Land use strategies to mitigate climate change in carbon dense temperate forests

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Objectives:

• Many U.S. states, including Oregon, plan to reduce their greenhouse gas (GHG) emissions in accordance with the Paris Agreement and thus urgently require informed strategies to mitigate carbon dioxide (CO₂) emissions.
• Strategies to mitigate CO₂ emissions through forestry activities have been proposed; however, regional assessments to determine feasibility, timeliness, and effectiveness are limited and rarely account for the interactive effects of future climate, atmospheric CO₂ enrichment, nitrogen deposition, disturbance from wildfires, and management actions on forest processes.
• This study examines the net effect of the above factors as well as the relative merits of afforestation, reforestation, specific management changes (increasing carbon density of existing forests and reducing emissions from deforestation and degradation), and harvest residue bioenergy use as mitigation strategies in the Pacific Northwest, at fine resolution (4-km grid).
• The questions that drove this inquiry were: how much carbon can the region’s forests realistically remove from the atmosphere in the future, and which forest carbon strategies can reduce regional emissions by 2025, 2050, and 2100?
• The study used an integrated approach that combines observations with models and a life cycle assessment (LCA) to evaluate current and future effects of mitigation actions on forest carbon and forest sector emissions in temperate regions.
• The authors also estimated the recent carbon budget of Oregon’s forests and simulated the potential to increase the forest sink and decrease forest sector emissions under current and future climate conditions, then provide recommendations for regional assessments of mitigation strategies.

New Science:

• Oregon’s net ecosystem carbon balance (NECB) was equivalent to 70% of total emissions in 2011–2015.
• Simulations show increased net carbon uptake with little change in wildfires by 2100.
• Reforestation, afforestation, lengthened harvest cycles on private lands, and restricting harvest on public lands increase NECB 56% by 2100, with the latter two actions contributing the most.
• Resultant co-benefits of these strategies included improved water availability and biodiversity, primarily from increased forest area, age, and species diversity.
• Converting 127,000 ha of irrigated grass crops to native forests could decrease irrigation demand by 233 billion m³ y⁻¹.
• Utilizing harvest residues for bioenergy production instead of leaving them in forests to decompose increased emissions in the short-term (50 years), reducing mitigation effectiveness.
• Increasing forest carbon on public lands reduced emissions compared with storage in wood products because the residence time is more than twice that of wood products.
• Forest sector emissions tracked with our life cycle assessment model decreased by 17%, partially meeting emissions reduction goals.
Significance:

- Greenhouse gas reduction must happen quickly to avoid surpassing a 2 °C increase in temperature relative to preindustrial times.
- Forests are carbon-ready and do not require new technologies or infrastructure for immediate mitigation of climate change, and alterations in forest management can contribute to increasing the land sink and decreasing emissions by keeping carbon in high biomass forests, extending harvest cycles, reforestation, and afforestation.
- Robust forest sector assessments are urgently needed as states and regions take a larger role in implementing climate mitigation steps.
- The results of this study show that temperate forests with high carbon densities and lower vulnerability to mortality have substantial potential for reducing forest sector emissions.
- The integrated approach outlined in this study, which combines observations, an LCA, and high-resolution process modeling (4-km grid vs. typical 200-km grid) of a suite of potential mitigation actions and their effects on forest carbon sequestration and emissions under changing climate and CO₂ provides an effective analysis framework that can be applied in other temperate regions.

![Graph showing carbon sink and sources](image)

Oregon’s forest carbon sink and emissions from forest and energy sectors. Harvest emissions are computed by LCA. Fire and harvest emissions sum to forest sector emissions. Energy sector emissions are from the Oregon Global Warming Commission (14), minus forest-related emissions. Error bars are 95% confidence intervals (Monte Carlo analysis).
Future change in carbon stocks and NECB with mitigation strategies relative to Business as Usual (BAU) management. The decadal average change in forest carbon stocks (A) and NECB relative to BAU (B) are shown. Italicized numbers over bars indicate mean forest carbon stocks in 2091–2100 (A) and cumulative change in NECB for 2015–2100 (B). Error bars are ±10%.
Spatial patterns of forest carbon stocks and NECB by 2091–2100. The decadal average changes in forest carbon stocks (A) and NECB (B) due to afforestation, reforestation, protected areas, and lengthened harvest cycles relative to continued BAU forest management (red is increase in NECB) are shown.