Leveraging advances in global ecology to quantify permanence and additionality in forest nature-based climate solutions

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How do we use forests’ climate potential?

Generally, forest NCS projects must:

1. Cool the climate
2. Account for leakage
3. Be additional
4. Address permanence
Critical questions:
1. What is the magnitude of the climate risks that forests face?
2. How can we provide rigorous science to inform forest NCS?
Climate/ecosystem risks & human-system risks

- Fire
- Drought/temperature stress
- Biotic agents
- Wind events
- Ecological dynamics (e.g. range shifts, compositional changes)
- Other disturbances

- Financial failure
- Management failures (e.g. illegal harvesting, over-harvesting)
- Policy changes
- Governance changes
- Economic changes

What is the integrated 100 year risk of these?
Current forest offset protocols are not using rigorous science in many key areas

Climate permanence risks in protocols:
• Do not vary in space (e.g. identical risk across US + Alaska)
• Do not vary in time or by climate scenario
• Are not based on scientific literature
• Are strikingly low (e.g. 2-4% 100-year probability of carbon loss for wildfire; 3% for insects in CARB’s 2015 protocol)

Carbon storage over 21st century:
• Based on forestry growth models (e.g. FVS) that do not include climate change effects on growth, mortality, regen or disturbance
• Do not consider biophysical feedbacks and net climate effects

Anderegg et al., 2020, Science
Towards rigorous risk assessment

Risks to forests:
• Are non-stationary and increasing in the 21st century
• Vary spatially enormously
• Can be estimated historically and we can start to model future risks
• Rigorous estimates of the climate risks are crucial for management, carbon finance and offsets
• Publicly available maps, datasets, and tools urgently needed

Anderegg et al., 2020, Science
Current risks

- Fire risks highest in Western US and California in particular
- Drought and insect risks highest in the Intermountain West (e.g. mountain pine beetle and other beetles)
- Covariation in drought & insect risks for many reasons (both ecological and dataset-driven)

Anderegg, Chegwidden et al., 2022, Ecology Letters
Future projected climate risks

Anderegg, Chegwidden et al., 2022, Ecology Letters
Is the future of US forests C gain or loss? Depends on the method.

- **Earth system models**
  - +39.3% Total AGL C change

- **Growth mortality models**
  - +3.6% Total AGL C change

- **Climate niche models**
  - -4% Total AGL C change

- **Average**
  - C gain agreement

Wu et al., in review
Current California forest offset projects are at substantial risk of C losses even in SSP245.
A global climate risk assessment of Earth’s forests

Anderegg et al., in press
Additionality & baselines are huge challenges

Systematic over-crediting in California's forest carbon offsets program

Grayson Badgley, Jeremy Freeman, Joseph J. Hamman, Barbara Haya, Anna T. Trugman, William R. L. Anderegg, Danny Cullenward

Badgley et al., 2022, GCB
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Take-home messages

1. Nature-based Climate Solutions (NCS) **urgently need better science** to inform net climate impacts, additionality, leakage, and permanence
   
   A. Key needs: i) Tools, ii) Transparency & accountability, iii) Mechanisms to incorporate new science

2. Climate risks to forest NCS are substantial, uncertain, and currently widely underestimated in policies and protocols.
   
   A. Buffer pools need to be re-assessed. Potential role of management in risk reduction. This is an enormous scientific call to action.

3. We need to **explore and develop forest NCS mechanisms besides carbon offsets**, many of which are likely not delivering benefits for the climate currently
Thank you! Questions?

Collaborators: Chao Wu, Shane Coffield, Anna Trugman, Grayson Badgley, Oriana Chegwidden, Jeremy Freeman, Danny Cullenward, Joseph Hamman, Henry Todd, Alexandra Konings, Christa Anderson, Ann Bartuska, Philippe Ciais, Christopher Field, Scott Goetz, Jeffrey Hicke, Deborah Huntzinger, Robert Jackson, John Nickerson, Stephen Pacala, James Randerson

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