MITIGATION

MANAGING ECOSYSTEMS TO LIMIT CLIMATE CHANGE

AGRICULTURAL MITIGATION

Many agricultural ecosystems have the capacity to store additional carbon in the soil. By leaving crop residue above ground, conservation tillage slows decomposition, storing more carbon in the soil than standard practices while improving soil fertility and water retention. Agricultural managers can also reduce nitrous oxide emissions (the largest cropland contributor to global warming) which result primarily from fertilizer use.

SEQUESTRATION POTENTIAL: Studies suggest that conservation tillage, if adopted for large areas, could eventually sequester all agricultural CO_2 emissions, plus up to 1% of total US emissions. Strategies to reduce nitrous oxide emissions could more than double the ability of soil to sequester carbon.

POSSIBLE RISKS: Managing cropland for carbon sequestration may reduce atmospheric CO_2 concentrations, but it may also have significant side-effects. For example, the benefits of fertilizing fields to enhance sequestration can be negated by secondary emissions—manufacturing fertilizer emits CO_2, and fertilizing soil produces nitrous oxide. Similarly, carbon offset markets may encourage the planting of biomass crops and trees in semi-arid regions, requiring extensive irrigation. In addition to being water intensive, irrigation uses a great deal of energy. The CO_2 cost of this energy can exceed the sequestration benefits of the irrigated ecosystems.

UNCERTAINTIES: Agricultural systems require consistent management to keep carbon sequestered—changes in land-use or management can quickly release carbon back into the atmosphere. As the needs of society change, it may be difficult to ensure that specific lands remain carbon sinks. Strategies to reduce agricultural emissions, while they must also be sustained to be effective, are not at risk of this kind of rapid reversal.

FOREST MANAGEMENT

Forests are essential to natural greenhouse gas regulation and offer several options to mitigate carbon emissions:

- ***Reduce deforestation***: This straightforward approach offers many additional ecological benefits derived from habitat preservation.
- ***Engage in reforestation***: This can also provide additional ecological benefits, depending on the species planted and the prior nature of the land. For example, old growth forests can sequester carbon for hundreds of years, but are being replaced by forest plantations, which grow specific species for commercial use. This replanting disrupts the forest floor and accelerates the decomposition of organic material—forest plantations are thus often sources of carbon, rather than sinks.
- ***Increase carbon uptake in existing forests***: Although this can reduce atmospheric CO_2 without requiring significant land-use change, it can also cause a variety of broader ecological disruptions associated with intensive management (e.g. wildlife mortality, reduced resource availability, changes to food webs and nutrient cycling). In addition, fires release stored carbon—as wildfire frequency and intensity increase, forests will become less reliable as long-term carbon sinks.

SEQUESTRATION POTENTIAL: Allowing forests to mature undisturbed greatly enhances their capacity for carbon storage. Globally, forest preservation and reforestation, coupled with agricultural mitigation, could offset 10-20% of projected fossil fuel emissions by 2050.

POSSIBLE RISKS: Managing forests as carbon sinks requires fire prevention measures, although measures such as controlled burns may themselves release carbon. However, certain forest structures offer greater fire resistance, providing managers with a way to balance this tradeoff.

UNCERTAINTIES: Carbon management is often difficult because of uncertainty regarding carbon stocks—the amount of carbon stored—and their dynamics, particularly below the surface. Forest carbon storage is subject to substantial spatial and temporal variation, complicating efforts to monitor gains and losses at larger scales.

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CARBON CAPTURE & STORAGE

Carbon capture and storage (CCS) is a process whereby CO_2 emissions from power plants are captured and stored in underground geologic reservoirs. CCS is increasingly being considered as an option to reduce greenhouse gas emissions.

SEQUESTRATION POTENTIAL: Although carbon capture is itself an energy-intensive process, CCS systems could lead to a substantial (up to 20%) reduction in CO_2 emissions.

POSSIBLE RISKS: CCS technologies could significantly increase energy use at generation stations, and would need to be engineered to prevent the release of other pollutants, including metals and radioactive matter, into the environment. There is also the possibility of leakage over time or during earthquakes.

UNCERTAINTIES: To limit the risk of leakage, all potential reservoirs should undergo rigorous evaluation; once in use, they should be monitored consistently.

GEOENGINEERING

Some research now focuses on geoengineering—modifying the environment to increase carbon uptake or cool the atmosphere. Proposed strategies range from atmospheric aerosol injection (injecting particles into the upper atmosphere to deflect solar radiation) to ocean iron fertilization (using iron to stimulate ocean algae growth and thus carbon sequestration via photosynthesis).

Geoengineering strategies are characterized by extensive environmental manipulation. If not adequately researched and monitored, they could have lasting or widespread negative ecological impacts, undermining efforts to protect ecosystems. Broad, long-term evaluations will be necessary to determine if proposed strategies can safely and effectively limit global warming.

ADAPTATION

MANAGING ECOSYSTEMS TO WITHSTAND THE IMPACTS OF CLIMATE CHANGE

MANAGING FOR MOVEMENT

Facilitating species migration across human dominated landscapes

Habitats are shifting in response to the changing climate, driving plants and animals out of their typical geographical range. The American pika, for example, has migrated up the western mountain ranges it inhabits, climbing to altitudes nearly 2000 feet above where the species lived a century ago. This migration has isolated populations, preventing them from breeding amongst each other and from moving across the range—several populations have already gone extinct.

Plants face a different problem: They rely on seed dispersal to relocate over generations, which means they may not be able to migrate quickly enough. This limitation imperils not only the plant species themselves, but also the animals that rely on them for food and shelter. Organisms now residing in parks also lack viable migration options. Park boundaries frequently mark the end of migration corridors, making coordinated and climate-conscious management in these areas imperative.

Management strategies that increase habitat connectivity at the ecosystem scale and across multiple jurisdictions, including private lands, are critical to climate change adaptation. As a last resort, assisted migration (managed relocation) may be considered as a conservation tool, but researchers and managers are still evaluating its ecological, social, and ethical implications.

MANAGING AT THE ECOSYSTEM SCALE

Collaborating across boundaries

Climate change has already begun to impact the ability of ecosystems to provide society with vital resources. In areas like the American Southwest, for example, freshwater resources are under tremendous pressure from higher temperatures, reduced snowpack, and increased demand. Addressing the resulting shortages is particularly complex because water resources are tightly allocated and shared between multiple states, Mexico, and Native nations. As is the case with all natural resources, various entities may access, use, and value water differently, but independent conservation measures, although important, will likely not be sufficient in managing major river systems.

The transboundary nature of water requires extensive cooperation across borders and among sectors. Climate change will demand new models of collaboration and renewed efforts to understand interactions among climate, water, and ecosystem dynamics.

The Colorado River provides a compelling example: Stakeholders including federal agencies, the Colorado River Basin states, Native American tribes, and conservation organizations collaborated to produce "Conservation Before Shortage" guidelines. These guidelines link biodiversity conservation to water and energy management, with the goal of conserving water resources to the degree necessary for ecological and societal wellbeing.

MANAGING FOR INCREASED VARIABILITY

Anticipating extreme events

Fires, floods, droughts, and other natural disturbances often play an important role in ecosystem self-regulation. Still, there is strong evidence to suggest that changes in climate will increase the frequency, severity, and scale of such disturbances. Hurricane Katrina caused an enormous forest blowdown, killing or severely damaging some 320-million trees throughout 5-million acres of Gulf Coast forest.

In the Southwest, severe and prolonged drought has left trees vulnerable to bark beetles. Beetle outbreaks, combined with the direct effects of increased temperature and decreased water, have caused a rapid increase in tree mortality over recent years. The Four Corners area, for example, has lost 90% of its mature piñon trees since 2002.

As the frequency of disturbances increases, so too will the degree of uncertainty around ecosystem distribution and function. To account for this increased variability, managers will need a diverse portfolio of adaptive measures, coupled with increased monitoring and modeling at appropriate scales. Scenario-based planning, which considers a number of hypothetical futures, is an important tool for identifying management options. It allows stakeholders to consider adaptation options in the context of uncertainties inherent to climate and ecosystem dynamics, as well as institutional constraints, laws, and budgets.