



Global forces of change: Implications for forest-poverty dynamics

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ABSTRACT

This article examines global trends likely to influence forests and tree-based systems and considers the poverty implications of these interactions. The trends, identified through a series of expert discussions and review of the literature, include: (i) climatic impacts mediated through changes in forests, (ii) growth in commodity markets, (iii) shifts in private and public forest sector financing, (iv) technological advances and rising interconnectivity, (v) global socio-political movements, and (vi) emerging infectious diseases. These trends bring opportunities and risks to the forest-reliant poor. A review of available evidence suggests that in a business-as-usual scenario, the cumulative risks posed by these global forces, in conjunction with limited rights, resources, and skills required to prosper from global changes, are likely to place poor and transient poor households under additional stress. The article concludes with an assessment of how interventions for enhancing forest management, combined with supportive policy and institutional conditions, can contribute to a different and more prosperous future for forests and people.

1. Introduction

Global economic, political, and environmental forces shape the forms poverty takes and the pathways that lead to it. Global changes, which can be opaque at local or regional scales, create enormous shocks that limit efforts to alleviate poverty and alter human-forest relationships (Oldekop et al., 2020). These changes create uncertainty regarding the efficacy of existing policy interventions to alleviate poverty, especially for those dependent on forest resources (Hajjar et al., 2021b, this issue). On the other hand, such changes may also generate socio-economic opportunities that help move people out of poverty (Shyamsundar et al., 2020). Thus, it is useful to consider global forces of change to anticipate or forecast likely scenarios in forest-poverty dynamics.

Forest fragmentation and the increase in zoonotic diseases, such as COVID-19, demonstrate the need to attend to the linkages among forest cover change, health, and sustainable development (Di Marco et al., 2020; Dobson et al., 2020). These connected changes also exemplify how transnational processes can directly and indirectly affect

communities living in, near or otherwise relying on forests. Forest-reliant households move in and out of poverty through multiple conduits (Jagger et al., 2020). In this paper, we seek to understand and develop an analytical framework for examining how global forces affect these pathways. While global changes have impacts on forests and people across scales, our focus is on local poverty dynamics.

Global changes affect poverty through their direct impacts on tree cover and by altering the magnitude and distribution of forest and tree use. Transnational mechanisms can help move forest- and tree-reliant people and households out of poverty by creating new economic opportunities; they may enable households to preserve their current economic status and well-being by maintaining the flow of forest and tree-related goods and services; they may affect transient poverty by changing risk exposure, thereby temporarily pushing households above or below national poverty lines; and /or, people may be driven deeper into poverty through increased uncertainty and exposure to hazards or because access to trees and other forest resources becomes more costly as a result of global changes. Differing socio-economic conditions across

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3. Climate change, forests and positive feedback loop

Climate change increases risks to the lives and livelihoods of the forest-reliant poor by affecting the forest ecosystem services on which they depend. These changes will worsen with deforestation, itself a major contributor to climate change (Gibbs et al., 2018; Lawrence and Vandecar, 2015), creating a positive feedback loop that accelerates climate change (Staal et al., 2020).

Climate induced changes have varied effects on forests. Changes in temperature, carbon dioxide and precipitation can increase the length of tree growing seasons (Walther et al., 2002); alter the distribution of terrestrial vegetation (Bertin, 2008); shift species' geographic ranges (Hansen et al., 2001; Ortega et al., 2019); influence productivity (Vitasse et al., 2009); increase the risk and intensity of natural disasters such as drought, fires, flooding, and insect outbreaks (Seppälä et al., 2009; Staal et al., 2020); and affect biodiversity and ecosystem services (Seymour and Busch, 2016), among others.

The release of sequestered forest carbon resulting from deforestation, degradation, and forest fires also produces a significant amount of greenhouse gases. Conversely, improved forest management can offset carbon losses (Griscom et al., 2017). For instance, reductions in deforestation and increasing reforestation in the tropics can cost-effectively provide some 10–20.9% of the reductions needed between 2020 and 2030 to meet the 2° C warming goal outlined in the Paris agreement (Busch et al., 2019).

3.1. Increasing climate risks faced by the poor

Climate change directly threatens the forest-reliant poor by destroying assets, impeding livelihoods, and reducing ecosystem services (Hallegatte et al., 2015; IPCC, 2018). As forests degrade, those that depend on forests and trees for income and subsistence may have to travel further or migrate to maintain their livelihoods. Air pollution, water contamination, psycho-social harm and visibility impairment from wildfires can seriously harm human health (Fowler, 2003). Even though the exact regional impacts of climate change are unclear, drier and hotter areas will most likely see negative impacts on livelihoods (Olsson et al., 2019; Seymour and Busch, 2016).

Two key climate effects – increased frequency, intensity, and/or amount of hydrologic and heat events and stressors (Coffel et al., 2018; Mora et al., 2017; Olsson et al., 2019; Prevedello et al., 2019) are likely to have direct and forest-induced poverty effects. Increased flooding (Neumann et al., 2015; Zhu et al., 2010), intensified cyclones (Bacmeister et al., 2018; Walsh et al., 2016) and increased coastal erosion (Alongi, 2015; Harley et al., 2017; Johnson et al., 2015) threaten existing forests and tree-based goods and services. Floods, tropical storms, degraded landscapes, and landslides in forest landscapes can also lead to loss of human life, livestock, and dwellings (Das and Vincent, 2009; Samir, 2013).

Increased drought and loss of evapotranspiration from forests pose threats to agriculture (Aryal et al., 2020; Lawrence and Vandecar, 2015) and to non-timber forest product (NTFP) availability (Gurung et al., 2021; Kunwar, 2011), making rain-dependent, small-scale farmers and NTFP harvesters more vulnerable to income losses and food insecurity (Cooper et al., 2009; Damania et al., 2017; Wani et al., 2009). Deforestation can exacerbate microclimates, making them drier and hotter (Lawrence and Vandecar, 2015), potentially driving people to deforest more land (Desbureaux and Damania, 2018). For instance, cocoa farmers in Cote d'Ivoire have replaced forests with farmland from the drier east to the wetter southwest of the country, which has further contributed to drier conditions in a positive feedback cycle (Ruf et al., 2015). Increasing temperatures, exacerbated by forest loss (Cohn et al., 2019), can make outdoor labor more hazardous (Suter et al., 2019) and increase mortality (Mora et al., 2017). In many locations, extreme droughts are also predicted to increase the number, intensity, length, and severity of forest fires (Abatzoglou and Williams, 2016; Jolly et al.,

2015; Knorr et al., 2016; Taufik et al., 2017).

Migration will likely be an important adaptation response to climate-induced events (Cattaneo et al., 2019). While difficult to estimate, there has been a steady climb in international migrants, from 85 million people in 1970 to 272 million people in 2019 (International Organization for Migration, 2019). Although climate change-induced migration is expected to increase in the future (Marchiori et al., 2012; Missirion and Schlenker, 2017), peoples' movements will vary depending on the speed of climatic events (slow or rapid onset), available adaptation opportunities, and household access to resources (Cattaneo et al., 2019). Notably, Rigaud et al. (2018), considering demographic, socio-economic and climate scenarios, estimate that there will likely be 143 million 'within-country' climate migrants by 2050. There are, however, many uncertainties in projecting future migration (Cattaneo et al., 2019).

Improved forest and tree management can play an important role in climate change adaptation (Keenan, 2015), providing new income opportunities for forest-reliant communities (Hajjar et al., 2021b, this issue; Ota et al., 2020). For example, tree planting has increased milk production and dairy income in East Africa (Wambugu et al., 2011), reduced human-wildlife conflict in South Africa (Chakeredza et al., 2007), and improved farm productivity during a drought period in Malawi (Amadu et al., 2020), making agroforestry an important climate smart agricultural adaptation strategy. Domesticating and commercializing indigenous fruit trees increases food security and incomes across Sub-Saharan Africa, with potential for increasing income from commercializing fruit trees (Omotayo and Aremu, 2020). Although tree planting projects can have negative impacts on livelihoods if they compete for land used by the poor (Seppälä et al., 2009; Smith et al., 2019), they can also help secure land tenure (Guillerme et al., 2011; Ota et al., 2020), reduce soil erosion (Korkanç, 2014) and associated flooding (Yin and Li, 2001), and landslides (Pradhan et al., 2012), and potentially reduce risks and increase farm yields (Brown et al., 2018; Maas et al., 2013). The local (Prevedello et al., 2019) and regional (Cohn et al., 2019) heat-reducing effects of increased tree cover will be particularly important in tropical areas (Coffel et al., 2018; Mora et al., 2017). The choice of tree species, local contexts, and instruments used to encourage tree planting will influence how poor households are affected (Erbaugh et al., 2020; Fleischman et al., 2020; Hajjar et al., 2021b, this issue; Razafindratsima et al., 2021, this issue).

4. Growth in commodity markets

Commodities produced in the tropics at the forest-agriculture frontier play an important role in deforestation and degradation (Curtis et al., 2018; Seymour and Harris, 2019). Demand for four commodities – beef, soybean, palm oil, and timber – have significantly contributed to landscape change (Curtis et al., 2018; Henders et al., 2018; Newton et al., 2013; Persson et al., 2014). Other commodities, such as coffee (Philpott et al., 2008; Tadesse et al., 2014), cocoa, cassava (Gockowski and Sonwa, 2011) and illicit coca production (Armenteras et al., 2013) also impact forests (Onder et al., 2021).

Beef production has had the biggest impact on deforestation to date (Henders et al., 2015; World Economic Forum, 2020). Brazil, China, the European Union, and the United States are major beef producers (Brack et al., 2016), with Brazilian cattle production having the largest forest footprint (Henders et al., 2015; Pendrill et al., 2019). Brazil and the United States are also major producers and exporters of soybean (le Polain de Waroux et al., 2019), which is mainly used for animal feed (Brack et al., 2016), with China being a major importer.

Indonesia and Malaysia produce about 80–90% of all palm oil (Brack et al., 2016; Henders et al., 2015). Deforestation from oil plant cultivation shows a downward trend, with its contribution to deforestation declining from an estimated 23% (2001–16) to less than 15% (2014–16) (Austin et al., 2019). Tropical timber is mainly produced in Brazil, Indonesia, Malaysia, and Papua New Guinea (Persson et al., 2014). During 2000–16, timber plantations contributed to 14% of deforestation

in Indonesia, with the rate peaking in 2010–12 (Austin et al., 2019). Arguably, timber plantations play multiple roles – they can also reduce pressure on natural forests (Ainembabazi and Angelsen, 2014; Bowyer et al., 2005), contribute to restoring degraded lands (Bowyer et al., 2005), and improve smallholders' livelihoods (Khamzina et al., 2012; Roshetko et al., 2013). In general, however, evidence on plantation-led improvements in livelihoods and poverty is both limited and mixed (Malkamäki et al., 2018; Santika et al., 2019).

Available projections on beef, soybean, oil palm, and timber suggest that commodity production is likely to see double-digit growth over the next decade (see Table 1). This reinforces the urgency of understanding the connections among commodity demand, production, deforestation, and poverty.

4.1. Can decoupling commodity production and deforestation contribute to poverty reduction?

As demand for tropical forest commodities increases, there is pressure to decouple the growth of commodity production from deforestation. Ten strategies (see Table A1) offer opportunities to achieve net zero deforestation while maintaining or increasing production of forest-impacting commodities (World Economic Forum, 2020). These strategies build on core principles of sustainable intensification (certification, pilot scaling); increased funding for sustainability (influencing demand and financing); and improved governance (property rights, jurisdictional approaches, enforcement). The potential poverty outcomes from decoupling deforestation and commodity growth, however, are likely to vary based on local conditions, as discussed below. The poverty reduction benefits of tenure reform, for instance, are dependent on complementary conditions such as law enforcement, access to justice, technical assistance, access to finance etc. (Hajjar et al., 2021a, this issue), which differ significantly across countries.

Changing land use from forests to commodity agriculture offers opportunities to smallholders if they can take advantage of global markets. Evidence from Paraguay, for instance, suggests that farmers and Indigenous communities have improved incomes and livelihoods through soybean cultivation (Cardozo et al., 2016). Likewise, there is evidence that oil palm cultivation has increased smallholder incomes and rural employment in Asia, reducing poverty rates (Qaim et al., 2020) and benefiting non-farm employment and income (Bou Dib et al., 2018). In Brazil, soybean cultivation supports an estimated 2.5 formal sector jobs outside of agriculture per square kilometer of production (Richards et al., 2015). Contract production, a type of partnership between buyers and smallholder commodity sellers that is well established in countries such as India, Thailand and South Africa (Boulay and Tacconi, 2012; Sartorius and Kirsten, 2002), shows poverty mitigation potential (Hajjar et al., 2021a, this issue).

Commodity markets also bring risks. In Brazil and Indonesia, lack of legal clarity on rights has made households vulnerable to land grabbing (Friends of the Earth et al., 2008; Gabay and Alam, 2017), with land speculation contributing to rural conflicts (Nepstad et al., 2006; Nepstad and Stickler, 2008; Rist et al., 2010). In Malaysia, expansion of oil palm cultivation has brought in foreign workers and contributed to wage

suppression (Abdullah et al., 2011). The Brazilian state has sought to counter smallholder displacement by resettling landless farmers from poor regions and connecting them directly to soybean companies. However, rugged geography, small-scale operations, and high production costs have limited smallholder partnerships with companies (Lima et al., 2011).

Institutional and policy reforms can contribute to better social and environmental outcomes associated with commodity market growth (Climate Focus, 2017). Security over land rights can reduce land grabbing, and jurisdictional approaches may be able to increase access to information through more transparent decision-making (Hajjar et al., 2021b, this issue; Razafindratsima et al., 2021, this issue). About 35–40% of palm oil is produced by small landholders (Climate Focus, 2017). Thus, improving credit, training and technology access to such smallholders can increase productivity (Climate Focus, 2017; World Economic Forum, 2020). Vietnam is illustrative of how smallholder forestry and incomes can grow with policy reforms that strengthen land security and improve the access to credit (Nguyen et al., 2010; Sikor, 2011; World Bank, 2019). Institutional innovations and cooperatives that enable smallholders to pool resources and increase market shares are also important (Poole and de Frece, 2010). Studies of cacao producers in Côte d'Ivoire and Ghana (Calkins and Ngo, 2010) and small-scale timber producers in Turkey (World Bank, 2017) point to members in cooperatives having higher incomes relative to non-members; however, causality is difficult to explicitly show in many such examples (Hajjar et al., 2021a, this issue).

In general, the implications of supply chain reforms on heterogeneous poor communities need additional careful research and analyses (Hajjar et al., 2021a, this issue; Newton and Benzeev, 2018). In their meta-analysis of 24 cases, DeFries et al. (2017), for instance, found that certification was associated with economic and environmental outcomes that were overwhelmingly positive or neutral, while social outcomes were more variable. Gender and indigeneity are two axes along which the social impacts of certification and other schemes are likely to vary, requiring special attention in scaling up these strategies (Loconto, 2015; Lyon et al., 2010). Furthermore, data on reforms, such as how zero-deforestation commitments (ZDC) affect social dimensions, lag well behind evidence on the impacts of such commitments on forest cover change (Newton and Benzeev, 2018). Additional evidence on the social dimensions of different supply chain reform initiatives would help identify whether companies are adopting voluntary practices (Thorlakson et al., 2018), how these align with national policies (Carodenuto, 2019) and whether they mitigate poverty (Newton and Benzeev, 2018).

5. Public and private forest sector financing

The forest sector is generally financed through budgetary allocations from domestic governments, international aid, and, increasingly, private sources. Support for forestry covers efforts to reduce deforestation as well as for private and public tree planting and restoration. The overall and relative amounts from different funding sources is changing, with implications for poverty reduction.

5.1. Overseas development forest aid

Overseas development assistance (ODA) for forestry often supports forest protection and improvement, rural economic development, and forest-related climate mitigation and adaptation (Environmental Defense Fund and Forest Trends, 2018). Building on previous work (Agrawal et al., 2013), we reviewed multilateral international forestry aid. Data for this analysis came from the Organization for Economic Cooperation and Development (OECD), World Bank, Global Environment Facility, Asian Development Bank, African Development Bank, and Inter-American Development Bank databases. Forest-related aid projects in these databases were identified using the following keywords in titles or descriptions: “forest,” “agroforestry,” “deforestation,” or “tree.”

Table 1
Projected Increase in commodity production at the forest-agriculture frontier.

Commodity	Projected Increase (%)	Source
Beef production, developing countries (2016–18 to 2028)	17.0	OECD/FAO (2019)
Soybean Exports (2016–17 to 2028)	49.0	Gale et al. (2019)
Soybean production (2005–07 to 2050)	79.7	Alexandratos and Bruinsma (2012)
Oil Palm (2016–18 to 2028)	18.0	OECD/FAO (2019)
Volumetric demand for wood (2010–2050)	284.7	WWF (2012)

While broad-based “Restoration” was not included, forest restoration projects were otherwise included. Data include forest-related climate financing (e.g., REDD+) to the extent that this was identified through the search terms. To eliminate duplicates, we removed projects with the same name, country and/or committed amount.

Forest sector aid over the last 5 years represents 1% of ODA across all sectors (USD 177.18 billion) (OECD, 2021). During 2014–2017, nearly USD 7 billion in international and bilateral aid was allocated to forest projects (Fig. 2). This suggests that average annual forest aid was ~ USD 1.7 billion, a reduction from USD 3.5 billion per year between 2000 and 2013. Not all data were available for 2018 and 2019, but trends at the World Bank and Inter-American Development Bank indicate that forest-related funding decreased during these years relative to 2017 by 77% and 53% respectively. Overall, these figures suggest that international forest aid may be showing a stagnant or declining trend.

The geographic allocation of international forest aid was unequal during the study period. Asian nations received the greatest amount of funding (USD 3.1 billion), followed by countries in the Americas (USD 1.4 billion), and Africa (USD 1 billion). Projects that received forest aid cover a range of approaches, including afforestation/reforestation, payments for ecosystem services, alternative livelihood provision for forest-proximate people, forestry agency reforms to reduce deforestation, consolidation of national parks, and sustainable forest management and agroforestry, among others.

5.2. Growth in private investments and markets

Although systematic data on private financing of the forestry sector is limited, some evidence suggests the value of carbon forest offset markets is increasing, as is the value of private forestry impact investments with the goal of generating both public and private returns (Bass et al., 2019; Ginn, 2020).

The Global Impact Investing Network (GIIN) estimates that over 1,720 organizations managed USD 715 billion in impact investment assets globally in 2019 (Hand et al., 2020), with 37 funds managing at least USD 9.4 billion directly in forests and related assets (Bass et al., 2019). These funds represent investments that aim to provide returns from forest products while also achieving environmental and social co-benefits. Most of the funds focus on investments in Australia, Canada, and the United States, though six of the 37 funds invest in projects in sub-Saharan Africa, Latin America, and Southeast Asia (Bass et al., 2019). Accurately identifying how much of the investment is directed

toward forests is, however, difficult because these investments have dual- or triple-bottom lines and may be categorized within larger, less specific categories like conservation projects (Hand et al., 2020), and because reliable data on foreign and domestic private investments in forestry are limited (Castrén et al., 2014).

Voluntary forest carbon offsets represent a specific area of private sector growth. The market typically brings private sector funding to Forest and other Land Use (FLU) projects related to afforestation/reforestation, avoided deforestation, degradation and sustainable forest management (e.g., REDD+), landscape management, and agroforestry. To identify the growth in the forest carbon offset market, we draw from Forest Trends’ State of the Voluntary Carbon Market reports (2006 through 2020) (Forest Trends’ Ecosystem Marketplace, 2021). Market value and total transacted volume of offsets were identified from total values from the 2019 report (Forest Trends’ Ecosystem Marketplace, 2019), for all years from 2006 through 2018.

Fig. 3 shows that the voluntary forest carbon market is still small (~ USD 300 million in 2018). Though there is significant fluctuation in both the total market and the proportion of FLU projects from year to year, FLU offsets show a slight upward trend over the 2006–18 period. Because of the reporting methodology, the percentage of total offsets in each year from FLU is likely underestimated.

5.3. Financing poverty reduction through forestry investments

Identifying the poverty impacts from overseas forestry investments, either through aid, impact investment, or voluntary carbon offset programs, is challenging. Inconsistent monitoring and evaluation, lack of publicly available data, long gestation periods between project investment and benefit accrual (from tree-planting, for instance), and the presence of multiple “bottom lines” make estimating causality difficult.

An appraisal of the forestry portfolio of the largest donor in the sector, the World Bank, sheds some light on the poverty implications of forestry aid. Shyamsundar et al. (2020) show that the World Bank’s forestry investments (worth over USD 1 billion and completed between 2002 and 2015) are mainly in middle-income countries, with low-income countries accounting for only 10% of projects. A majority of projects in the World Bank’s forestry portfolio included poverty-related components such as technical support and training to improve community forestry and/or smallholder plantations, support for nurseries and small-scale forest businesses, and strengthening forest rights (Shyamsundar et al., 2020). While there is generally limited evidence on poverty outcomes from forestry aid, pointing to the need for careful evaluations, many assessments of REDD+ projects (which are largely publicly financed (Well and Carrapatoso, 2017)), are available (Duchelle et al., 2018; Lawlor et al., 2013). Hajjar et al. (2021a, this issue), discussing in detail the implications of REDD+ on poverty, suggest that available evidence points to mixed results.

Private sector financing in the form of impact investments usually complements public or private non-profit financing (Ginn, 2020). Financing of nascent forestry enterprises and locally owned small and medium forest enterprises can generate employment and spread prosperity to local forest-reliant communities (Hajjar et al., 2021a, this issue; Kozak, 2007; Macqueen et al., 2020; Macqueen, 2008; Sanchez Badini et al., 2018). Financing in the agroforestry space has seen some investors (e.g., TechnoServe, 2021) combining business advice with capital investments, and others, such as the One Acre Fund non-profit, providing technical assistance and financing for tree planting to some one million African farmers (One Acre Fund, 2021). Agroforestry benefits can differ along gender lines, with positive benefits to women ranging from reduced burden from collecting wood to cash income from tree product sales to improved nutrition (Razafindratsima et al., 2021, this issue). Also, as previously noted, certification of sustainable products, often financed through impact investments, appears more likely to contribute to positive economic outcomes relative to social and distributive outcomes (DeFries et al., 2017).



Fig. 2. Forest-related international aid, 2014–2017.

Source: Authors’ assessment based on data from OECD, World Bank, GEF, Asian Development Bank, African Development Bank, and Inter-American Development Bank.

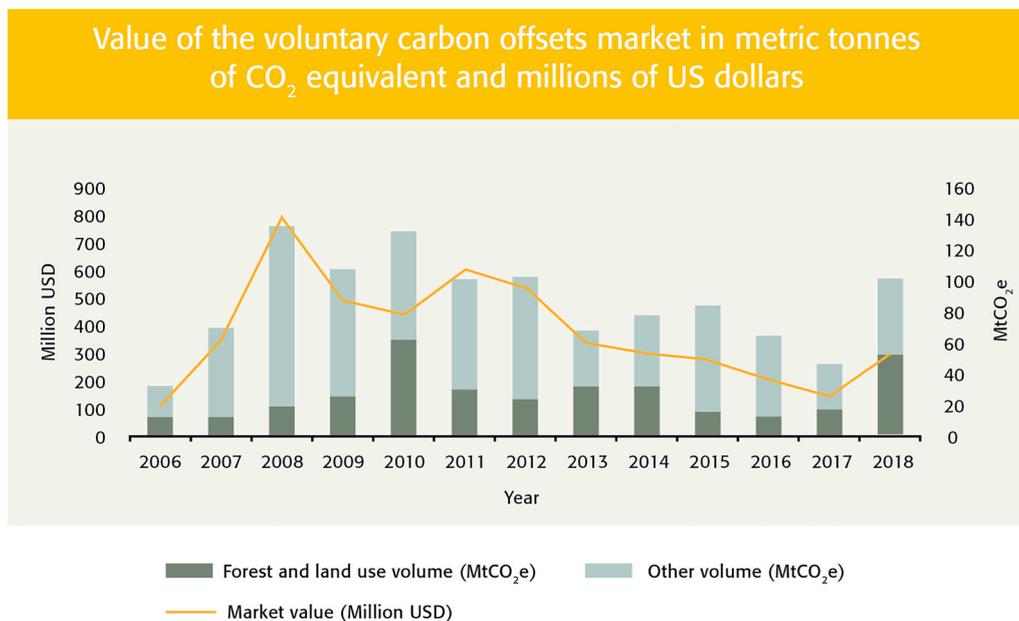


Fig. 3. Value of the voluntary carbon offsets market in metric tons of CO₂ equivalent and millions of US dollars.

Source: Data drawn from multiple reports, Forest Trends State of Voluntary Carbon Market reports (2007–2019) (Forest Trends' Ecosystem Marketplace, 2021).

Consideration of co-benefits, including poverty reduction, by the voluntary carbon offsets market may be increasing. From 2016 to 2018, the number of forestry and land use projects certified using a combination of Voluntary Carbon Standard (VCS) and Climate, Community and Biodiversity (CCB) standards, the latter of which pays attention to social outcomes, increased by 325%, while total carbon offsets only increased 53%, indicating market preference for projects with social and environmental co-benefits (Forest Trends' Ecosystem Marketplace, 2019). Of the 166 forestry and land use projects currently under some stage of verification or validation for CCB, 38 are in Africa, 50 in Asia, and 70 in Latin America, with China, Brazil and Colombia leading the use of this approach in their respective regions ("Verra Registry Database," 2021). Documented evidence on the poverty reduction benefits of the voluntary carbon offsets market is relatively lean. Available information from Mozambique suggests that forest restoration with CCB verified emission reductions may have had mixed results (Jindal et al., 2012; Mathur et al., 2014). The authors found that communities had limited power and ability to advocate for themselves (Mathur et al., 2014), but gains may have accrued from broader project-related economic development activities (Jindal et al., 2012).

Even though private sector forestry funding is steadily increasing, both public and private investments remain small relative to, for example, the financing required for large-scale forest restoration (Castrén et al., 2014). To prevent worst case scenarios of land grabbing and corporate 'greenwashing,' and to ensure that the voluntary carbon offsets market meets social objectives, standards need to pay greater attention to issues such as income predictability, transaction costs, and meaningful local participation, especially for and among smallholders (DeFries et al., 2017; Franco and Borrás, 2019; Fuente and Hajjar, 2013; Melo et al., 2014). Understanding how women participate in and benefit from forest carbon financed projects is a particularly important social consideration. Evidence from REDD+ programs in Nepal (Khadka et al., 2014) and the Congo Basin (Brown, 2011), for instance, suggests that more equitable outcomes can be achieved when women are involved in the planning and execution of these programs.

6. Technological change and rising interconnectivity

Pathways that link forests and livelihoods are moderated and

mediated by material technology. Changes in bio-geophysical data availability, remote sensors, and computational speed have improved the ability to monitor and study forest-livelihood relationships. Rapid advances over the past thirty years in computing and internet technology have contributed to publicly available, high-resolution earth observation data, enabling reliable and replicable assessments of global land cover change (Loveland and Dwyer, 2012).

Increases in interconnectivity – including via social media – have shifted the dissemination of forest-livelihoods knowledge and emerged as new means for organizing by forest-proximate peoples, including providing new pathways for their participation in broader decision-making processes (Castells, 2007; Loader and Mercea, 2011; Stevens et al., 2016). Together, these technologies potentially affect forest-livelihood relationships by improving information available on forest resources, providing more accurate and scalable methods for forest monitoring, and connecting forest proximate peoples.

6.1. Improved monitoring and evaluation of forests

Over the last decade, a variety of spatial products and new remote sensors have enhanced forest monitoring and evaluation, with widespread uptake of high-resolution tree-cover maps from Landsat data beginning in 2000 (Hansen et al., 2013). Public and private satellites that provide higher-resolution imagery, LIDAR technology piloted on unmanned aerial vehicles (UAVs), and the use of artificial intelligence (AI) to analyze data compose the technological frontier of spatial data and analysis. Satellite imagery at resolutions greater than 30 m per pixel help identify fine spatial patterns and changes in forest structure (Kayitakire et al., 2006; Steven et al., 2003). LIDAR imagery enables three-dimensional analyses of canopy height and density, facilitating assessments of forest structure (Ferraz et al., 2016; Ganivet and Bloomberg, 2019). New monitoring technologies, such as acoustic sensors and UAVs, have also enhanced the ability to monitor and regulate products provisioned by forest systems (Marvin et al., 2016).

The variety of new data types, sources and methodologies result in improvements for real-time tracking of forest changes as well as forest fires and generate novel ways to monitor forest ecosystem services (Davies et al., 2009; Hansen et al., 2016; Wheeler et al., 2014). For example, combining data from different sensors, which enables the

estimation of above-ground forest carbon (Asner et al., 2010; Le Toan et al., 2011), with spatial data on the extent of forest cover, can help identify a suite of carbon sequestration and other ecosystem services (Martínez-Harms et al., 2016). Bioacoustics and spatial data can help identify the connections between forest conservation, regeneration, and biodiversity (Burivalova et al., 2019). These technologies spot and count wildlife, map land cover, and promote real-time monitoring of protected areas (Iacona et al., 2019; Wich and Koh, 2018), including the detection of poachers and poaching in real-time (Kamminga et al., 2018). Forensic science uses visual, chemical, and genetic techniques to determine the origin of a wood samples (Dormontt et al., 2015), which can potentially reduce illegal logging and strengthen legally sourced supply chains (Sasaki et al., 2016; Tnah et al., 2010).

6.2. Social media and the rise in user-group connectivity

Mobile phones and associated social media access enable knowledge exchange, network building, and political claims-making for forest-reliant communities. Indigenous and forest community groups increasingly connect through applications such as Facebook and Twitter in order to develop alliances in favor of community forest rights, pursue ‘boomerang effects’ that galvanize international attention to pressure national governments to respect or support local management of forests, and to share news about specific phenomena (Keck and Sikkink, 1998; Sauls, 2020). Mobile phones and more accessible photovideo technology also enable forest communities to capture and share their own narratives (e.g., “If Not Us Then Who?,” 2021) (Mitchell-Walthour, 2020). Groups that engage in international training or exchanges use social media to maintain networks, which serve to disseminate best practices around sustainable forestry and effective advocacy (Duncombe, 2016; Sauls, 2020). Even as mobile phone accessibility can enhance access to market information, facilitate peer-to-peer learning, and ease logistics planning for smallholders, the impact of these innovations on the income of forest-reliant communities is, as yet, unclear (Baird and Hartter, 2017; Duncombe, 2016; Sife et al., 2010).

6.3. Technology, knowledge, and changes in power relationships

Remotely sensed spatial data, advances in acoustic sensors, data from UAVs, and forensic timber science provide replicable, reliable, and low-cost methods to monitor forest resources. In addition, these technological advances are helpful in designing governance mechanisms, such as payments for ecosystem services (Curtis et al., 2018; Mitchell et al., 2017), and community-based forest management (Blackman et al., 2017; Santika et al., 2019). These advances may also aid in curtailing human-wildlife conflict, a major cause of crop raiding, injury, and even death in many tropical forests (Nyhus, 2016) and in facilitating the mapping and monitoring of Indigenous territories (Paneque-Gálvez et al., 2017; Radjawali et al., 2017). Such technologies also provide employment opportunities for technologically literate forest-proximate people, advance opportunities for research on forest areas, strengthen sustainable supply chains, and contribute to community-based forest management or co-management (Bellfield et al., 2015; Iacona et al., 2019; Marvin et al., 2016).

In general, however, enhanced availability of material technologies improves the detection of forest cover change but does not provide immediate solutions to address the complexities of forest-related policies, land tenure, monitoring, and enforcement challenges (Erbaugh and Nurrochmat, 2019; Gaveau et al., 2017). Improved technologies for forest monitoring often reinforce pre-existing regulations (Musinsky et al., 2018). This can limit the informal or extra-legal access communities have to forestlands. For example, by harmonizing formal tenure and maps of tree-cover through the One Map initiative, the Government of Indonesia has prioritized sequestering carbon and clarifying formal tenure. This process has led to the identification of informal forest use by forest proximate people and has enabled exclusion of forest use among

some communities that live near or within government forests (Astuti and McGregor, 2017). In Tanzania, REDD+ readiness projects combined remotely sensed forest imagery with a focus on formal tenure to become harbingers of “conservation-related exclusion” (Lund et al., 2017). The benefits from technology-enhanced monitoring are not necessarily equitable.

Advanced forest monitoring technology remains largely the purview of experts (e.g., states, researchers, and NGOs). Unless capacity building is included when rolling out new technologies, the ability of rural communities to leverage these tools to enhance their own livelihoods may be limited. However, counterexamples are emerging. New smartphone applications such as TIMBY (*This Is My Backyard*) and ForestLink offer communities in Liberia and Cameroon, respectively, the capacity to monitor illegal logging, and recent reports from Peru suggest these types of programs can be effective (Eilu, 2020; Slough et al., 2021). The Association of Forest Communities of Petén (ACOFOP) in Guatemala has made concrete livelihoods gains by leveraging geospatial data and smart phones to improve forest management and responsiveness to threats, which has also helped ACOFOP gain political support (Millner, 2020). In general, democratizing the use of material technology and interpretation of associated data is a critical next step in empowering communities to manage forest resources and directly alleviate poverty.

7. Global socio-political movements

Climate change and biodiversity loss have transitioned from topics discussed primarily by biophysical scientists to issues of widespread public concern informed by international efforts to synthesize scientific evidence (Díaz et al., 2018; IPBES, 2019; IPCC, 2018). A range of global social movements shape contemporary politics around forests and the forest-reliant poor. Such social movements include protests on inequality and racism and in support of Indigenous peoples’ rights and climate change action, as well as countervailing forces, such as anti-environmental populism. These global movements are shaping contemporary politics around forests and the forest-reliant poor.

7.1. Shifting political and civic landscapes

Recent changes in global discourses and political priorities have shifted political and civic landscapes related to forests and the environment. In several countries, governments have rejected climate mitigation and other environmental policies: the re-positioning of several governments, including the United States’ multi-year withdrawal from the 2015 Paris climate agreement and Brazil regarding protections in the Amazon, exemplifies this trend (Fearnside, 2018; McCarthy, 2019). The changing political landscape portends potential conflicts between priorities at local, national, and international scales, particularly real and perceived trade-offs between conservation and forest-based economic development. In some cases, national growth strategies are in fact deepening commitment to extractivism as the basis of development (Bebbington et al., 2018a, 2018b; Humphreys Bebbington et al., 2018), with a reduction in environmental and social protections for forest peoples and ecosystems (de la Vega-Leinert and Schöenberg, 2020).

The contemporary moment also features a major counter-current to national, anti-environmental political shifts. Public awareness of the threat that environmental change poses to human well-being has coincided with renewed resistance to social injustice, inspiring new socio-political movements across the globe (Fagan and Huang, 2019; Lee et al., 2015). The climate youth movement, for example, has become increasingly popular and inspired a suite of new, often young, activists. In September of 2019 alone, there were over 2,500 events scheduled in over 150 countries to sound the alarm about the climate crisis (Tollefson and Monastersky, 2019). Other movements such as Extinction Rebellion call for nonviolent, civil disobedience to compel governments to act before biodiversity loss and rising temperatures reach a tipping point. Forests—and other ‘natural climate solutions’ (e.g., Griscom et al.,

2017)—are central to the demands made by these movements, which are occurring simultaneously with other mass movements demanding political accountability (e.g., Brazil, Chile, France, Hong Kong and the US) and the fusing of environmental and social justice concerns (e.g., Green New Deal in the US or the European Green Deal) (Wright, 2019).

7.2. Indigenous rights and social justice movements

Indigenous Peoples and local communities are estimated to have legal rights to over 15.3% of forestland in the 58 most forested countries in the world (Rights and Resources Initiative, 2018), although the actual figure is likely to be much higher. The growing recognition of Indigenous and community rights over forests since the 1980s reflects shifts in development and environmental conservation theory, as well as self-identified and well-organized forest-reliant communities staking their ancestral claims to land and resources. When faced with local protest while implementing forest governance reforms, major development donors, such as the World Bank, increasingly supported formalized, collective land rights arrangements (Anthias and Radcliffe, 2015; Bryan, 2012; Jackson and Warren, 2005). Since the 1990s, the failure of exclusionary models to consistently achieve biodiversity and forest conservation without negatively affecting human rights has also led to the inclusion of Indigenous and local communities in forest management via extractive reserves, Indigenous and Afro-descendant territories, and co-management arrangements (Brockington, 2004; Hutton et al., 2005).

The COVID-19 pandemic has also precipitated a worldwide recognition of systemic injustice, especially anti-Black racism, and other forms of discrimination related to racial, ethnic, and religious identities. Building from previous protest waves in the UK, South Africa, Brazil, and the United States in particular, this emerging international movement has raised awareness of institutionalized racism across many countries and sectors, including the environment (Finney, 2014; Knudsen and Andersen, 2019; Miles, 2019). While these protests have, on the one hand, highlighted how marginalized groups are harmed by policies of the state, they have also underscored how excluding diverse voices in professionalized forestry, conservation, and development organizations may lead to an undervaluation of the lived experiences of minority groups and their experiences in nature (Finney, 2014; Hays, 2019; Kloek et al., 2017). The current movement is already spurring reflection amongst conservation and forestry groups on how they might become more inclusive, including by directly grappling with legacies of colonialism and dispossession that have disproportionately affected Indigenous peoples and people of color (Mollett and Kepe, 2018).

7.3. Implications for forest-poverty dynamics

New environmental movements, often rallying around visible threats like forest fires, are pushing governments toward action on climate change and forest loss. These efforts, reinforced by global dissatisfaction with increasing inequality (Hickel, 2017), and layered onto on-going Indigenous rights' movements, often view social and environmental justice as paired goals. This combined set of priorities could substantively address poverty in forested areas; however, whether attention translates into action – and whether actions to address climate change and forest loss are inclusive of the needs of forest-proximate and -reliant communities – depends on broader political conditions.

The rise of populist governments provides a direct challenge to environmental movements. The anti-environmental perspectives often held by these governments may sacrifice forests and the environment for national economic growth, with limited benefit to the poorest people. Populism often layers onto underlying political conditions, including extractivism, the roll back of social protections, endemic corruption, and in some cases even illicit activities (such as illegal mining, poaching, and narco-trafficking) across scales (Devine, 2014; McSweeney et al., 2014; Tollefson, 2016; Yagoub, 2017), which can threaten the well-being of forest-reliant peoples.

Given many Indigenous and local communities' dependence on forests for their livelihoods, land rights and secure access to forests is a priority for these groups (Rights and Resources Initiative, 2018). Although the causal link between forest rights and poverty alleviation is mixed, case study evidence suggests that income and community-provided social services increase with greater control of forest resources (Bocci et al., 2018; Hajar et al., 2021b, this issue). The implications of forest rights for ecological and social well-being depends on many contextual factors, including how local institutions and practices interact with dominant economic forces and external institutions (Bebbington et al., 2018a; Robinson et al., 2014), and the degree to which governments respect the rights of forest groups or use force to suppress pro-pro-social and environmental civic action (Middeldorp and Le Billon, 2019; Scheidel et al., 2020).

8. Infectious disease and forest cover change

Infectious diseases are an important cause of global morbidity and mortality, responsible for some 10 million deaths or 1/5th of all deaths worldwide in 2016 (Hay et al., 2017). The past two decades has seen a rise in emerging infectious diseases (EIDs), such as Ebola, SARS, MERS, the novel Coronavirus (COVID-19) and others, a trend that is likely to continue (Allen et al., 2017; CDC, 2020a). Some 70% of EIDs originate from interactions among wild and/or domestic animals and humans (Morse et al., 2012).

Research over the past several decades has documented the importance of forest loss and increasing forest edge for established vector-borne diseases, such as dengue and malaria (Chaves et al., 2020; Husnina et al., 2019; MacDonald and Mordecai, 2019). However, zoonoses (diseases that spread from vertebrate animals to humans) received less widespread global attention until COVID-19 (Di Marco et al., 2020). Anthropogenic changes, including deforestation and expansion of agricultural land that increases contact between humans and wildlife, intensification of livestock production near wildlife areas, and increases in hunting and trading of wildlife all contribute to zoonoses (Allen et al., 2017; Dobson et al., 2020). Deforestation and biodiversity disruption can create new breeding habitats for disease vectors by changing the ecological conditions that regulate predator-prey relationships and make wildlife more vulnerable to disease (Keesing et al., 2010; Pongsiri et al., 2009). Climatic changes, such as increases in temperature and changes in precipitation patterns in forested areas, can also change the geographic range and population density of zoonotic pathogens and the pathogen load in individual hosts and vectors (Mills et al., 2010). Trade in wildlife and wet markets contribute to zoonoses by increasing contact between animals and humans (Dobson et al., 2020; Wolfe et al., 2005), though the emergence and spread of zoonoses can take different complex pathways (Altizer et al., 2011; Epstein et al., 2006).

8.1. Pandemics and the rural poor

Pandemics affect rural communities, including the forest-reliant poor, through health-related and economic pathways. The Ebola outbreak in West Africa killed more than 11,000 people by 2016 (CDC, 2020a), contributed to a 12% reduction in the combined GDP of Guinea, Liberia and Sierra Leone relative to pre-Ebola expectations, and changed economic transactions across several other countries in Africa (World Bank, 2015). COVID -19, as of 23rd July 2021, had infected over 192 million people, resulting in over 4 million deaths worldwide (John Hopkins University and Medicine, 2021). Varying estimates suggest that the global economy may contract by 3–5% in 2020 (International Monetary Fund, 2020; World Bank, 2020a). Assuming a 5% contraction of the global economy, rural populations in extreme poverty are expected to increase by 15% globally (Laborde Debutquet et al., 2020). Notably, in many parts of the world, COVID-19 is occurring where the background rate of malaria, dengue, and other infectious diseases already take a huge health toll (Lorenz et al., 2020; Saavedra-Velasco

et al., 2020).

Fig. 4 illustrates the many pathways through which COVID-19 continues to affect rural households. In addition to health losses, for many forest-reliant poor, economic disruptions have led to changes in labor and non-labor income, especially where work is tied to forest-related tourism or disrupted forestry supply chains (FAO, 2020; Spenceley et al., 2021). The implications of the complete stoppage of ecotourism, identified as a critical lever for poverty reduction (Hajjar et al., 2021a, this issue), is particularly dire. Household consumption can decline as urban members return, public services decline, or if laws against bushmeat hunting are strengthened, reducing access to subsistence (Nasi and Fa, 2020; Shyamsundar, 2020; World Bank, 2020b). In remote Indigenous territories, EIDs can pose a serious existential threat because of limited access to immediate health care and ability to reduce spread, once exposed, as evidenced in the Brazilian Amazon in 2020 (Conde, 2020; Taylor, 2020).

There are potential positive feedback loops between health shocks and rural poverty (Rohr et al., 2019). Forests tend to act as a safety net when rural communities face covariate shocks (Wunder et al., 2014). Thus, pandemic-related economic shocks can lead rural communities to increase their extraction from forests, contributing to deforestation and degradation, with additional indirect negative effects on household welfare (Shyamsundar, 2020). Initial findings from Madagascar, for instance, note an increase in fires and forest clearing near protected areas as people who normally relied on tourism income prepare to invest more in agriculture (Eklund et al., 2020). In addition, macro-policy responses to the economic contractions resulting from COVID-19 may lead to a reduction in overseas development aid, including funding for forests, and incentivize governments to loosen regulations around forest protection, potentially increasing forest encroachment by outside actors and undermining subsistence and forest-based income and forest rights

(Bebbington et al., 2018a; Gonzales, 2020; Vila Benites and Bebbington, 2020).

Previous policy responses to risks associated with zoonoses have been largely reactive, focusing on disease investigation and vaccine development. However, given the enormous costs and welfare implications of the COVID-19 pandemic, there is increasing interest in cost-effective ‘preventive’ policies (Dobson et al., 2020), such as the One-Health approach, which seeks to integrate ecological and human health considerations (CDC, 2020b; Di Marco et al., 2020). These may include a range of strategies: reduction in forest fragmentation and livestock and agricultural production in proximity to wildlife; increase in forest buffer areas; investment in rural health clinics; wildlife trade restrictions; and/or improved wildlife and livestock disease surveillance (Bloomfield et al., 2020; Di Marco et al., 2020; Dobson et al., 2020). To the extent that the forest-reliant poor may be involved in the pathways leading to zoonotic epidemics, public investments that strengthen food supply chains, provide alternatives to illegal wildlife use and trade, and reduce unmanaged encroachment of natural areas may offer triple-win opportunities.

9. Discussion

Forests play a varied role in poverty dynamics (Jagger et al., 2020). They help maintain peoples’ well-being by supporting subsistence needs, act as a safety net by helping to reduce risk by smoothing consumption, and can be a source of prosperity; noting, however, that benefits are not necessarily shared equitably across people of different gender, ethnicity, or race groupings. Forest-reliance can also have negative impacts on local well-being, such as through wildlife conflicts or pest infestation that push people further into poverty. The impact of global changes on forest-poverty dynamics may be magnified by the

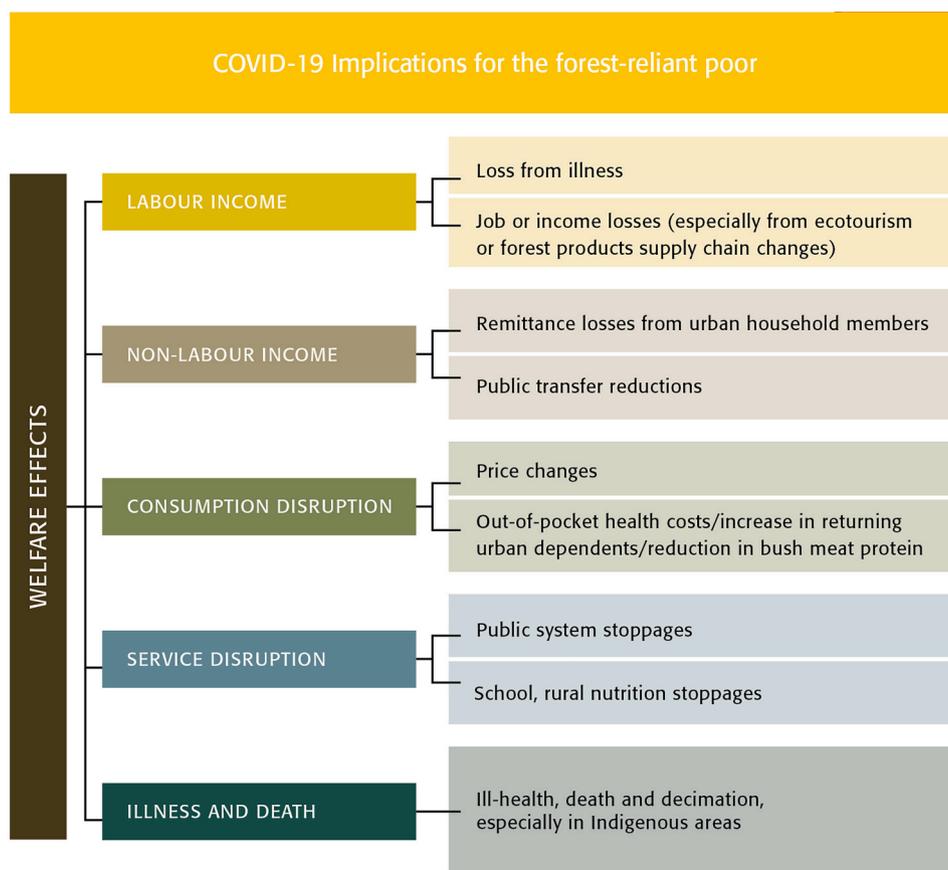


Fig. 4. COVID 19 implications for the forest-reliant poor (adapted from Fig 1. in World Bank, 2020b).

multidimensional vulnerabilities that forest-reliant communities experience and local to global adaptive responses.

Fig. 5 illustrates how the intersection of multiple global forces deepens the impact on forest-poverty dynamics (see also Table A2). For example, climate change and EIDs pose health and economic risks to the forest-reliant poor that may together push larger numbers of households into transient or chronic poverty. At the same time, some of these global forces may act as powerful countermeasures. Public finance can help people move out of poverty (e.g., through capacity building or access to credit) and support well-being by strengthening ecosystem services (e.g., restoring watersheds to improve water quality and reduce flooding). Targeted private financing can increase cash income flows (through payments for carbon, for example), enabling smallholders to build assets to move out of poverty and better adapt to climate change. Advanced technology, wielded well, can clarify rights, reduce land conflicts, and help poor communities access markets. Interconnectivity is also a powerful tool for social networking, helping Indigenous communities, for instance, to advance forest rights movements. However, rapidly emerging technologies can also increase poverty in cases where technical forest monitoring reduces subsistence forest uses.

Global changes offer both opportunities and risks to the forest-reliant poor. In a ‘Business as usual’ scenario (Fig. 6), multiple risks posed by global changes to the forest-reliant poor may overshadow any opportunities for poverty alleviation. This is largely because poor households have limited capacity or resources to take advantage of new opportunities. Nevertheless, policy, market and institutional reforms that reduce risks and improve access to new opportunities could enable movements out of poverty. Cross-sectoral strategies, such as OneHealth, that transcend the silos of health, biodiversity conservation, and poverty alleviation, can also mitigate risks and lead to alternative models of development for forest landscapes (Di Marco et al., 2020).

Fig. 6 identifies a potential improved future scenario for the forest-reliant poor with measures undertaken to reduce global risks and strengthen capacity to manage vulnerability and embrace opportunities. Specific measures may include: a) financing commodity supply chain reforms (strengthening transparency, training, networking and resources for smallholders to access global value chains); b) deploying technologies that work for the poor (including those that enable monitoring of investments and commodity flows); c) strengthening land rights, particularly of Indigenous Peoples; d) integrating sectoral interventions, e.g., OneHealth actions (buffer areas between agriculture and livestock production and forests, wildstock and human disease surveillance, alternatives to wildlife trade); e) investing in climate adaptations that reduce exposure to natural disasters and stabilize ecosystem services; and, f) encouraging global social movements that boost the voice of forest-reliant peoples while countering trends toward criminalization.

These strategies can build the enabling environment for promising levers of change that contribute to poverty reduction, including community forest management, ecotourism, agroforestry, and small and medium forest enterprises (Hajjar et al., 2021a, this issue).

10. Conclusions

This article has identified a set of cumulative threats and opportunities that global changes pose to forest-reliant poor households. Many of the global changes discussed in this paper act as shocks to households – they manifest as negative health impacts, land losses, land-use conflicts, loss of resource access and political support, among others. However, they may also open new opportunities that contribute to income and employment of forest-reliant people, enhance their connection to broader networks, and empower them with strengthened self-

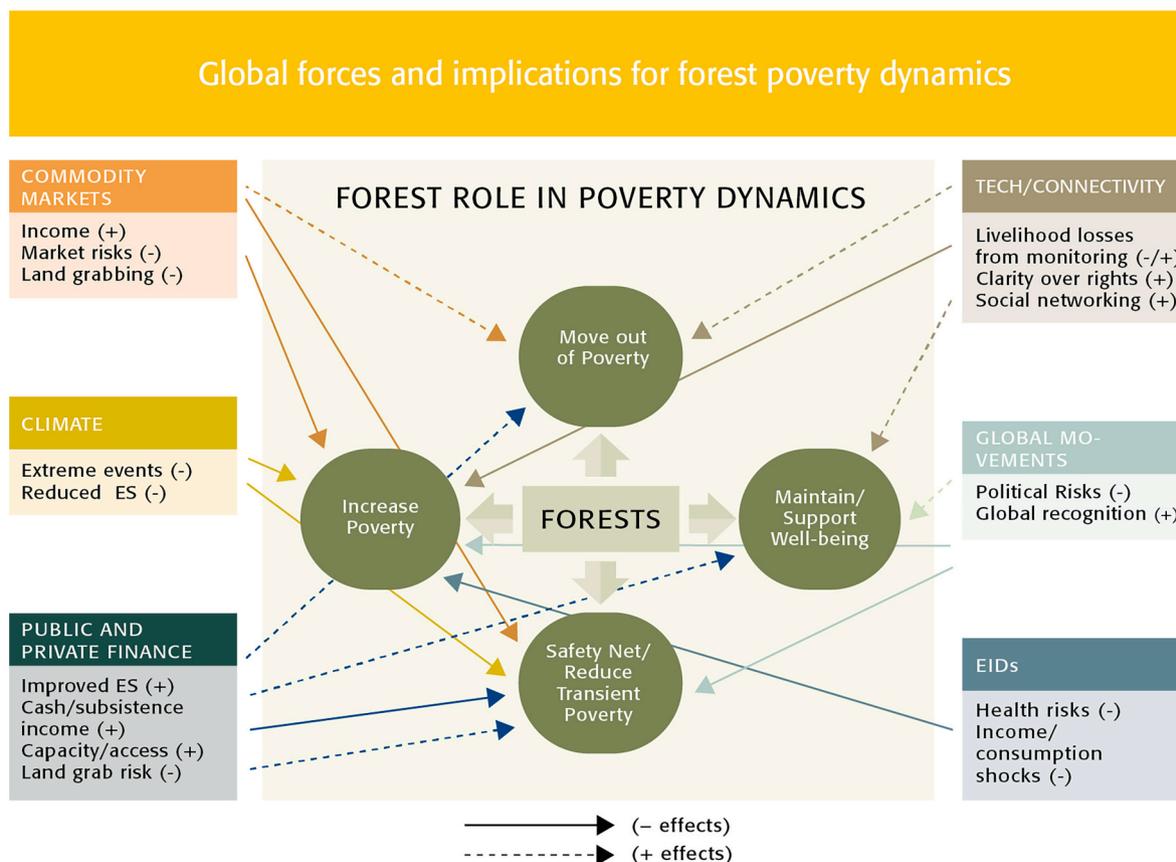


Fig. 5. Global forces and implications for forest poverty dynamics. Note: ES = Ecosystem services, EIDs = Emerging infectious diseases.

Business as usual versus improved scenarios where the net effect of the risks and opportunities posed by global forces are positive for poverty alleviation

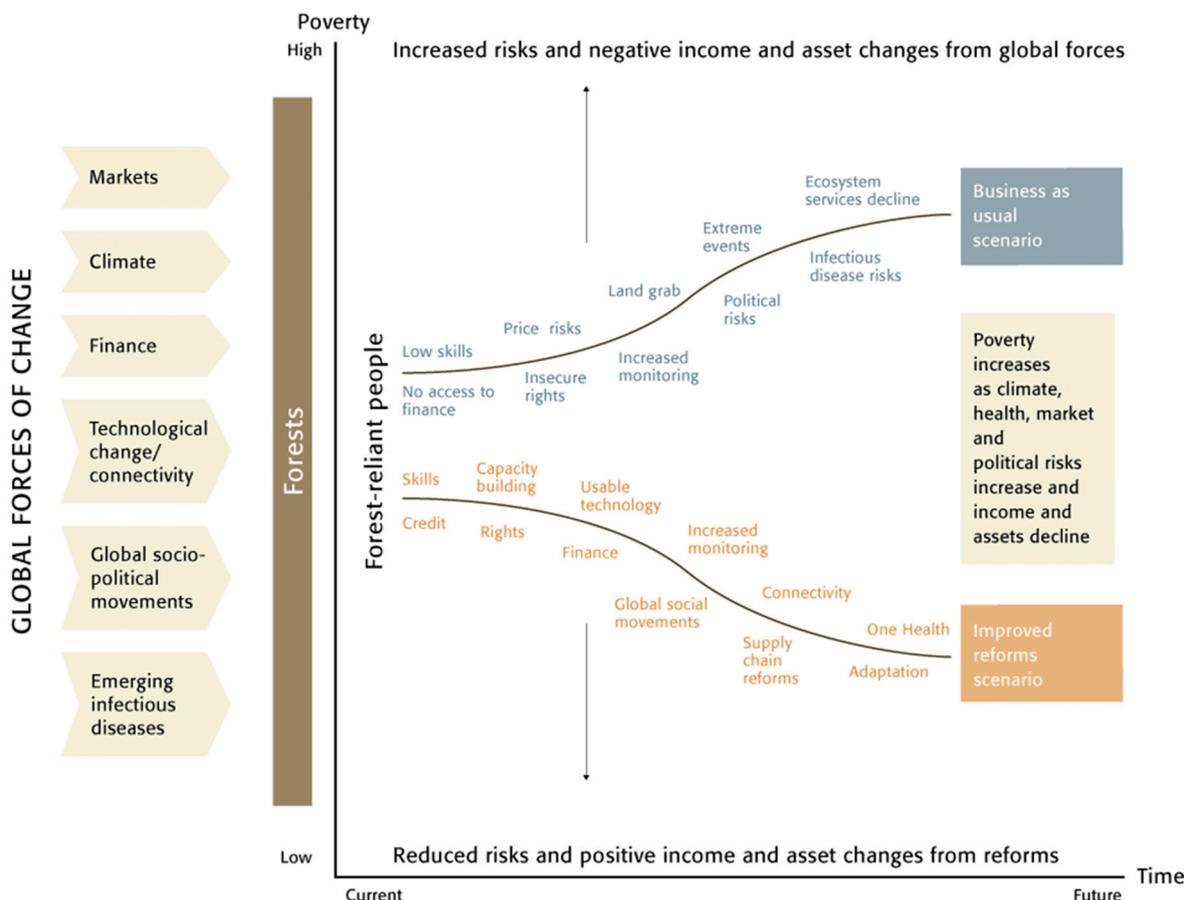


Fig. 6. Business as usual versus improved scenarios where the net effect of the risks and opportunities posed by global forces are positive for poverty alleviation

governance and technical skills. Democratizing the use of technology and building capacity for data interpretation will further help to empower forest communities. Private and public financing in improved forest management can build resilience and, when aligned with social and environmental outcomes, can enhance the position of forest-reliant peoples.

There are large gaps in knowledge related to both global trends and forest-poverty dynamics (Hajjar et al., 2021b, this issue). The published literature on varying effects of climate change on the forest proximate poor and of market supply chains on human welfare, for instance, is limited. Thus, our analyses related to global changes depend, in part, on historical evidence or conceptual theories of change. Furthermore, the analysis in this chapter does not address meta-trends such as urbanization or broad-based economic globalization that have indirect, uncertain, but potentially large effects on the forest-reliant poor. It is also unable to do justice to the uncertainties related to available projections on future global changes.

The poor are not a homogenous class of people and are differentiated by gender, access to assets, social status, and so on. Thus, global changes will likely have distinct effects on different sub-groups (women, landless labor, Indigenous communities) based on pre-existing inequities and socio-economic and political realities (Hajjar et al., 2021a, this issue;

Oldekop et al., 2021, this issue; Razafindratsima et al., 2021, this issue). Few studies that examine the poverty impacts of forest-related policy, institutional, and market reforms provide evidence of differentiated impacts (Hajjar et al., 2021a, this issue). Thus, understanding how global changes land on different sub-groups among poor households, and the role of policy reforms in reducing poverty among these sub-groups considering global changes, is an important area for additional research.

Figs. 5 and 6 in this paper provide an analytical framework that can be tested and further explored in specific contexts. For instance, the potential poverty implications identified in these figures (and Table A1) could be verified at national, regional, or local scales depending on data availability. Knowledge of socio-political conditions may also help clarify the differentiated effects of global changes on different demographic groups. There are also potential feedback loops in regions where global changes degrade forest and increase poverty, which may, in turn, lead to further degradation of forest and tree-based systems, resulting in a vicious cycle of poverty and forest loss. These complex feedback loops could be empirically traced in national contexts where global and local actions collude to damage forests and increase poverty.

This article provides opportunities to consider where poverty alleviation and forest management can coalesce to serve ecological, social,

and economic goals. Given that global forces of change on forest-poverty dynamics will vary across local contexts (Oldekop et al., 2021, this issue), it will be necessary to continue broad-scale and case study research to better understand the implications of global changes on specific forest management and use mechanisms (Hajjar et al., 2021b, this issue). Research into measures across sectors that account for the combined strength of these (and other) global forces may serve to improve outcomes on forest-poverty dynamics and lead to alternative models of development for forest landscapes.

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Appendix A. Supplementary data

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