encompass a patchwork of lands that were previously oak savanna. Managing these patches for different goals can promote optimization of carbon and biodiversity goals across the broader landscape.

Below, pictured on the left, are four patches within the Preserve and associated lands that vary by condition. There are often multiple management goals being pursued at a given site; for the purposes of this example we are considering ecosystem carbon storage (focusing on the plant carbon pool) and savanna-dependent plant biodiversity. Within any given patch, it may make more sense to prioritize one goal over another given its status. For example, panel A shows a remnant oak savanna with high biodiversity where the management goal is to maintain current conditions such that oak savanna-dependent biodiversity will be maintained or increased and carbon will not be significantly affected. This contrasts with panel B, which shows a former oak savanna patch encroached by woody species such as black walnut and buckthorn. Here, the goal to restore oak savanna and increase savanna-dependent biodiversity will require removing woody biomass (and therefore reducing carbon storage).

On the right, potential trade-offs between carbon and biodiversity management goals are illustrated for each patch. At the Meyer Preserve, we combined scientific and land manager expertise to qualitatively map potential trade-offs. We did not do quantitative assessments related to either goal. It is unrealistic to accurately quantify carbon for most management projects. Instead, this exercise was intended to stimulate conversation about the magnitude and timescale of trade-offs. Speculating about the future inherently involves some uncertainty, but this activity is a good opportunity to highlight assumptions and draw upon multiple viewpoints.



Questions to consider when thinking about carbon alongside other management goals

- Roughly, what are the relative sizes of plant versus soil carbon pools at my site?
    - *Recall that a mature closed canopy temperate forest may store ~50% of carbon in plant pools compared to a prairie where less than 20% of carbon may be stored in plant pools.*
- Are management actions going to affect plant and/or soil carbon pools? How might ecosystem carbon storage change immediately following the management action versus several decades later?
- Are some management goals a higher priority than others? It might be helpful to compare ecosystem carbon storage to multiple other management goals to explore different tradeoffs, while also keeping in mind which management goals are most important.
- How might climate change and future disturbances affect the ecosystem? Will management actions make the ecosystem more (or less) resilient to future impacts?