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Globalization of land use: distant drivers of land change and geographic displacement of land use

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Several streams of research have recently converged to identify the growing importance of distant drivers of land change, interconnections between social-ecological systems that are separated geographically, and the indirect consequences of land use changes. Local to national-scale interventions to *promote* sustainable land use may *have unintended effects* owing to a displacement of land use within and across countries. Such leakage or 'indirect land use change' critically depends on international geographies of trade. Computing various material flows and environmental indicators embodied in international trade highlights the differences between producer and consumer-based biophysical accounting. Causal attribution of the links between material and monetary flows across countries, and actual land changes and environmental impacts at local level requires a combination of economic simulation models, statistical studies, place-based empirical studies, value chain analyses, and biophysical accounting.

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Introduction

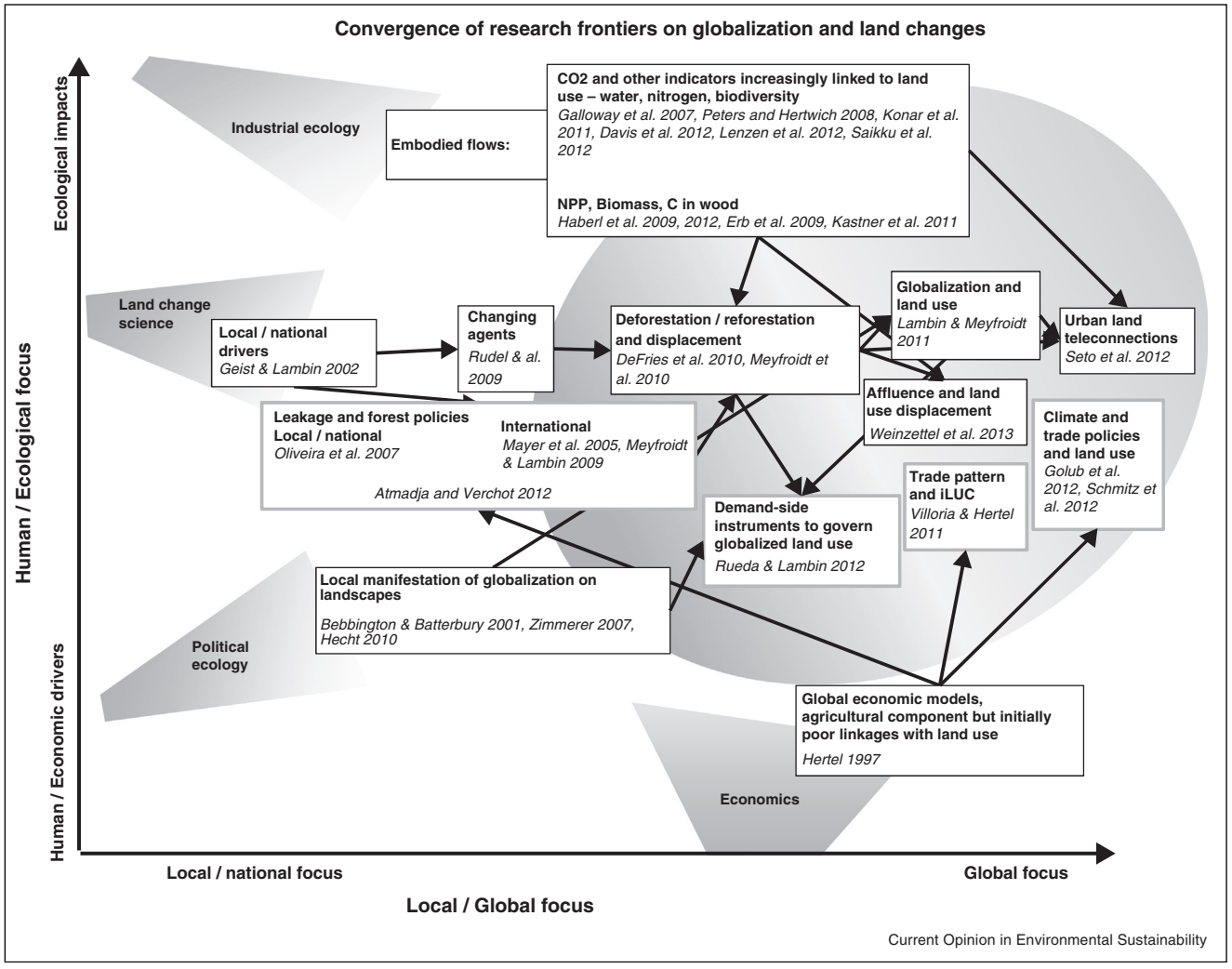
Land change science has a tradition of place-based studies, focusing on local causes of land use/cover change, treating national and global factors as boundary conditions [1]. Several independent streams of research have recently converged to identify the growing importance of distant drivers of land change, interconnections between social-ecological systems that are separated geographically, and the indirect consequences of land use changes as they arise across international borders and in the context of differing national policy regimes (Figure 1). The objective of this review is to trace these multiple streams of literature, and propose paths to interweave them. First, we describe the expansion of land change research from local to global processes, taking the example of deforestation, one of the most intensively studied areas of land change. Second, we discuss unintended consequences of local or national policies on land use in other countries — which are likely subject to different national policies. We then review metrics to assess land use and environmental impacts of trade. Finally, we refer to an emerging literature linking local land use changes with socio-economic processes of globalization. We conclude with research perspectives.

From local processes to globalization of land changes

Causes and agents of deforestation have evolved over time [2••]. From 1960s to 1980s, small-scale farmers, sometimes supported by state programs of agricultural modernization or colonization, were the main actors of tropical deforestation. In a neo-Malthusian narrative, poverty, poor agricultural technologies and population growth were viewed as the main causes of deforestation. Pathways to deforestation have been shown however to be more complex, involving economic, demographic, technological, cultural and political factors acting at multiple scales, and influenced by geopolitical interests, governance, social and ethnic struggles [3,4]. Although international forces were recognized, deforestation and other land changes were analyzed as domestic processes, by linking remote sensing data on land cover with socio-economic survey data on land use decisions by agents [5,6]. Spatially explicit land use models only accounted for the proximate determinants of land use changes [7].

With the expansion of globalization and urbanization, the agents of deforestation have changed, in particular in Latin America and Southeast Asia. Even though the majority of agricultural and forestry production remains destined for domestic markets, international trade is far

Figure 1



Convergence of research frontiers on globalization and land changes, and land use displacement. Arrows trace the evolution and cross-fertilization of research lines. The *X* axis situates research topics on a gradient from studies focused on local processes, to studies focused on global processes, with the middle being occupied by medium-range studies or studies explicitly linking local processes to global forces. The *Y* axis situates research topics on a gradient of focus from the human processes driving land changes, towards measuring and tracing environmental impacts. Some studies (with bolded border) are directly oriented towards the governance of linkages between globalization and land changes.

more volatile than domestic sales, and therefore plays an outsized role in determining changes in land use. Estimates for 2004, factoring in both the direct and indirect input requirements for land use, suggest that on net, international trade accounts for 24% of the global land footprint [8••], or 12% of the total human appropriation of net primary production (NPP) [9]. For some products and countries, export markets can be very important — for example, about 46% of Brazilian oilseeds sales and 48% of Russian forestry products sales in 2001 took place in the export markets.[1] An important factor contributing to expansion of this footprint and the associated deforestation has been the growth in agribusinesses and large-scale, highly capitalized farm and forestry firms, producing commodities for global markets [2••]. Distal interconnections and remote causes of land change received more attention. Cross-country statistical analyses showed that recent tropical deforestation is associated with international trade of agricultural products and remote urban demand, rather than with rural population growth [10••]. A few key countries, including Brazil and Indonesia have increasingly absorbed the growth in global demands for key agricultural products such as soybeans and palm oil, leading to rapid agricultural and logging expansion, and lost forest cover [11–13]. Urban centers also affect land change well beyond the limits of their traditional hinterland through changing

[1] Numbers taken from the Global Trade Analysis Project (GTAP) 6 database for the year 2001, available online at https://www.gtap.agecon.purdue.edu/databases/v6/default.asp.

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consumption patterns associated with urban lifestyles and their wider networks of influence [14•]. Indeed, 42% of the terrestrial surface show an imbalance between production and consumption of biomass, and thus participate to trade, one prominent aspect being rural to urban transfers of biomass [9]. Increasing influence of distant causes, including remote markets, diffusion of technologies and international political forces, was also shown for other land use/cover changes, for example, in swidden cultivation systems [15].

Unintended consequences of land use policies: leakage and indirect land use changes

Early studies of reforestation and forest transitions — defined as national-scale shifts from shrinking to expanding forest areas — also focused on local and national-scale processes: agricultural intensification and industrialization driving labor scarcity in agriculture and concentrating production on the most suitable land; scarcity of forests driving tree plantation, forestry intensification and forest protection; and tree-based land use intensification by smallholders [16,17]. Other studies have explored the unintended consequences of forest recovery beyond the borders of reforesting countries (Figure 1). Recent forest transitions in a handful of developing countries were associated with an outsourcing of land use and forest exploitation abroad via increased wood and sometimes agricultural products imports [18•,19]. Economic globalization thus facilitated a national-scale forest transition in some countries through a displacement of land use — broadly defined as a geographical shift of land use from one place to another. Displacement can result in spatial separation between the land used for agricultural or wood production and the place of consumption of these products, as it occurs with trade [9]. This displacement can occur across but also within countries, when 'facilitating regions' — for example, the US Midwest and Brazilian Amazon — supply increasing amounts of resources and goods to other regions, for example, Northeastern U.S. or Southeastern Brazil, thus facilitating set aside of land and reforestation in these regions [20]. Displacement can also result from population movements.

When assessing the impacts of environmental policies, for example, for forest protection or renewable fuels through bioenergy crops, leakage refers to a displacement of the environmental impact, thereby counteracting the intended effects of the initial policy. Leakage is thus one form of land use displacement. Early studies of leakage were conducted at a local scale, following the establishment of protected areas or other land use restrictions [21,22]. Recent studies quantified leakage across countries following carbon sequestration projects in forestry under REDD+ and other schemes [23]. Protecting forests in Northeastern U.S. while outsourcing timber extraction to tropical countries where forestry practices are more destructive creates an 'illusion of preservation' [24]. Forest protection policies in Finland and China [25,26] and in Vietnam [27] displaced logging pressure to neighboring countries. Causal attribution is a challenge in displacement studies: how to distinguish leakage from shifts in production that would have occurred anyway due to evolving international trade in the absence of new land use policies? Solutions include natural experiments — for example, before/after the policy is implemented [25] — or constructing a counterfactual of the likely behavior of the system absent the policy change [27,28••]. We still lack local-scale empirical studies that track and relate land use changes in interconnected places, in both source and target countries.

Interest in the issue of leakage and other global land use impacts associated with biofuels production — called 'indirect land use change' (iLUC) in that context — has grown recently [29]. The iLUC associated with biofuel mandates put in place in the EU and US to reduce GHG emissions have been estimated to exceed the environmental benefits from these renewable fuels in some cases [30]. Most analyses of global land use changes stemming from biofuel production use economic simulation models (often Computable General Equilibrium or CGE models) [31] (Figure 1). This work has highlighted the importance of market-mediated effects induced by higher feedstocks prices, including shifts in area from competing crops, higher yields, reduction in intermediate usage (e.g. feedstuffs) and reduced consumption [32]. Parameter uncertainties remain a major concern in these models, requiring sensitivity analyses but also pointing to the importance of further empirical work. One of the few empirical studies of global cropland displacement focuses on national area responses to a rise in the US coarse grains price, as spurred by the US maize ethanol program [33••]. Those authors find that countries which compete head-to-head with the US in third markets, such as Argentina, are most strongly affected by the US price rise. Some, very large, coarse grains producers such as India are much less affected due to limited interaction with US exports in the global marketplace. Because countries more exposed to US trade also have relatively higher yields and lower GHG emissions intensities than those which do not compete with US maize exports, failure to account for this geography of trade leads to an overstatement of GHG emissions from US biofuel policies of nearly 100%.

Given the importance of spatially varying crop yields and emissions factors in assessing land displacement effects, some global models have begun disaggregating land use all the way down to the grid cell — for example, GLOBIOM [34,35], MAgPIE [36•]. These partial equilibrium studies offer the potential to explore a richer set of policy responses to control displacement and iLUC, for example, showing that direct land use zoning in tropical countries to protect high carbon and biodiversity forests may reduce iLUC more effectively than sustainability

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criteria imposed by biofuels-importing countries [34]. Spatially explicit models also allow for exploration of regional variation in those factors driving future land use change, concluding, for example, that global trade liberalization would encourage further deforestation and agricultural exports in Latin America [36•], while in the Congo Basin, investments in transport infrastructures would have the largest influence on future agricultural expansion, logging and exports of agricultural and forestry products [35].

Biophysical accounting: from land change to environmental impacts

Another stream of research, originating mainly in industrial ecology and ecological economics, links trade with land use through a quantification of material flows embodied in trade. Upstream flows related to land-based products are product-specific and region-specific, depending on the characteristics of production systems. Environmental impacts associated with one unit of traded or consumed product are thus highly variable. Data on international trade volumes alone are therefore insufficient for analyzing interlinkages of land-based production and consumption. In addition to describing trade in quantities of agricultural and wood products being exchanged, a variety of material flows embodied in, and environmental indicators associated with international trade are also being computed, including: virtual water [37], land resources [38], water and nitrogen [39], biomass flows [9], land use [18•,40,41]; embodied carbon stocks [19] or carbon emissions [42••,43•], as well as impacts on biodiversity [44]. These studies often rely on the same global databases as do the CGE models (e.g. GTAP [45], itself based on COMTRADE and national input–output tables, supplemented with FAO statistics) to translate physical intensities into 'virtual' trade flows. Methods vary in sophistication, but the most popular approach involves multiregional input–output analysis [46]. These studies highlight the differences between producer and consumer-based environmental accounting. Despite the growing sophistication in tracking cross-country material flows, few studies establish causal links between trade and actual land changes at local level. And these studies have only recently begun to take account of the role of transport mode in determining overall emissions associated with international trade [47].

Other socio-economic dynamics affecting land use

A few geographers and political ecologists studied the impact on agro-ecosystems and land use of various socio-economic trends associated with globalization [48,49,50•] (Figure 1). The distant factors affecting land use include a growing concentration of global commodity value chains, foreign investments in land and large-scale land acquisitions by foreign actors, and the emergence of niche commodities destined for high income markets. Other relevant processes are the diffusion of market and technological information to producers using new technologies, impacts of migration on labor availability, and remittances from migrants to rural areas. The expansion of protected areas, which is promoted by various international organizations, exemplifies the interplay between globalization and local geographies, in particular by the incorporation of agriculture and resource use into conservation programs [51].

Novel work analyses how new forms of market-based governance such as sustainable corporate sourcing, eco-labelling, market exclusion of commodities that do not meet minimum sustainability criteria (moratoria and boycotts), and multi-stakeholder commodity roundtables, influence land use through global value chains of specific forest and agricultural products. Understanding their influence requires analyzing how, for example, price premiums for goods certified as meeting sustainability criteria are distributed along the supply chain [52••]. Sustainability standards adopted by large agri-business corporations trigger new land use practices among their suppliers. Nature conservation programs that are based on payments for ecosystems services and implemented at the international level (such as REDD+) are another form of demand-driven interventions on land use that link global actors, public or private, with local land use. A key issue is to understand the effectiveness of different governance structures combining state regulation, civil society advocacy, responsible consumerism, and corporate environmental responsibility in delivering transformational progress towards sustainable land use [53].

Discussion and conclusion

Land use changes are strongly influenced by globalized flows of commodities, information, capital and people, and are increasingly driven by factors in distant markets, often associated with the growing urban consumer class in emerging markets [54••]. Local to national-scale interventions to promote sustainable land use may have unintended effects abroad owing to a displacement of land use across countries. Understanding these emerging interactions and feedbacks between distant social–ecological systems and effectively harnessing the new opportunities presented by globalization represent major challenges.

The theoretical lenses through which displacements of land use across countries can be framed have been insufficiently explored. One view would see displacement as driven by comparative advantages, resulting in the progressive refinement of the optimal spatial matching of the land use and the productive potential in each region [55]. By boosting global productivity, such a matching process for agriculture and forestry has the potential to relieve pressure on marginal ecosystems. Deforestation in high yielding areas could thus lead to land sparing at the global level. Retrospective analysis of the land-sparing nature of

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the green revolution suggests that, while it did precipitate area expansion for wheat in developing countries, overall, it led to a reduction in global cropland area, when compared to a scenario without these productivity gains [56]. Looking forward, factoring in slower population growth, favorable changes in food tastes, abandonment of biofuels, and continued improvement of technology, one study foresees a release of some 146 Mha of cropland to nature in 2050 [57]. However, this study says little about the geographic pattern of land use changes, and the role of trade in these dynamics. Globalization of production systems could also lead to environmental degradation when the regions engaged in technological 'catch-up' exhibit high land supply response, low yields and low environmental efficiencies [58]. Furthermore, inflows of cheap products via trade can also decrease incentives for agricultural intensification in some places. Indeed, modelling experiments show that trade liberalization could increase exports from regions with comparative advantage, but, by reducing agricultural prices, could reduce the adoption of technological innovations in most regions (except Latin America) and thus encourage further deforestation instead of land sparing [36•]. Another view, based on the unequal exchange theory, holds that developed countries externalize their consumption-based environmental costs to less-developed countries, including through land use embodied in trade [59,60]. Dependency theory asserts that, given their position in the world system, developing countries are dependent on natural resource exploitation for exports and to service their foreign debt [61]. Empirical evidence is mixed: for carbon emissions and biodiversity, consumers in developed countries indeed outsource an important share of their environmental load to developing countries [42••,44]. For land-based products in general, biomass flows predominantly from low to high population density areas [9,62••]. Bivariate correlations showed no relation between development status and net trade [62••]. But multivariate regressions showed that, with higher income, countries trade more land-based products, but imports increase faster than exports, so that net displacement of land use increases with income [8••]. This pattern is particularly strong for wood products [8••,63]. Differences in biophysical endowments remain important determinants of trade patterns: in general, countries with high per capita biological productivity export more agricultural and forestry products [8••,19,37,39].

Researching the linkages between globalization, including material and monetary flows across countries and value chains, and actual land use changes and environmental impacts poses methodological challenges. Cross-fertilization and integration between the research streams described in this paper (Figure 1) is crucial to overcome these challenges. Biophysical accounting and CGE models provide analytical frameworks for understanding the relations between trade and production, by estimating the impact of trade in a specific commodity on aggregate production and land use, and the magnitude of indirect land use changes. Place-based studies provide a richer understanding of how these aggregate changes actually occur locally — that is, through agricultural expansion or intensification; whether land conversion is encroaching into forests, other natural ecosystems, or agricultural lands; and what are the social and environmental costs of these changes in land use. Combining global economic models with place-based studies and developing a new generation of multi-scale models and methods to couple local and global processes [64] are required to better understand causal relationships linking land change, trade, policies and other underlying drivers such as demographic and lifestyle changes. Pattern-oriented modeling, that is, models constructed to reproduce 'realistic' patterns, for example, of households' outcomes, is one promising way, but requires detailed knowledge from empirical studies to design and calibrate such 'realistic' patterns [65].

Research on the impact of globalization on land change informs decision-makers and the public on the potential for unintended and distant consequences of environmental policies and consumption patterns. Recent policy debates — for example, REDD+, the European Union's FLEGT scheme, the 2008 amendments to the Lacey Act in the US, iLUC associated with biofuels in the Renewable Energy Roadmap of the EU and the US Renewable Fuel Standard (RFS) — are slowly starting to acknowledge the role of international trade and the distant impacts of consumption in developed countries. Promoting sustainable land use and avoiding shifting geographically negative environmental externalities requires better integrating factors associated with the demand for land-based resources, and commodity value chains that link producers and consumers at the global level, in addition to the more traditional place-centered, supply-side view of land change.

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