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Linking national wood consumption with global biodiversity and ecosystem service losses

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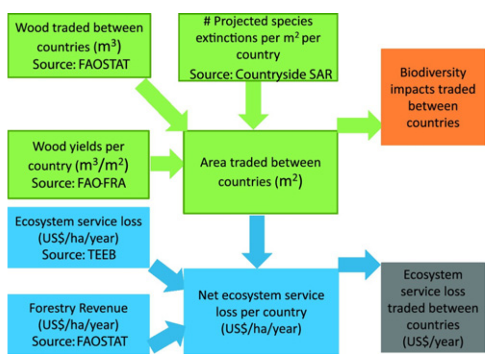
HIGHLIGHTS

- We combine countryside species-area relationship with global wood trade and yields.
- 155 out of total 485 forestry driven global extinctions (32%) are due to exports.
- We calculate species extinctions due to wood production for all world countries.
- Some low-income nations may be losing ecosystem services worth >3000 US$/ha/year.
- Forest land use in tropics drives biodiversity as well as net economic losses.

GRAPHICAL ABSTRACT



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ABSTRACT

Identifying the global hotspots of forestry driven species, ecosystem services losses and informing the consuming nations of their environmental footprint domestically and abroad is essential to design demand side interventions and induce sustainable production methods. Here we first use countryside species area relationship model to project species extinctions of four vertebrate taxa (mammals, birds, amphibians and reptiles) due to forest land use in 174 countries. We combine the projected extinctions with a global database on the monetary value of ecosystem services provided by different biomes and with bilateral trade data of wood products to calculate species extinctions and ecosystem services losses inflicted by national wood consumption and international wood trade. Results show that globally a total of 485 species are projected to go extinct due to current forest land use. About 32% of this projected loss can be attributed to land use devoted for export production. However, under the counterfactual scenario with the same consumption levels but no international trade of wood products, an additional 334 species are projected to go extinct. Globally, we find that losses of ecosystem services worth $1.5 trillion/year are embodied in the timber trade. Compared to high-income nations, tropical countries such as Philippines, Nicaragua, Sri Lanka, Gambia and Bolivia presented the highest net ecosystem services losses (>3000 US$/ha/year) that could not be compensated through current land rents, indicating underpriced exports. Small tropical countries also gained much lower rents per species extinction suffered. These results can help internalize these costs into the global trade through financial compensation mechanisms such as REDD+ or

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through price premiums on wood sourced from these countries. Overall the results can provide valuable insights for devising national strategies to meet several of the global *Aichi 2020* biodiversity targets and can also be useful for life cycle assessment and product labelling schemes.

1. Introduction

The world's forests cover almost 31% of the land surface, and the majority of terrestrial species dwell or depend on these forests. Anthropogenic forest exploitation leads to wood valued over US$100 billion being extracted from forests globally each year (FRA, 2015) and is the major driver of forest degradation (Kissinger and Herold, 2012). Forestry operations result in changes or complete removal of microhabitats, change in the tree age structure, composition of tree species and vertical stratification, with negative consequences on forest biodiversity (Barlow et al., 2007; Chaudhary et al., 2016). High number of species loss within a region can result in disruption of ecosystem function and services ultimately cascading into human health and economic losses (Dirzo et al., 2014).

Increasing globalization of trade means that the environmental impacts often occur far from the place of consumption (Weinzettel et al., 2013; Meyfroidt and Lambin, 2009; Lenzen et al., 2012). Despite this seemingly increased connectivity between different world regions, end consumers are rarely aware of the environmental damage and ecosystem changes occurring at the origin of production (Kissinger and Rees, 2010), often leading to unsustainable consumption levels (Lambin and Meyfroidt, 2011). Many countries have reduced forest exploitation and achieved forest transitions (i.e. a shift from net deforestation to net reforestation) by importing wood products from other countries experiencing decline in forest areas (Meyfroidt et al., 2010; Kastner et al., 2011a; Mills Busa, 2013). By displacing the negative externalities associated with wood production to other countries, importing countries can falsely appear to be sustainable at the local scale.

Traditional conservation measures such as setting aside areas rich in biodiversity (Myers et al., 2000) could be complemented through integrated approaches to halt biodiversity declines (Tittensor et al., 2014). In particular, changing consumption patterns can go a long way in halting current high rate of species loss. To this end, the environmental impacts embodied in the global supply chains need to be estimated and communicated to end consumers — potentially inducing environmentally conscious purchasing decisions (Lenzen et al., 2012) and supply chain interventions such as demonstrated by the 'Brazil's soy moratorium' (Gibbs et al., 2015a, 2015b). Such interventions present new opportunities for global biodiversity conservation by pushing or providing incentives to exporting countries to reduce deforestation or adopt environmentally friendly production methods.

Efforts to quantify biodiversity and ecosystem services (ES) losses incurred due to wood production and trade at a global scale are rare. Through The Economics of Ecosystems and Biodiversity (TEEB) initiative, researchers have recently quantified the total monetary value of ES provided by ten different biomes, with tropical forests presenting the highest values (de Groot et al., 2012). However the only analyses of the estimation of the value of ES loss embodied in timber trade is restricted to tropical countries (Chang et al., 2016). Regarding biodiversity, the study by Lenzen et al. (2012) and Moran et al. (2016) are one of the very few attempts at quantifying IUCN listed '*species threats*' (IUCN, 2011) embodied in global trade of forestry products. Another exception is Nishijima et al. (2016) and Kitzes et al. (2016) who estimated the impacts of timber trade on birds. Others authors have estimated the forest land area (Meyfroidt et al., 2010; Yu et al., 2013) imported or exported by different countries through wood products trade. As biodiversity is non-uniformly distributed across the world, embodied forest land is not a good proxy for embodied biodiversity impacts. For example, saving tropical forests in species rich Costa Rica at the expense of temperate forests in the United States can lead to a more positive balance in terms of species conservation than reflected by calculations of land-use areas alone (Meyfroidt et al., 2010). Similarly, the areas of absorbed land alone will not reflect the actual losses of ES (Chang et al., 2016).

Alternative trade databases and biodiversity impact assessment methods to quantify species loss (as opposed to "species-threats") and methods estimating ES losses at the global scale are needed to further advance the understanding of the tele-connected implications of timber trade on the environment. The aim of this study is to quantify the biodiversity and ES impacts caused by forest land use in different countries and estimate the impacts embodied in bilateral wood trade.

2. Methods

We first trace the origin of imported wood items using the approach by Kastner et al. (2011b) and estimate forest land area (in m^2) imported and exported by 174 countries in the year 2011. Next we derive biodiversity characterization factors (i.e. species extinctions caused by per m^2 of forest land use in different countries) using countryside species-area relationships (Pereira et al., 2014) for four vertebrate taxa (mammals, birds, amphibians and reptiles). We then use the global database on monetary value of ES provided by different biomes (de Groot et al., 2012) to derive ES characterization factors (i.e. net ES loss in US$ caused by per m^2 of forest land use) for each country. Finally, linking the characterization factors with traded forest area, we calculate the biodiversity and ES impacts caused by wood production, consumption, imports and exports of each country.

2.1. Calculating forest area embodied in traded wood products

We applied the following three step approach to calculate the forest area devoted for domestic consumption, export production and embodied in wood imports of each country:

2.1.1. Step-1

We first obtained bilateral trade linkages between 174 countries for following wood products from forestry trade flows data of FAO (FAO, 2013) for the year 2011: industrial roundwood, sawnwood, paper and paperboard, chips & particles, and wood based panels. Wood fuel, which is traded internationally only in very small quantities, is not available from the above database. For all seven products, data were available in m^3 except newsprint which was reported in tons. We converted each wood product item into a common unit – tons of carbon based on factors from IPCC (2006) (see Table 1 in Kastner et al., 2011a). Note that the limitation of this trade data is that it does not provide information on whether the imported product originated in the country exporting it. For instance, it might be that roundwood originating from Brazil is first exported to a port in Belgium, from where it is exported to Poland. FAO trade data present this as two separate trades with no "chain of custody" data to show that it is the same roundwood from Brazil (FAO, 2013).

2.1.2. Step-2

We therefore use the approach proposed by Kastner et al. (2011b) to trace the origins of a given country's wood imports. This approach is equivalent to the mathematics of input–output analysis, as introduced by Leontief (1986). While input–output analysis studies the interrelations between different sectors of an economy, based on the assumption of proportional distributions between sectors, the approach by Kastner et al. (2011b) investigates the trade interrelations between countries, assuming proportional distributions between domestic production