Evaluating the mitigation effectiveness of forests managed for conservation versus commodity production using an Australian example

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Abstract

Forests are critical for biodiversity conservation and climate change mitigation: reducing emissions, increasing removals, and providing resilient ecosystems with stable long-term carbon storage. However, evaluating the mitigation effectiveness of forests managed for conservation versus commodity production has been long debated. We assessed factors influencing evaluation of mitigation effectiveness—land area, time horizon, reference level, carbon stock longevity—and tested the outcomes using analyses of carbon dynamics from an Australian ecosystem. Results showed that landscape scale accounting using carbon carrying capacity as the reference level and assessed over a series of time horizons best enables explicit evaluation of mitigation benefits. Time horizons need to differentiate between near-term emissions reduction targets (2030 and 2050), relative longevity of carbon stocks in different reservoirs, and long-term impacts on atmospheric CO₂ concentration. Greatest mitigation benefits derive from conservation through continued forest growth (52% gain in carbon stock by 2050) and accumulating carbon to attain carbon retention potential (70% gain). Cumulative emissions from harvesting result in permanent elevation of atmospheric CO₂ concentration (32 times the annual emission by rotation end). We recommend these time horizons and landscape scales for evaluating forest management to better guide policies and investments for achieving climate mitigation and biodiversity conservation.

Keywords

carbon carrying capacity, carbon retention potential, climate change mitigation, forest age distribution, forest carbon storage, forest conservation, global warming potential, landscape scale, primary forests, reference level
INTRODUCTION

A much-debated question for climate and forest policy concerns which forest management strategy provides the most effective mitigation benefits. Two contrasting strategies are: (1) forest conservation management—avoiding emissions from current forest carbon stocks by preventing harvesting and enabling atmospheric carbon dioxide (CO₂) removals from continuing forest growth that accumulates carbon in large, stable stocks; and (2) forest commodity production management—harvesting to maintain young forests with high sequestration rates and use of wood products to store carbon and substitute for other products (IPCC, 2019; EC, 2021b).

Forest management for carbon storage and sequestration is a critical mitigation activity and many countries rely on their land sector, mostly forests, contributing 20–25% of global emissions reduction, to achieve Nationally Determined Contributions (NDCs) aimed at reaching carbon neutrality by 2050 (Forsell et al., 2016; Grassi et al., 2017; IPCC, 2019). To meet the European Union Green Deal and European Climate Law objective of climate neutrality by 2050 and 55% emissions reduction by 2030 requires nearly double the current level of removals. A target has been set for 310 Mt CO₂-eq yr⁻¹ removals, mostly by forests, and incentives are being developed for enhanced carbon storage (EC, 2021a).

A key challenge to meeting these objectives is the controversy about appropriate methods for evaluating the effectiveness of different mitigation activities and their benefits (Mackey et al., 2013). Forest management strategies also vary in their impact on biodiversity conservation (Seddon et al., 2020). The mutual reinforcing of climate change and biodiversity loss means that assessment of mitigation strategies needs to consider the consequences for biodiversity (Pörtner et al., 2021). Investment in emissions reduction activities, particularly related to forest management, can result in poor mitigation and conservation outcomes if decisions are based on inappropriate comparisons related to the land area, use of reference levels, and time horizons (Klein et al., 2013; Bouriaud et al., 2019; Krug, 2019), which result in flawed analyses. Such analyses fail to properly reveal the actual change in the atmospheric carbon stock of different activities at the land areas and time horizons relevant for decision making.

It has been proposed that forest management mitigation strategies require trade-offs between maximizing carbon stocks or maximizing sequestration rates (IPCC, 2019). Highest carbon stocks occur in older forests with large, old trees, whereas highest rates of sequestration as carbon dioxide uptake through photosynthesis occur in younger fast-growing trees. Contradictory results have been reported about strategies to maximize mitigation benefits (Law et al., 2018; Nabuurs et al., 2017), and there are no internationally agreed guidelines to support such evaluations. We argue here that much of the difference in results that has led to conflicting advice on the mitigation benefits of contrasting forest management strategies is due to the different land areas and time horizons selected for analysis of forest carbon.

Our objective is to improve evaluation methods for forest management strategies that will reveal the most effective mitigation benefits. To help advance understanding of this issue, we identify a set of factors related to spatial and temporal scales that influence the evaluation of forest mitigation effectiveness. To demonstrate the effect of these factors in evaluating mitigation effectiveness, we applied the methods to a case study using a forest carbon model calibrated with field inventory and spatial data from a well-studied temperate forest ecosystem in Australia. We discuss policy implications of the use of these methods to assess forest management scenarios and conclude with recommendations for how more reliable and consistent guidance can be generated for decision makers.

FACTORS INFLUENCING EVALUATION OF MITIGATION EFFECTIVENESS

Three broad categories of forests are recognized based on their current management regimes and degree of natural ecosystem functioning: (1) primary forests dominated by natural processes; (2) naturally regenerated forests managed for commodity production; and (3) planted forests (definitions and references in S1). These forest categories differ in their tree age and size distributions, structural characteristics, and biodiversity, which influence their provision of ecosystem services and the quantity, quality, and longevity of their carbon stocks (Keith et al., 2019).

2.1 Land area

The extent of land used for carbon accounting can span regional, national, biome, and global scales (IPCC, 2019). However, the underlying basic unit of spatial analysis is often the “stand level” (~1 ha⁻¹) because this equates with the scale of forest inventory measurements and harvest scheduling. It is also the spatial scale at which “forest” is defined in international agreements (S1). Stand-level analysis may be appropriate for carbon accounting in even-aged forests but is not adequate for comparing different management strategies and age structures in forests that exhibit variability across the landscape. Natural forests are a landscape-level phenomenon with significant variability.
in their composition and structure as a function of topographic, substrate, natural disturbance regimes, and land use history.

Comparisons based on stands of a similar age (Bouriaud et al., 2019), or range in ages (Krug, 2019), or over a rotation period (Klein et al., 2013), do not reflect fully the impact of human activities on the forest age distribution and, therefore, the total ecosystem carbon stocks or the characteristics of ecosystems that maintain stable stocks. Landscape-scale metrics (S1) are more appropriate as they account for the spatial scales at which ecological and evolutionary processes and natural disturbance regimes operate, such as described by Net Biome Production (Schulze et al., 2000).

### 2.2 Time horizon

The most widely used time period is annual, following the accounting for emissions from and removals by forests in the national greenhouse gas (GHG) inventories submitted under the UN Framework Convention on Climate Change (UNFCCC). These annual inventories are useful for tracking fossil fuel emissions but are inadequate for forest ecosystems that require longer time horizons to reveal the effectiveness of mitigation outcomes in relation to temperature goals. The Paris Agreement objective is to limit the increase in global average temperature to less than 2°C above preindustrial levels and pursue efforts to limit the increase to 1.5°C. Practically, this means that the critical factor is not the annual rate in the flux of carbon to and from the atmosphere per se. Rather, the key variable to measure is the change in the accumulated stock of atmospheric carbon measured as the atmospheric CO₂ concentration and volume (Keith et al., 2021), because global mean surface temperature increases as a near-linear function of the cumulative total global CO₂ emissions (IPCC, 2021). Evaluating the mitigation outcomes of different management strategies, therefore, requires accounting over time horizons sufficient to assess their impact on the magnitude and longevity of forest carbon stocks and the resulting change in the atmospheric stock.

### 2.3 Reference level

A key element of time horizons is selection of an appropriate reference level (i.e., the baseline or initial condition) for comparing the mitigation outcomes of forest management strategies. If a short time horizon is used, then the reference level is typically the current carbon stock. In a forest managed for commodity production, this reflects the influence of the logging regime on maintaining younger standing trees, reducing soil carbon, and type and longevity of products. Selecting a longer time horizon allows the use of a reference level that reflects the full extent of carbon dynamics across the forest landscape, that is, the “carbon carrying capacity” defined as the maximum total ecosystem carbon stock under natural environmental conditions and disturbance regimes (S1). This metric better reveals the long-term mitigation outcomes as it enables the estimation of a forest’s potential carbon storage, that is, its “carbon retention potential” (S1).

### 2.4 Carbon stock longevity

The pools within a forest’s carbon stock used in accounting should be consistent and as comprehensive as feasible, ideally including living and dead above- and below-ground biomass, coarse woody debris and litter, and soil carbon. As well, it is necessary to account for the wood removed off-site and used in manufactured products. The longevity of carbon stocks varies between these pools and the fluxes of carbon between them occur at different time scales. Forest management strategies differ in how they affect the longevity of these pools and rates of fluxes. In primary forests, where population dynamics are controlled by natural processes, trees continue accumulating carbon throughout their lifespan (Stephenson et al., 2014), and dead biomass remains in the ecosystem for long periods undergoing decomposition and transfers to soil organic matter, with pools becoming increasingly stable over time. In commodity production forests, harvest rotation age is usually defined by maximum mean annual increment and thus curtails the lifespan of trees, with most of the harvested biomass removed off-site or combusted (Keith et al., 2015). Hence, production forests have lower carbon stocks in their living and dead trees, coarse woody debris, forest floor and soil (Noormets et al., 2015; Mayer et al., 2020), and wood products of varying longevity (Keith et al., 2015; Law et al., 2018; Hudiburg et al., 2019).

The longevity of the carbon stock in the atmosphere is affected by the relative timing of emissions and removals. Emissions due to combustion or decomposition of forest biomass occur at the time of harvesting, processing, and use of bioenergy or discarding of wood products. Removals by forest regrowth occur for many decades into the future, long after the use of products. It is this temporal imbalance between emissions and removals that results in an elevated atmospheric CO₂ concentration (Bentsen, 2017). The climate impact of this imbalance can be estimated by a metric called the “global warming potential” (S1). This metric is based on a mathematical decay function that approximates the atmospheric lifetime of a pulse of CO₂ emissions from a harvest event (Archer, 2005). The longevity of these emissions in the atmosphere can then be calculated as the
aggregate accumulation from multiple harvests that represent the logging regime of a forest management system (Holtsmark, 2014).

3 METHODS

We developed a set of interrelated models to examine how the impact of forest management strategies on carbon stocks and mitigation outcomes was influenced by land area, time horizons, reference levels, and carbon stock longevity. The models were calibrated using data from a well-studied forest ecosystem of temperate tall, wet eucalypt dominated forest in the Central Highlands of Victoria, Australia (study area of 732,737 ha, S2, Figure S1). Forest types within the ecoregion include primary forests largely conserved in formal protected areas, and naturally regenerated forests managed for commodity production mainly by clearcut logging but there is increased trialing of variable retention logging. All forests are subject to a natural disturbance regime of wildfires. The major steps in the analysis were:

1. Forest growth stages were identified corresponding to age classes that represent dominant cohorts of trees in the region derived from the two major disturbance factors of logging and wildfire.

2. The spatial distribution of forest age was determined from maps of logging and fire history. Carbon stocks and stock changes were modeled spatially across the study area as functions of the age of the forest and the environmental variables that influence productivity, and calibrated with site data (S3).

3. Forest carbon dynamics, that is, the change in carbon stocks over time, were first calculated at the stand scale to determine the time series of each carbon pool in relation to processes of growth, mortality, decomposition, combustion, and transfers between pools that occur in response to different disturbance regimes.

4. The current spatial distribution of growth stages across the landscape, and their corresponding age classes and carbon stock densities, were represented as matrices for the area of each forest management type. The number of grids in each growth stage within the matrix is proportional to their area in the landscape. The carbon retention potential for carbon stock gain through continued growth of regenerating forest was calculated as the difference between the current carbon stock of the regrowth forest and the carbon carrying capacity of the primary forest.

5. Forest carbon dynamics at the landscape scale were calculated based on the current age class distribution and carbon accumulation function over time. Projections of future carbon stocks were derived from the carbon dynamics for a logging rotation of 80 years, either clearcut or variable retention, and a wildfire return interval of 250 years.

6. Two forest management scenarios were used to examine the impact on landscape carbon dynamics: (1) forest management for conservation; and (2) forest management for commodity production with logging regimes of either clearcut or variable retention at 10% or 30% remaining. The simulation started with the 1990 age class distribution and showed the net change in carbon stocks over a rotation when logging continued under the traditional regime of clearcutting, compared with a change in management to retain patches of 10% or 30% of the coupe area, or to cease logging and allow continued natural forest growth. The logging scenarios were based on maximum utilization of wood products, including using harvested biomass as bioenergy to substitute for fossil fuel energy and wood products to substitute for other materials with higher embodied emissions.

7. The impact of emissions from forest management on the atmospheric CO2 concentration was calculated as the global warming potential biomass index (GWPbio) (Cherubini et al., 2011), which accounts for emissions from harvesting and removals from regrowth, plus land and ocean global carbon sinks, against a reference level of no harvest (Holtsmark, 2014) (S5 and Table S2).

4 RESULTS

Stand-level carbon dynamics show the differences in magnitude of carbon stocks and their change over time for a production forest subject to a logging rotation and a primary forest subject to a natural wildfire regime (Figures 1 and S2). The landscape level shows the current spatial distribution of growth stages and their corresponding carbon stock densities for the forest types in the study area (Figure 2). The current regrowth forest used for commodity production has the potential for a 70% gain in carbon stock (Figure 2c). This is possibly an underestimate of the potential gain because it is likely that areas already logged were the more productive sites and there are no remaining older forests of similar site productivity to use as calibration for modeling the spatial distribution of carbon stocks. The total carbon storage at the landscape scale and changes over time illustrate in three dimensions the spatial and temporal scales used in the analysis (Figure S4).

Analysis of net change in carbon stocks over a rotation with scenarios of forest management strategies showed that with continued logging at the current area per year, the carbon stock over the whole logged area would decline
by 5% by 2050 (Figure 3). Inclusion of products and substitution effects resulted in gains by reduced emissions of 11% and 15% by 2030 and 2050, respectively. Change to a variable retention silvicultural system resulted in slightly higher carbon stocks in the forest but less in products (Table S1 and Figure S3). However, greater gains of 25% and 52% of carbon stocks by 2030 and 2050, respectively, were achieved by forest management for conservation allowing continued growth that produced an upward trajectory of carbon storage. For the carbon stock to reach the carbon carrying capacity, however, would take approximately 170 years.

Following a pulse of emissions from a harvest event, the atmospheric CO$_2$ concentration remains elevated during
(a) Current Carbon Stock in regrowth forest managed for commodity production

(b) Carbon Carrying Capacity in primary forest managed for conservation

(c) Carbon Retention Potential through protection and regrowth

Figure 2 Diagrammatic representation of the growth stages and corresponding age class distribution (using the legend in Figure 1) and resulting carbon stocks at the landscape scale for the Central Highland study area. The area of the matrix represents the land area for each forest management type in the study area. The number of grids in each age class within the matrix is proportional to their area in the forest management type. The distribution of carbon stock densities in living biomass is shown for the corresponding areas of (a) the current carbon stock in naturally regenerated forest in the area managed for commodity production and logged previously, and (b) the carbon carrying capacity in primary forest in the area managed for conservation. (c) Potential change in carbon stock distribution for the regenerated forest area through protection and continued growth that would result in the distribution of age classes derived from the proportions in the primary forest. The difference in the carbon stock distribution between the current carbon stock and the carbon carrying capacity is the potential gain or the carbon retention potential.
FIGURE 3  Current carbon stock calculated from the age distribution and carbon stock densities in the Central Highlands forest region from 1990 to 2015 in the area that has been logged. Projections in carbon stock from 2016 to 2070 are based on modeled carbon dynamics, including gains from growth, losses from logging and fire, storage in wood products and landfill, and substitution using bioenergy and wood products. The carbon retention potential is predicted as the potential gain in carbon stock if logging ceased and the forest continued growing. Potential gains in carbon stock by 2030 and 2050 are predicted under the management scenarios of logging and maximum utilization of wood products (blue) plus substitution (yellow), and forest conservation and continued growth to attain the carbon retention potential (green). The carbon stocks counted under conservation management included the substitution of wood products foregone by protecting the native forest and derived instead from existing areas of plantations. (Graphs for other production forest silvicultural systems in Figure S3)

the whole 80-year rotation period (Figure 4a and S5). The fraction of CO₂ remaining in the atmosphere from an emissions pulse is, therefore, not zero during this time, and hence, adds to human-induced global warming. Assessing the climate impact of forest harvest management requires aggregating the accumulated atmospheric CO₂ emissions from each annual harvest event over the rotation (Figure 4b). By the end of the rotation, the aggregated emissions represent 32 times an annual pulse (Figure 4c). The cumulative effect of the annual emissions approaches a positive asymptote, that is, a permanent elevation of atmospheric CO₂ concentration.

The GWP\textsubscript{bio} for an 80-year rotation is 1.06 and 0.63 for 20- and 100-year time horizons, respectively. This means that the climate impact over 100 years when CO₂ is emitted from logging and removed by regrowth over the rotation is 0.63 times a permanent carbon stock loss. A single harvest event and regrowth may be carbon neutral, but creates a carbon deficit in the land sector because the cumulative effect of multiple harvests over the rotation plus the foregone continued forest growth result in an increased atmospheric carbon stock.

FIGURE 4  (a) The fraction of atmospheric CO₂ emissions remaining after a single annual pulse based on the following scenarios: (1) from deforestation as a permanent carbon stock loss (gray dashed), where removals occur through land and ocean sinks in the global carbon cycle, (2) from a harvested forest system as a temporary carbon stock loss with removals over a rotation of 80 years (brown), where removals occur through regrowth of the forest plus land and ocean sinks in the global carbon cycle converging to an asymptote of zero, (3) from continued growth of the forest after 80 years when there is no harvest (yellow), and (4) from the net effect of harvesting derived from the emissions due to harvesting plus the foregone removals from continued growth of the forest (dark green). Elevated CO₂ persists in the atmosphere throughout the rotation of harvested forest thus impacting the climate. (b) Pulses of emissions occur every year (1 unit each year and the
5 | POLICY IMPLICATIONS

5.1 | Comparisons of forest management strategies

Our comparison of forest management strategies and alternative silvicultural systems showed that the greatest mitigation benefit for the studied forest landscape was achieved by management for conservation that allows continued growth in age and carbon accumulation in the forest for both near-term 2030 and 2050 targets, as well as in the long-term through maintaining relatively stable ecosystem carbon stocks. The magnitude and longevity of stocks in the forest plus wood products was less in the harvested forest.

The comparison of forest management strategies depends on the relative effect of natural disturbance regimes and harvesting on the carbon dynamics of the total system in terms of losses and gains in carbon stocks and changes in rates of transfers between pools. In our case study of the *Eucalyptus* forest in Victoria, the main natural disturbance regime is infrequent wildfire. In other forest ecosystem types, disturbances may include windstorms, landslides, drought, or pest damage, which will change the carbon dynamics, mostly in terms of transfers between pools. The relative effect of different disturbance types depends on their frequency, the degree of mortality, and processes causing carbon loss, such as combustion. The carbon stock in the primary forest used as the reference level for comparisons incorporates the range resulting from the dynamics of natural disturbance regimes (Keith et al., 2014).

Natural disturbance regimes are being increasingly impacted by human-influenced climate change, including dangerous fire weather conditions, ignition sources, wind, hydrological conditions, distributions and competitive relationships between species, and more (Canadell et al., 2021; Collins, 2020; Gross et al., 2020). In many cases, these new disturbance regimes will affect all forests irrespective of their management for conservation or commodity production, although many are likely to have greater impacts on forests with even-aged, single-species and higher tree densities. Forest management strategies are then compared between the reference level from these new disturbance regimes and the direct human activities such as harvesting but recognizing that the difference may represent an underestimate because the human managed system experienced greater impact from the new disturbance regime. The impacts of changing disturbance regimes will increasingly need to be included when considering forest growth and carbon dynamics. However, this will not alter the basic difference between the management strategies, where commodity production from forests results in additional removal of biomass and conversion to pools with shorter lifetimes.

Our comparison of the carbon dynamics in forests managed for commodity production included clearcut and partial harvesting systems. Retaining a proportion of trees in the logged area, which may represent various silvicultural systems, such as variable retention, selective harvesting, and continuous cover forestry, does increase the carbon stored in the forest ecosystem but not to the same magnitude as does strict protection of forest for conservation. Any removal of biomass and conversion to products reduces the magnitude and longevity of the total carbon stock.

The relatively minimal mitigation benefit from wood products has been also shown for European managed forests, where the increase in carbon stored in products did not compensate for the loss in forest carbon stock (Pilli et al., 2017). Studies reporting that the highest mitigation benefit is achieved from managed forests with wood product storage and substitution of products and energy often do not clearly state the time horizon (e.g., Klein et al., 2013; Forster et al., 2021). Substitution may provide benefits but only after many decades and, as our results illustrate, a sufficiently long time horizon is needed to account for the GWP_{bio}. An additional consideration is that comparative studies exhibit many confounding issues in experimental designs that must be assessed carefully (S6). Decisions about forest management are made at various scales depending on the extent of forest types, water catchment areas, land tenure, or administrative boundaries. Similarly, accounting for forest carbon stocks is assessed at a basic spatial unit and then aggregated to these different scales. However, we contend that evaluation of climate mitigation benefits should consider the age distribution across the forest ecosystem type and that this requires a landscape-scale perspective. This is particularly important in order to incorporate the potential for older age classes that may not necessarily occur within the boundaries of a forest managed for commodity production. To evaluate the effect of...


| Factor in analysis                                                                 | Advantages                                                                                                                                 |
|-----------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------|
| 1. Land area using the landscape scale                                             | Enables inclusion of the variability in the forest ecosystem’s tree age distribution. The result is the area average carbon stock over the landscape that incorporates forest dynamics. Appropriate scale for forest management planning and policy. |
| 2. Time horizons based on carbon stock change                                      | Assessing emissions reduction targets to 2030 and 2050 in terms of decreasing the atmospheric carbon stock. Reporting magnitude and longevity of carbon stock change to assess long-term carbon storage. |
| 3. Reference level using the carbon carrying capacity                              | Enables inclusion of the mitigation opportunity cost of not allowing continued growth and accumulation of carbon in forests. Carbon carrying capacity may be only approximated for some ecosystems but is more effective as a reference than current carbon stock. |
| 4. Carbon stock longevity in biosphere and atmosphere                              | Assessing longevity of carbon stocks demonstrates that temporary losses of carbon from harvesting and regrowth increase the global warming potential of the atmosphere and are not climate neutral. The lifetime of most harvested wood products is far less than the lifetime of trees. |

Forest management on carbon storage and conservation status, decisions should be made within the context of the landscape scale. This approach can form part of national strategies for climate mitigation, adaptation, and biodiversity conservation.

5.2 Informing climate change policies

International and national policies governing rules for carbon accounting, GHG emissions reduction targets, and allowable mitigation activities are part of the process of implementing the Paris Agreement and reporting on NDCs for global stocktakes. Additionally, substantial funds and investments are provided by governments and business for mitigation activities, conservation measures, and commercial enterprises in the forest sector. Currently, the foregone mitigation benefit of not allowing forests to continue growing to achieve their carbon retention potential, and the time that emissions remain in the atmosphere are not included in accounting for carbon stock changes and their climate impacts. This means that emissions from biomass combustion do not incur carbon taxes nor are they included in emissions trading schemes, resulting in an implicit subsidy (Holtsmark, 2014). Arguments based on rates of biomass accumulation against a reference level of the current carbon stock (Bouriaud et al., 2019; Krug, 2019; Nord-Larsen et al., 2019) or assumptions that the climate impact of logging emissions is removed by forest regrowth (UNFCCC, 2015) are inadequate and fail to recognize the mitigation benefits of the full range of forest management strategies. The forest system may be carbon flux neutral over some time horizon, but it is not climate neutral at temporal scales relevant for effective climate mitigation policy and decision making.

Therefore, the rules for carbon accounting would benefit from including more explicit guidelines regarding the land area and time horizons needed for comparing the mitigation benefits of different management strategies. Negotiations about forest and climate policy where these rules are relevant include the EU Green Deal, the EU Forest Strategy, UNFCCC CoP26, and national reporting and targets for NDCs. In drafts of the EU Forest Strategy and UNFCCC, primary and secondary (or regrowth) forests are distinguished and the benefit of protecting primary forests for biodiversity and avoided carbon stock loss is recognized (EC, 2021b). In responding to these emerging policy opportunities, we offer recommendations for improving evaluations of forest management strategies in terms of their effectiveness for conservation and climate mitigation outcomes (Table 1).

Decisions about forest management strategies that are appropriate in different locations and for different purposes will include many considerations, including the demand for resources of wood products and bioenergy, the potential for substitution of higher emissions-intensive sources, as well as climate mitigation and provision of other ecosystem services, such as clean water (Taye et al., 2021). Our approach in this study is to provide guidance for evaluating the climate mitigation benefit so that this
component can be quantified accurately and inclusive of all relevant factors. Use of biomass from forests for products or energy causes an increased atmospheric carbon stock at the time scales that are critical for mitigation action. Hence, shifting resource demand onto forests under the pretence of being carbon neutral is not a solution to the climate problem.

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**CONFLICT OF INTEREST**

All authors declare no conflict of interest.

**AUTHOR CONTRIBUTIONS**

HK and BM conceived the research. MM identified issues in the literature. MSvi identified statistical issues. HK performed the analyses and wrote the first draft of the paper. BM assisted in interpretation of results. HK, ZK, MM, MSvi, MSvo, and BM contributed to identifying key points for discussion and writing of the paper.

**DATA AVAILABILITY STATEMENT**

Data available in cited references.

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