Reports of the economic cost of global forest protection have been greatly exaggerated

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Abstract

Protecting earth’s remaining forests is central to achieving global climate and biodiversity goals, but is also thought to represent trillions of dollars of lost income (“opportunity costs”) for forest-land producers. To explore this tension, we applied partial-equilibrium models to three scenarios for protecting an additional 471–863 million hectares of forest under 30x30. These economically comprehensive models projected a modest bottom-line increase for forest-associated producers, strongly contradicting the results from current, simpler opportunity-cost approaches. This non-intuitive benefit is caused by the market effects of scarcity, similarly to how oil producers increase profit by reducing production. Current approaches greatly exaggerate large-scale opportunity costs because they ignore these market effects. Opportunity costs for other global environmental goals may be similarly overstated, causing unnecessary opposition.

Introduction

Conservation is often perceived as economically costly, fuelling long-standing opposition to environmental protection worldwide[1–3]. Forests present one of the most important examples of this problem. Protecting the worlds’ forests is key to halting biodiversity loss and slowing global warming, and indeed to supporting the livelihoods of about 1.3 billion often-marginalized forest-dependent people[4–7]. However, the global forestry (wood products) sector also employs more than 33 million people[8] and contributes more than 1.5 trillion dollars per year to national economies[9,10]. Any initiative to protect forests therefore generates objections of “opportunity costs” – the economic loss suffered when producers are no longer allowed to exploit a forest[1–3] – and the resultant political and industry opposition.

To overcome this perceived conflict between commercial production and climate/biodiversity needs, various studies have estimated the cost of conserving global forests, primarily through “buying out” or compensating the value of the foregone production[11–13]. However, the estimated costs are so high – hundreds of billions of dollars per year, or several trillion dollars by 2050[11–13] – that they represent a major barrier to action.

The calculation method behind these very high costs first estimates the value of potentially “lost” production for each individual hectare of forest, then simply sums up those values for every forest hectare protected worldwide. However, such an approach ignores two key economic principles, causing it to potentially exaggerate the true cost. First, a cut in production can sometimes benefit producers, by making their commodity scarcer and thus increasing the price they receive. If production goes down but price goes up, then the bottom line (“output value” in the jargon) can actually increase. This phenomenon is exemplified by OPEC’s (Organization of the Petroleum Exporting Countries) strategic imposition of production limits, to enhance oil price and profits for its members. Second, reduced production in one country is frequently offset by increased production elsewhere, leading to muted impacts on global consumption. Due to these two principles, the economic impacts of ambitious, large-scale forest protection cannot be inferred by simply adding together thousands of small-scale opportunity costs. They can only be accurately evaluated by using a full, dynamic economic model that captures the interplay among price, demand, harvest volumes, trade (exports and imports), and revenues, in each country and in the world market overall.

The global commitment to protect 30% of all land for nature (also known as 30x30 or Target 3 of the Global Biodiversity Framework (GBF)) is one of the most ambitious nature conservation initiatives to date. With only 6.5% of forests currently under effective protection[14], expanded forest protection will be central to 30x30’s implementation, implying that profits in the global wood- and forestry-product sector will be strongly impacted. Global forests under 30x30 therefore provide an important test case of how current approaches to opportunity costs may be exaggerating the economic downside of large-scale conservation, and how full economic modelling could change our understanding of those costs. Here, we apply a partial equilibrium economic model to assess the impact of 30x30 on the global forestry sector’s bottom line. We find that, contrary to the simplified intuition of an automatic loss, ambitious forest protection is projected to cause a modest increase in the forestry sector’s bottom line, although with a finer-scale pattern of winners and losers. We explain why this occurs and the countries most affected. Lastly, we outline the implication of our results for global environmental policy more generally.

Results

The opportunity costs of global forest conservation

In our results we found that, as expected, 30x30 reduced the total harvestable forest area by 6.4% – 15.6%, causing a reduction in roundwood production of 0.7% – 1.8% (depending on scenario, Fig. 1). Despite these two decreases, annual global net output value (NOV) increased by 1.5% – 5.4% by 2060, representing a cumulative gain for 2025–2060 of $192 billion – $671 billion (Fig. 2, Supplementary Table S1). Interestingly, the BID (biodiversity-focused) scenario generated the largest reduction in harvestable area but also the largest boost to NOV (Fig. 2).

This pattern of lower production but higher NOV suggests that, under 30x30, prices rise by more than production falls. GFPM results indeed show global roundwood prices rising between 4.5% and 9.6% (relative to the baseline scenario), driving up also the prices of finished wood and paper products by 0.3% to 3.0% depending on the scenario and product (Fig. 2, Supplementary Table S2). These price rises are possible because demand for wood products remains strong, even when the commodity is scarcer and more expensive (Fig. 2, Supplementary Table S3).

At national and regional levels, we found a more detailed pattern of winners and losers. At national level, 87% of countries were projected to increase their NOV under HPR, 83% under CRJ and 72% under BID (Fig. 2, Supplementary Table S4). In BID, increases and decreases for individual countries were notably larger than in other scenarios, and therefore notably different from the global aggregate gain of 1.5% – 5.4%. For example, 70 countries in BID had projected increases of at least 10%, compared to four or less countries in other scenarios (Supplementary Table S1). Major beneficiaries included many developing countries such as Madagascar, Mali, Sierra Leone, Tanzania, and Botswana. However, twelve countries in BID also had particularly large losses (of > 20% and up to 57%), including Malaysia, Rwanda, Malawi, and Australia (Supplementary Table S1). It is important to highlight that countries like Malaysia and Australia see large forestry losses because after extensive deforestation, they have limited forested area left. Placing the last remaining forested areas off-limits to production therefore has an outsized economic impact. However, the last forest areas are also the last remaining habitat for those countries’ globally important biodiversity. Exploiting them could therefore cause multiple national (or global) extinctions.

At the regional level, all regions but one experienced a positive NOV benefit, including an increase of 2.0–6.4% for Africa and 4.2–12.1%, for Europe (Fig. 3, Supplementary Table S1; Oceania, alone, had positive changes under HPR and CRJ but not under BID). The one regional exception was Asia, which had projected NOV losses under HPR and CRJ (-0.8% and – 2.1%) only just broke even under BID (+ 0.01%). Asia also had the highest projected proportion of loss-making countries of any region (30% – 40%), driven by multiple countries with projected losses in the Middle East and Central Asia.

Sensitivity tests and caveats

To test whether our conclusions were sensitive to the parameterization of their main modelled drivers (the price effect and the production cost estimates), we re-ran the analysis with various different parameterizations. First, we adjusted the price elasticity parameter in either direction by +/- 15% (in modelling, higher price elasticity limits producers’ ability to raise prices, making it harder for GFPM to project a positive NOV effect). Second, we tried varying production costs by 4.5% and 9% in either direction (see Methods section in Supplementary Material), noting that higher costs will decrease NOV gains. A 9% increase in total cost is designed to showcase an underlying 25% increase in timber transport costs, which is the main sectoral cost-type likely to be affected by greatly-expanded forest protection. We acknowledge that, in reality, the industry would act quickly to offset such a 25% cost increase, so the 9% sensitivity test is fairly extreme. Decreases in costs could occur if 30x30 constraints motivate innovations in tree growing, harvesting or transport, or induce efficiency enhancements via supplier consolidation.

In the sensitivity test results, we found that unsurprisingly, reducing elasticity or costs generated larger NOV increases than in the main analysis (Supplementary Table S5-S7). Of more potential interest are the results of the tests that made it harder to reach our conclusion of a positive NOV effect. For those tests, we found that increasing price elasticity by 15%, or transport costs by 4.5%, did not alter the original conclusion, although the projected increases were smaller than before (Supplementary Table S5 and S6). In the most “profitable” scenario (BID), even the 9% increase in costs did not alter this conclusion: NOV still increased by 2.4%. In the other two scenarios, however (HPR and CRJ), 9% higher costs caused projected global NOV to decline by 0.9% and 1.4% respectively, equivalent to an average (mean) of $19–28 million per country per year, with losses concentrated in Canada, China, Russia, India, Turkey, and Thailand (Supplementary Tables S6). Overall, the conclusion of a positive economic impact was therefore largely robust to multiple parameter changes. In the worst-case scenario, the overall opportunity cost would still be minimal. We caution that forestry-sector modelling in GFPM does not capture the possibility that, under persistently high wood prices, substitution may eventually occur toward alternative materials like plastics, concrete or steel, weakening demand and price effects.

Discussion

Although removing forest land from production is critical to achieving global climate and biodiversity goals, previous studies have suggested that this could cost up to half a trillion dollars per year at current prices, mostly due to the high opportunity costs[11,12]. An update of the Stern Review similarly projected protection costs of $1.38 billion per country per year (at 2025 values) [15]. However, for the global wood- and forest-product industry – the economic sector in the front line of forest-protection opportunity costs – our model projected not a large cost, but a small benefit. This occurs because, at large scale, price effects mitigate reduced production, just as OPEC reduces oil production to increase profits. And as happens with oil, the wood/forestry sector’s bottom line was improved due to market effects, despite reductions in the amount of harvestable forest and lower production volumes. Even under the most conservative interpretation of our results, the opportunity costs of global forest protection would be minimal.

Our results also suggest a much broader issue with current opportunity cost methodologies. Simply summing up multiple, small-scale estimates of lost production, as current methods do, is likely to give reasonable results at smaller scales. But at large scales, where market effects will influence results, only full economic modelling can provide the necessary accuracy. Indeed, the small-scale approach can generate highly misleading exaggerations of the costs of large-scale initiatives. Two recent grey-literature studies that also used complex models have found non-intuitive outcomes similar to ours, for sectors outside forestry. Waldron et al.[16] studied the impact of 30x30 on agricultural NOV, using several integrated assessment models that incorporate market and trade effects, and projected only a small NOV change, with losses and gains of ~ 1% both possible. Johnson et al.[17] applied a partial equilibrium model to a different set of 30x30 scenarios and found that, in GDP terms, the global GDP opportunity cost could be as little as $13 billion per year, far below $300–400 billion calculated in earlier studies[18] .

If current methodologies are significantly overestimating the opportunity costs of global environmental action, the implications are far-reaching. Much of the friction that hinders achievement of climate and biodiversity goals comes from the belief that large-scale nature protection will significantly reduce economic output. As a result, conservation economics has put substantial (and often expensive) effort into either compensating for those losses (opportunity costs) or justifying them. Alongside the half-trillion-dollar climate example above, global compensation strategies with potentially high financial costs also include carbon credits and emissions trading markets[19,20], payments for ecosystem services[21], direct international assistance, biodiversity offsets and debt-for-nature swaps[22–24]. All these strategies will have exaggeratedly high cash expenditures if they use exaggerated opportunity cost estimates. Overpayments for opportunity costs are economically inefficient and may even be deemed unaffordable (in which case no pro-environment spending occurs). For countries that genuinely experience large opportunity costs, on the other hand, full economic models give a much better sense of the true magnitude of compensation needed. This would help avoid difficult political situations such as that in Palau, where the population has come to realize that ambitious conservation has lowered incomes without sufficient compensation, in contradiction to earlier assurances[25].

An alternative strategy to compensation is avoiding opportunity costs in the first place. In the extreme, this includes blocking the implementation of environmental protections upfront. Such blocking is more likely to occur when opportunity costs are exaggerated. More widespread application of full economic models could prevent governments from missing low-cost opportunities for environmental protection. More subtly, cost-avoidance can involve watering down the effectiveness of existing nature-conservation efforts. An example is common practice of creating protected areas in remote areas to minimize opportunity costs, often causing a failure to spatially capture threatened biodiversity[26,27]. Interestingly, our results suggest that this approach does not always have the simple, positive economic impact that it aspires to. Our HPR and CRJ scenarios were designed to avoid protected-area opportunity costs in exactly this way, whereas BID was not. HPR and CRJ did succeed in reducing the largest single-country losses: for example, Rwanda's loss shrank from 57% in BID to 3% in both HPR and CRJ, and Malaysia's loss shrank from 36% in BID to 0.4% in CRJ and indeed, became a 4% gain in HPR (Supplementary Table S1). However, the two strategic cost-avoidance scenarios also reduced global NOV gains by over 50%. Indeed, only one country achieved a NOV gain of > 10% in CRJ and only four countries in HPR, compared to 70 countries attaining that large benefit in BID (the non-cost-avoiding scenario, Supplementary Table S1). Pre-avoidance of opportunity costs could therefore significantly harm global market outcomes and reduce economic gains for many countries; this would be the trade-off for reducing losses in a smaller number of negatively-impacted countries.

In summary: changing the approach to opportunity costs so that it reflects the full complexity of economic interactions would have multiple benefits. Concerns about the negative economic outcomes of globally-important conservation initiatives might be widely attenuated, removing barriers to action. Greater use of such models could uncover other global environmental policy propositions that have lower-than-expected adverse effects. And win-win outcomes that are hard to intuit, such as OPEC-style boosts to income, can be identified and acted upon, to capture both economic and environmental benefits for the future.

Methods

Protected forest area scenarios

Most decisions about 30x30 implementation have not yet been made, so to model its economic effects, we used three different scenarios of where new protected areas might be implemented. The three scenarios were taken directly from Waldron et al.[16] and reflect a logic that when creating new protected areas, governments are likely to trade off biodiversity importance against economic or food-security considerations. The first scenario (called BID) is purely "biodiversity-focused", using Integer Linear Programming (ILP) to identify an optimal set of new protected areas without regard for economic consequences (see Waldron et al.[16] for details). The second scenario (HPR or "harsh political reality") is "agricultural production focused". It starts by identifying all current natural areas (including forests) that will require conversion to agriculture to efficiently meet future food-production needs (up to 2050) and removes them from possible protection, before running the ILP optimization as before. The third scenario (CRJ, for "crown jewels") is a biodiversity/production compromise, i.e. a land-use planning compromise between biodiversity needs and future agricultural production needs (see supplementary information and Waldron et al.[16]). We note that future forestry production is threatened by agricultural expansion as well as by protection. By prioritizing agricultural production and biodiversity conservation simultaneously in our scenarios, we capture some of the complex interplay between these three competing land demands. Further details regarding the scenarios can be found in the supplementary material.

Projecting the impact of 30x30 on the global forestry industry

To model how 30x30 affects output values across the global forestry sector, we used the Global Forest Products Model (GFPM)[28–30], a partial market equilibrium model that has been successfully applied to evaluate a range of questions about worldwide, regional, and country level forest sector outcomes[16,28,31–33]. The GFPM models production, consumption, price, imports, exports and revenues over time, for 14 categories of forest products in 180 countries and territories. It also projects changes in standing forest levels and wood volume levels, as trees grow naturally, are planted, or are removed in response to demand and price. Hence, it addresses the many, complex economic interplays that the simplified approach to opportunity cost ignores, including the possible increase in price and the shifting balances of production, consumption and trade. The GFPM takes as its initial input the reduction ("shock") in harvestable forest area implied by 30x30. It then projects the changes in production of roundwood and its downstream uses, and the evolution of prices, consumption, production, imports, exports, forested area and final revenues, from 2025 to 2060. For comparability with other opportunity cost studies, we assume that protection fully prevents exploitation, acknowledging that this is not always the case on the ground[34]. Additional details of the GFPM model are provided in the supplementary material.

The GFPM generates a gross output value (GOV) for the forestry sector (total forestry revenues per country). However, the more meaningful bottom-line metric is the net output value (NOV), which subtracts the costs of production (on which there is limited information) from the revenues earned. To convert GOV to NOV, we researched records of national forestry-production costs, collating results across 68 studies (see 'Forestry cost estimates' section below). The literature does not provide costs for several countries, so we took regional cost means and then applied sensitivity tests to our results (Supplementary Figure S1, Supplementary Table S8). The tests also explore the possibility that costs themselves might be affected by 30x30 (see the 'Sensitivity tests' section below). Finally, we calculated the 30x30 impact as the difference between the NOV for a reference baseline (in which no new protected areas are created) and the NOV projections for each of the three scenarios. This differencing approach isolates the effects of protected-area expansion on market outcomes under each 30x30 scenario.

Forestry cost estimates

The GFPM generates a gross output value (GOV) for the forestry sector (total forestry revenues per country). However, the more meaningful bottom-line metric is the net output value (NOV), which subtracts the costs of production from the revenues earned. Converting gross revenues to net output value (NOV) requires a database of production costs, which should then be subtracted from gross output value for the relevant country.

Information on forestry costs in all 180 countries modelled by the GFPM is limited. To generate the most comprehensive database possible, we searched the global peer-reviewed and grey literature for estimates of forestry costs. We found and collated 68 country-specific studies from various publications and the citations and data therein (including previous collation studies)[35–40]. Many of those studies reported harvest costs only. However, post-roadside costs (transport to mill/port) are known to represent 25–50% of the total costs, making them potentially at least as large as harvest costs[41]. Transport costs are only sometimes paid by the logging company[41], but we nevertheless chose to include them, in order to minimize the possibility of overestimating net financial outcomes (noting that the larger the cost estimate, the smaller and more potentially negative the 30x30 NOV impact becomes). Several studies on harvest costs included neither these large transport costs, nor the much smaller costs related to pre-harvest work. To overcome these lacunae, we used studies where either transport cost or pre-harvest cost (or both) was reported alongside harvest costs, to calculate the ratio between the harvest cost and the transport or pre-harvest cost. We then obtained the means of those ratios and applied them to impute missing pre- or post-harvest costs. We adjusted all the dollar values for inflation to 2018 constant-dollar values. The final estimated average regional total harvest costs (including harvest, pre-harvest, and transport to mill) are shown in column 3 of the Supplementary Table S8 and Figure S2. These were subtracted from the GOV model outputs to generate NOVs.

Sensitivity tests

Transport costs are the costs that are most immediately likely to change from their current (database) values under 30x30, for example if expanded forest protection causes spatial changes in logging sites and roads, and therefore in distances travelled. The large contribution of transport costs to total costs also makes such an effect potentially influential on the final conclusions about NOV. In practice, any increase in those costs will make it harder for the model to project an increase in NOV: if 30x30 increases GOV but increases costs more, then NOV will still be negative. To test the sensitivity of our conclusions to these possible cost differences, we recalculated NOVs after increasing transport costs by 12.5%, equivalent to a 4.5% overall cost increase. We also explored the impact of 25% higher transport costs, equivalent to a 9% overall cost increase, although this may be seen as extreme, not least because most wood-sector industries faced with such a large increase in one of their major costs would likely compensate for it urgently by cost-cutting, by raising prices, or by adjusting other operational aspects. For balance, we additionally tested the impact of cost decreases of 4.5% and 9%. A decrease in future costs may occur if technological advances lower input costs (per unit output), and indeed if 30x30 itself motivates greater efficiency.

Any OPEC-style boost to forestry earnings is also strongly driven by the degree to which prices rise as production is cut. We therefore also sensitivity-tested the outcomes of modelling runs in which (i) supply was made more price-sensitive, implemented by multiplying the price elasticity of supply by 1.15; and (ii) supply was made less price-sensitive, implemented by multiplying the elasticity by 0.85.

The main text describes the results of these sensitivity tests, which generally confirmed the robustness of the overall conclusion that ambitious increases in forest protection under 30x30 leads to a slight increase in forestry and wood sector NOVs.

Declarations

Competing interests

The authors declare no competing financial interests.

Data and materials availability

All data are available in the main text or the supplementary materials.

Author contributions

Provided in the cover letter

Acknowledgments

Provided in the cover letter

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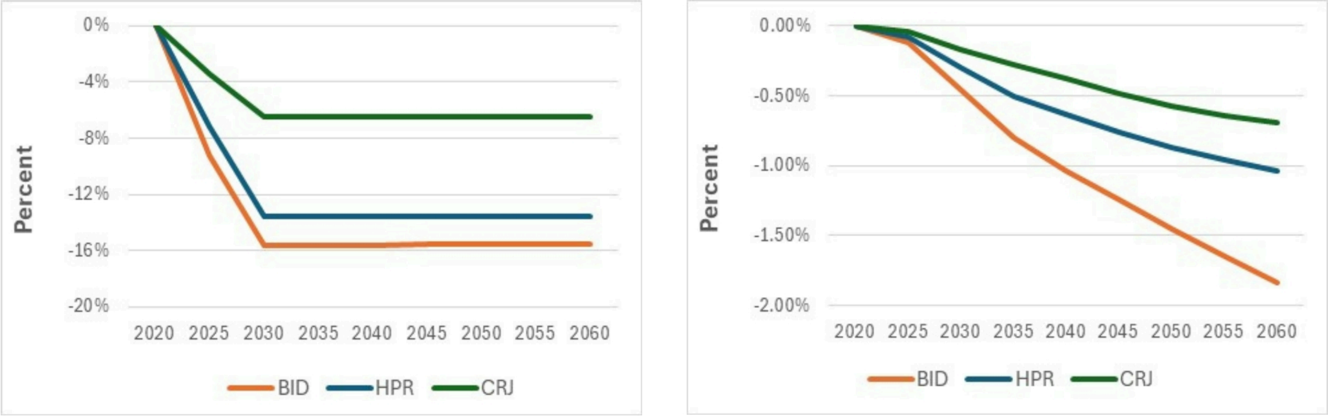
Figures

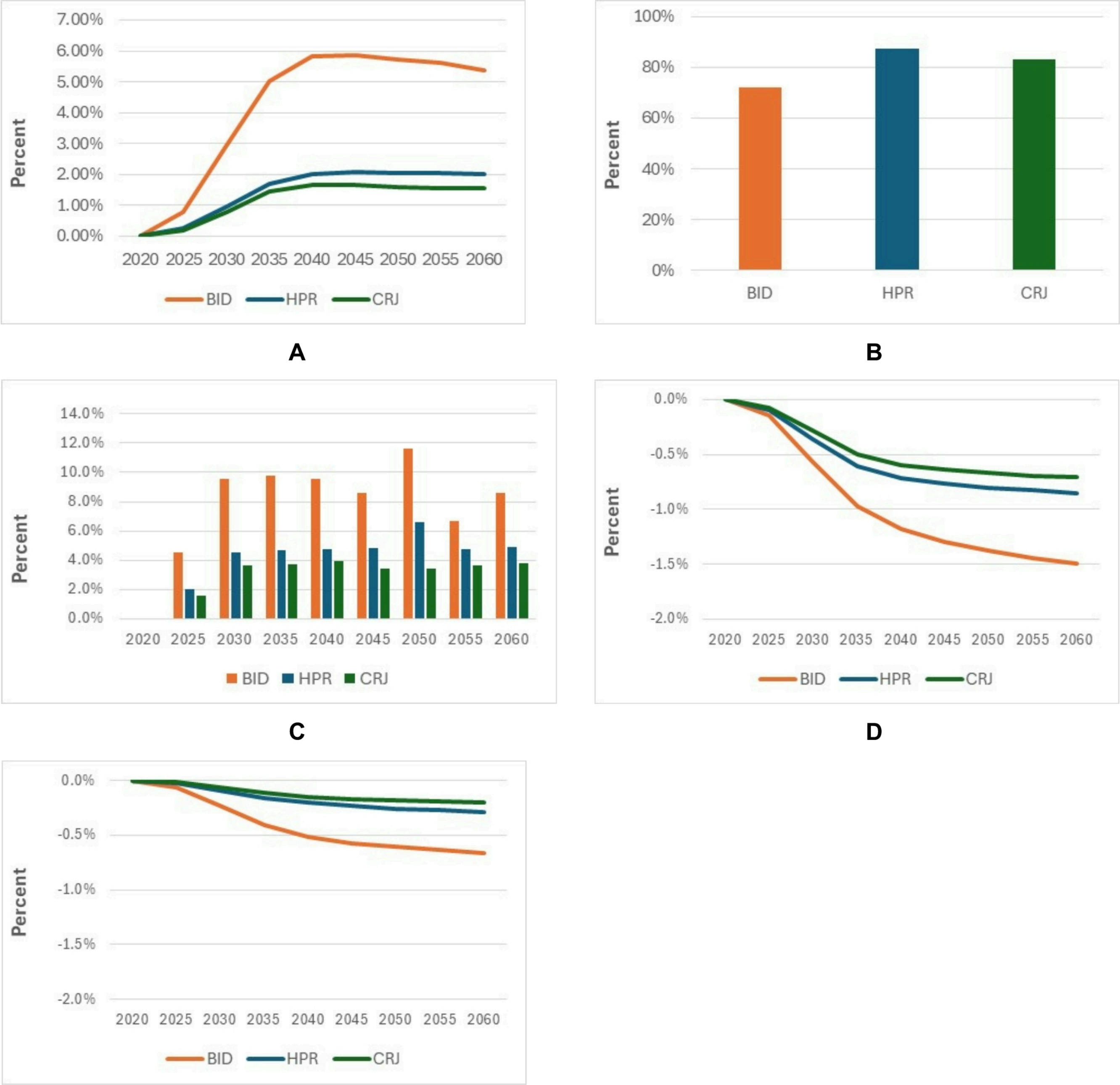


A

B

Figure 1

Projected impact of 30x30 on harvestable forest area and roundwood production relative to reference. (A) Change in harvestable forest area (%). **(B)** Change in roundwood production (%).



A

B

C

D

E

Figure 2

Projected impact of 30x30 on net output value, roundwood price, wood demand (consumption) relative to reference. (A) Change in net output value (NOV) due to implementation of 30x30 (%). **(B)** The proportion of countries that had a positive NOV change after 30x30. **(C)** Change in roundwood price (%). **(D)** Change in finished solidwood consumption (demand) (%). **(E)** Change in paper consumption (demand) (%).

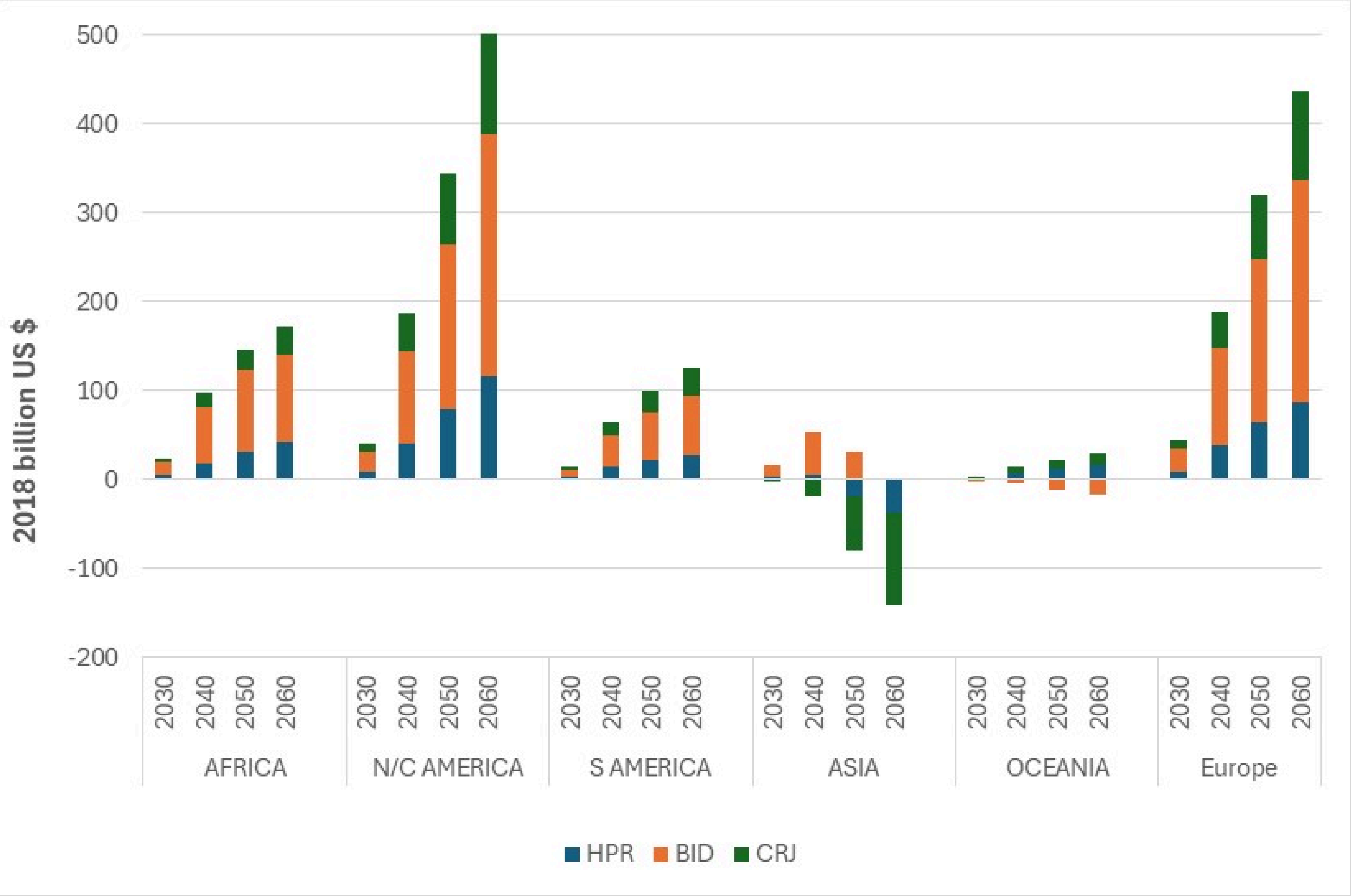


Figure 3

Regional differences in projected impact of 30x30 on net output value, across three scenarios.

Supplementary Files

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