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Guidelines for effective climate smart forestry

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E-mail: noah.shep@uga.edu**Keywords:** permanence, mitigation potential, carbon storage, land use

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1. Introduction

Since early 2021 in the United States, climate smart forestry (CSF) has become a popular term and a growing field [1], but few peer-reviewed articles have recognized or discussed CSF nuances. Broadly, CSF is a strategy to combat climate change effects with ongoing and innovative forestry practices. Some, like Shephard *et al* [1], recognize CSF as forest management that accomplishes the following objectives: (1) greenhouse gas reduction and removal, i.e. climate change mitigation; (2) enhanced forest resilience, i.e. climate change adaptation; and (3) sustainable forest production and income. It is noteworthy that the first objective, climate change mitigation, could mesh well with ongoing U.S. forestry practices [1]—especially since mitigation potential could be underestimated [2]. For example, due to predominately temperate growing conditions within the U.S. and tremendous productivity gains in working forests since the 1960s [1], increased natural, urban, and plantation forest productivity could represent 55% (181 Tg C yr⁻¹) of natural climate mitigation (i.e. 45% agriculture and grassland storage [3]).

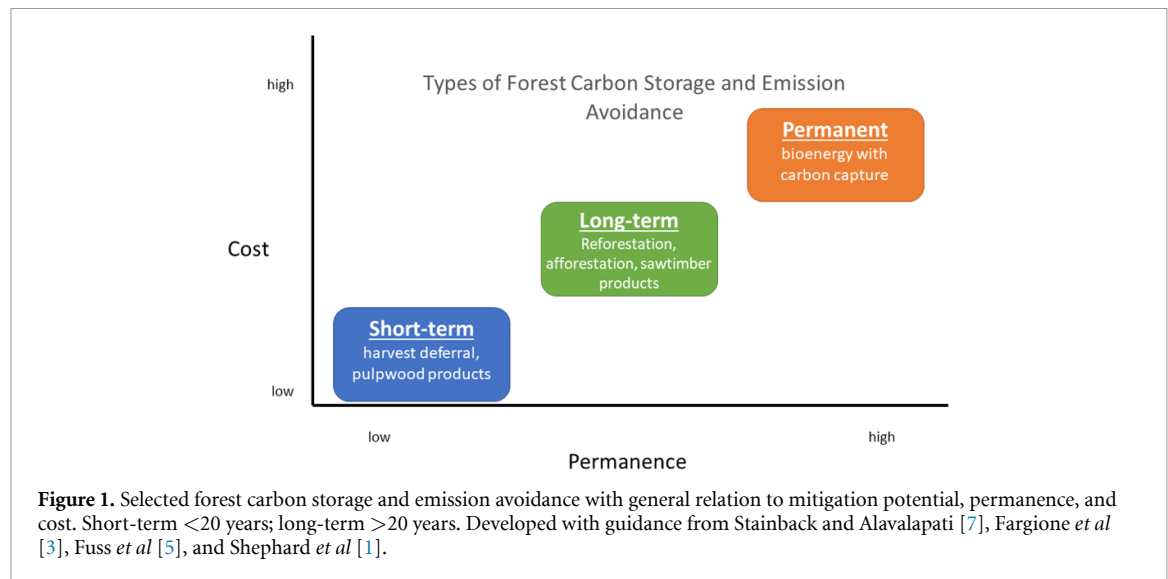
Prospective CSF policy should reflect a thoughtful, well-balanced approach to climate change. However, the combination of CSF popularity, simple mitigation tactics (e.g. increased productivity) [1], and limited academic CSF discussion has led to concern that CSF policy has become too carbon-centric [4]; CSF has become too focused on items like carbon credits and tree planting. We have two goals for this article: (1) spur discussion among stakeholders (academics, landowners, investors, etc) on how climate mitigation can be achieved with the help of production-focused forestry; (2) demonstrate how CSF needs to be refined and further researched to achieve successful climate change mitigation. We highlight four policy-related items to guide stakeholders to effective CSF: (1) carbon storage options;

(2) carbon tunnel vision; (3) investment disparity; (4) investment incentives. This is not an exhaustive list of strategies towards effective CSF, rather, mitigation-focused items others have brought attention to from extensive literature review [1].

1.1. Carbon storage options

Forest carbon storage options vary in permanence, mitigation potential, and cost. In a hypothetical scenario without concern for cost or feasibility, CSF should support carbon storage options that have high mitigation potential and permanence. An excellent ‘permanent’ [5] solution could be woody bioenergy production with carbon capture and storage (BECCS, [5]). BECCS has a high degree of permanence and mitigation potential since it simultaneously displaces fossil fuel and stores CO₂ underground [5]. Due to generally lower costs and greater feasibility [3, 5], long-term (i.e. >20 years) and short-term (i.e. < 20 years) carbon storage options are also useful (figure 1, [1]). However, there is concern short-term solutions overestimate climate change impact [6].

Permanent, long-term, and short-term solutions should not be considered equal (figure 1). Long- and short-term storage in forest biomass and forest products should be considered *temporary* biogenic storage options; there is no proxy for permanent carbon storage or reduced fossil fuel use, since long- and short-term carbon removal benefits generally decrease with time, and permanent solutions do not (see Levasseur *et al* [8] for further insight). But for economic reasons it may be impractical to devote large amounts of timberland for BECCS. Therefore, it is vital for policy to support a cohort of carbon-storage options like harvest deferral, reforestation, afforestation, pulpwood utilization, sawtimber utilization, and bioenergy utilization. It is especially important for policy to support sawtimber (long-lived) products that can simultaneously store carbon while substituting for



fossil fuel intensive products (e.g. cross-laminated timber, [1]). This is because forest product substitution can almost triple total carbon storage (i.e. $C_{\text{displaced fossil fuels}} + C_{\text{forest product storage}}$) [9], and sometimes lead to long-term carbon storage surpassing permanent carbon storage over multiple rotations [10].

Short-term carbon storage (<20 years) through forest carbon credits have gained popularity in the U.S. via project developers like Natural Capital Exchange (NCX), Finite Carbon, Bluesource, Green Trees, Forest Carbon Works, and the American Forest Foundation (AFF). At the time this article was written, NCX offered the shortest contractual commitment, with 1 year harvest deferral contracts and credits. Most other developers have longer contractual periods (ranging from 10 to 100 years). Forest carbon credits have potential to mitigate CO₂ successfully, but current short-term strategies are imperfect, largely due to the voluntary carbon market being unregulated. Without regulation, there is economic incentive to equate short-term solutions, like harvest deferral, to permanent storage solutions [11]. Claims on short-term viability have led to assertions that there is economic equivalence, distinct from physical equivalence [6], between multiple tons of short-term storage to 1 ton of permanent carbon storage (see [11], where $31 \text{ Mg } C_{\text{one-year}} \approx 1 \text{ Mg } C_{\text{permanent}}$). Additionally, short-term carbon accounting methodologies can be flawed due to reduced time-horizons. With shortened time-horizons, carbon release (i.e. wood product decay or combustion) can appear to be minimal [8]², in reality, carbon release is being ‘pushed’ out of the analysis

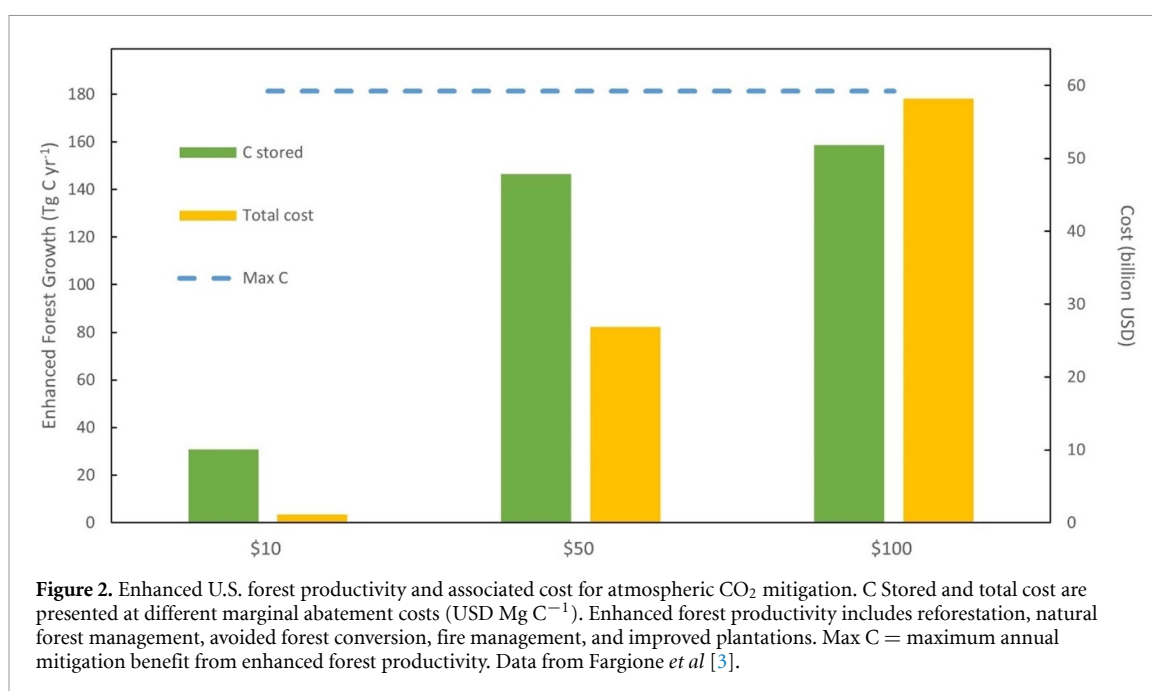
time-horizon. A remedy could be pricing distinctions between short-term harvest deferral credits and long-term carbon credits from afforestation, reforestation, or improved forest management [12].

1.2. Carbon tunnel vision and land-use optimization

Policy and land managers should guide nuanced forest management, hence, support enhanced forest productivity only when ecologically prudent. Under mitigation tactics, reforestation (i.e. replanting forests [3]), afforestation (i.e. planting previously non-forested land [13]), thinning [3], and extended rotation age [14], can all increase forest productivity. But U.S. forests vary in growth rate and not all forests and corresponding socioeconomic regions should be managed for greater productivity. This is because forest growth rates, driven in-part by regional ecology, lead to the development of regional timber markets—or lack thereof. The good news is that forest usefulness is not just limited to maximizing tree growth (i.e. carbon storage); whether it be for wood production, ecosystem function and health, and/or habitat quality, each U.S. forest region can serve a role towards climate change mitigation and adaptation. For instance, in fire-prone Western forests, prescribed fire could be more useful than afforestation or reforestation, as fire management can limit severe tree-killing fires that decrease forest productivity [3], while also increasing ecosystem health and habitat restoration. To support sustainable forestry and responsible land management, policy must avoid blindly prioritizing enhanced forest productivity. In a sense, *carbon tunnel vision* should be avoided.

To refrain from carbon tunnel vision, CSF implementation should be ecosystem and socio-economic specific. For example, due to favorable forest productivity and strong regional timber markets, marginal southern timberlands might be more suitable

² There is debate on short-term storage methodologies [10]. At the time this article was written, Winter 2022, Natural Capital Exchange (NCX) lost verification from carbon accounting certifier Verra.



for longer rotation ages [14]. Compared to southern region, the northeast region has lower forest productivity and weaker timber markets, thus, marginal northeast land could be more suitable for reforestation for woody biofuels [15]. On the other hand, western forests are productive but generally have weaker timber markets, thus, productive western timberlands might be best for longer rotation ages [14]. In regions with biodiversity objectives, CSF can also be compatible with increased biodiversity. With heavy thinning treatments carbon storage, consistent revenue, and biodiversity management can all occur. Compared to extended rotation ages or reforestation, heavy thinning treatments can emulate heterogeneous old-forest functionality, consequently supporting greater biodiversity and consistent revenue streams, while also storing additional living forest carbon [10].

A carbon tunnel vision dilemma suggests that an enhanced forest carbon sink is an optimization problem: if not all land, what lands should be enlisted for mitigation? To parse apart this question, one could think about forest, grassland, and cropland productivity. Forests have greater net primary productivity (NPP) than grasslands and croplands, so afforestation on grasslands or croplands could be an alluring prescription for enhanced forest productivity [16]. However, grasslands are crucial for biodiversity, water supply, and erosion control, and croplands are essential to feed a growing world. To optimize productivity with biodiversity, water supply, and erosion control, scientists have promoted avoided grassland conversion, and increased cover crop and cropland biochar use [3]. Such strategies can offer parallel NPP [16] and carbon storage [3] benefits as afforestation. With these alternatives to afforestation in mind, CSF policy should reflect alternative scenarios for mitigation and

adaptation strategies, not just enhanced forest productivity. Potential CSF policy could consider the following: (1) what ecosystems and socio-economic regions are most appropriate for greater forest carbon storage; (2) what ecosystems and socio-economic regions could be marginalized by enhanced forest productivity; and (3) how to balance enhanced forest productivity (mitigation) efforts with climate change adaptation.

1.3. Mitigation costs

Contrary to increased CSF popularity, disparities exist between actual climate change investments and investments needed to avoid serious climate change consequences. It was estimated that 2020 global climate change investments (USD 632 billion yr⁻¹) needed to increase by 590% (USD 4.5 trillion yr⁻¹) to avoid the worst climate change effects by 2030 [17]. In North America, USD 83 billion is contributed to climate change financing [17]. At potentially USD 50 billion, maximum enhanced U.S. forest productivity is not a trivial cost either (figure 2). But costs can be reduced. Broken down to a marginal abatement cost, 81% (146 Tg C yr⁻¹) carbon storage potential from reforestation, natural forest management, avoided forest conversion, fire management, and improved plantations could be funded at USD 50 Mg C yr⁻¹ (total USD 27 billion, figure 2). Or, half the mitigation needed to reach Paris Climate Agreement goals [3].

Rather than speculating on climate financing sourcing, we will mention potential synergistic benefits between thinning and the voluntary carbon market. In the Southern United States, the voluntary carbon market could reduce the marginal abatement cost of natural forest management and improved

plantations strategies (i.e. thinning). Since 1999, high relative density (>0.61) stands have increased in the Southern U.S. by 936% [18]. Thinning could remedy drastic high relative density, and increase carbon storage via decreased density-dependent, abiotic event, and biotic event mortality. To be specific, in loblolly pine (*Pinus taeda* L.) stands, commercial thinning can increase carbon yield by 17% ($+0.47$ Mg C, [1]). Assuming a USD 50 Mg C⁻¹ carbon credit price [10] and additionality (i.e. delayed thinning), commercial thinning could therefore generate approximately USD 22.50 ha⁻¹ in select loblolly pine stands (USD 50 = 81% of maximum storage, figure 2). In turn, the proposed USD 50 Mg C yr⁻¹ marginal abatement cost [3] would be cut-in-half for qualifying landowners. We realize a 50 USD Mg C yr⁻¹ price is above average voluntary carbon market prices in 2023, i.e. see the World Bank's 'State and Trends of Carbon Pricing' annual report. Our point is that a USD 50 Mg C yr⁻¹ price is where the majority (81%) of enhanced forest growth occurs (figure 2, [3]). Hopefully, carbon project developers and investors will realize that harvest deferral is not the only tool to increase carbon capture, thinning is also a crucial instrument to increase long-term carbon capture.

1.4. Incentives for CSF

Incentives must be present to scale-up current CSF investment. One solution could be increased federal incentives. Particularly, investments that support markets for forest products that substitute (see 1.1) for fossil-fuel intensive products, like woody bio-fuels in-place of coal or cross-laminated timber in-place of structural steel. In February 2022, the United States Department of Agriculture made USD 1 billion in grants available for Climate Smart Commodities grants aimed at jump-starting greater forest product substitution in the U.S. Further, in August 2022, the Inflation Reduction Act (IRA) was signed into law, which aimed for a 40% decrease in national emissions by 2030, and implemented a methane emissions fee on natural gas producers [19]. A possible step to a regulated carbon-accounting system, methane fees could also showcase the need for improved carbon-accounting methodology.

Incentives also exist in the private sector. One route is through the timber industry internalizing carbon pricing and benefits. From internalized carbon pricing, landowner profits, rotation age, long-lived sawtimber products, and carbon storage would all increase [7]. This could be the most cost-effective approach for CSF policy, as carbon pricing would simultaneously decrease atmospheric carbon while encouraging landowners to invest in timberlands, therefore, also preventing forest conversion [7]. Another option is through the voluntary carbon market, an approach that allows landowners to earn revenue through land-use rent (i.e. carbon rent).

Recent work has suggested a carbon market could help decrease atmospheric CO₂ via delayed emissions [11]. Due to little governance within the U.S. voluntary carbon market, this option should be considered the 'wild-west', as there is minimal transparency among financial actors [20]. If firms within the voluntary carbon market can pledge to improve upon shortfalls (see 1.1), there is hope for carbon credits to create meaningful mitigation.

2. Conclusion

CSF is more involved than just planting more trees or issuing carbon credits. Stakeholders should be mindful of carbon storage quality, carbon tunnel vision, financing needs, and the need for CSF incentives. Of course, topics like carbon storage quality and land-use optimization create ample opportunity for additional investigation. From a forest-science perspective, there is an urgent need for (1) improved carbon accounting methodologies and (2) ecosystem and socio-economic specific enhanced forest productivity. CSF has potential to be a useful tool for climate change mitigation, but without scientific innovation, it will be difficult for CSF to be a trustworthy mitigation strategy. It is now the responsibility of forest researchers, policymakers, investors, and forest industry to implement CSF effectively.

Data availability statement

No new data were created or analysed in this study.

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