Reviewing the evidence on the roles of forests and tree-based systems in poverty dynamics

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2021-10
Elsevier B.V.
http://hdl.handle.net/10138/564056
Razafindratsima, O H, Kamoto, J F M, Sills, E, Mutta, D N, Song, C, Kabwe, G, Castle, S E, Kristjanson, P M, Ryan, C M, Brockhaus, M & Sunderland, T 2021, 'Reviewing the evidence on the roles of forests and tree-based systems in poverty dynamics', Forest Policy and Economics, vol. 131, 102576. https://doi.org/10.1016/j.forpol.2021.102576

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Abstract

The alleviation of global poverty is a major objective of the 2030 UN Sustainable Development Goals (notably SDG1 "to end poverty in all its forms everywhere"). Many rural people experiencing poverty often rely on forests and tree-based systems, such as agroforestry, suggesting the existence of links between such systems and poverty outcomes. This paper reviews the evidence of such links across multiple dimensions of poverty and well-being, based on an expert panel convened by the International Union of Forest Research Organizations (IUFRO) and an extensive literature search. We consider whether, how, where, when, and for whom forests and trees in the wider landscape influence poverty dynamics. We organize the evidence according to four pathways through which forests and trees influence household poverty dynamics: 1) helping households move out of poverty; 2) maintaining well-being levels through subsistence, food security, health, and cultural and spiritual values; 3) preventing declines by mitigating risks and stabilizing consumption; 4) decreasing well-being by generating negative externalities that could lead to trapping or moving households into poverty. We found that local context matters considerably, with the roles of forests and trees strongly varying across geographical, social, economic, and political settings. Another key finding is that evidence of forests and trees providing livelihood diversification and benefits that help households move out of poverty remains limited, based primarily on a small number of case studies. Evidence on the impact of gender gaps in relation to forest landscapes and poverty pathways is also lacking. However, our findings do suggest that ecosystem services provided by forests and trees play critical roles in maintaining well-being and food security and have the potential to contribute more to helping households move out of poverty and mitigating risks amplified by climate change. This review also highlights cautionary findings related to negative forest externalities that can maintain or move households into poverty. Together, these findings call for policy efforts to support the conservation and sustainable management of forest landscapes and agroforestry systems that are more targeted towards meeting the diverse needs of the rural poor. Our results also point to a need for greater effort to address gender disparities, which have been largely overlooked yet provide a critical opportunity to not only enhance gender equality but also advance sustainable poverty reduction goals.

Keywords: Forest policy, agroforestry, poverty alleviation, poverty dynamics, livelihoods, sustainable development

1. Introduction

Forests and other tree-based systems[1] are vital resources for sustaining human populations worldwide (Cheng et al., 2019; FAO, 2020). In fact, more than 90 percent of the world's extremely poor depend on forests for food, energy, and other aspects of their livelihoods (FAO, 2020). Globally, forests contribute an average of 27% of household income in communities living within or in proximity to forests (Angelsen et al., 2014), which are generally characterized by relatively high poverty rates (Sunderlin et al., 2008). Tree-based systems, such as agroforestry and tree cash crops, also provide a suite of products and services that contribute to poverty

[1] Forests and tree-based systems include "the spectrum from natural old-growth forests, to those managed to optimise resource yields, to the broad spectrum of agroforestry practices and to single-species tree crop management" (Miller et al., 2020a).

alleviation and the improvement of overall human well-being (Castle et al., 2018; Kuyah et al., 2020; Leakey et al., 2005; Miller et al., 2020b). Sustainable forest management, agroforestry, and other tree-based systems are therefore potentially significant contributors to achieving the first UN 2030 Sustainable Development Goal (SDG) to "end poverty in all its forms everywhere" (UN 2015), as argued in a range of different contexts (Castle et al., 2018; Garrity, 2004; Griggs et al., 2013; Lawlor et al., 2019; Waldron et al., 2017).

The contribution of forests and tree-based systems to poverty alleviation have often been examined through case studies. A comprehensive synthesis of evidence regarding the variety of ways that forests and trees outside them affect poverty in all its forms remains lacking. Shyamsundar et al. (2020) provide a start at this, focusing on a framework for policy and management interventions in forest landscapes that encourages consideration of activities addressing multiple poverty pathways. However, existing syntheses and reviews to date are based on earlier literature and treat forests and trees outside them in isolation; *i.e.,* reviews on the evidence of the contributions of forests (Cheng et al., 2019, 2017; Miller and Hajjar, 2020) and agroforestry (Castle et al., 2021; Miller et al., 2020b) to poverty alleviation exist, but no synthesis has combined them in a single frame. Here, we address these gaps by reviewing relevant literature published since 2000 on how forests and tree-based systems are linked to four potential poverty pathways in different contexts and across different spatial scales.

Historically, the potential contributions of forests to poverty alleviation have been obscured by other narratives. One of those narratives has been that rural populations who rely on shifting cultivation and pastoralism, including many forest-proximate populations, need to be "settled" in fixed communities in order to escape poverty (Adger et al., 2001; Levang et al., 2005). This is rooted in the assumption that traditional grazing and small-scale cultivation systems – such as swidden agriculture – trap them in poverty and are responsible for deforestation, despite considerable evidence to the contrary (Curtis et al., 2018; Dressler et al., 2020; Thu et al., 2018). However, swidden agriculture is characterised by temporary deforestation and then recovery, whereas commodity production leads to permanent forest conversion (Curtis et al., 2018). This framing of smallholders as primarily responsible for deforestation has persisted since colonial times and has been used to justify claims on forests for large-scale production of global commodities such as timber at the expense of local forest stewardship (Doolittle, 2007; Dove, 1983). This discourse remains common in debates over the use of forest resources and climate change (Skutsch and Turnhout, 2020; Weatherley-Singh and Gupta, 2015), despite the potential of traditional integrated farming systems to generate joint benefits for livelihoods and climate change mitigation (Bruun et al., 2018, 2017; Dressler et al., 2017).

This review aims to synthesize the pathways through which forests and other tree-based systems affect poverty dynamics, thus providing a framework to inform future research and policy discussions related to poverty. Our integrated review of both forests and tree-based systems is informed by integrated landscape approaches, which are increasingly seen as a critical way forward for more sustainable and equitable land management (Reed et al., 2020; Sayer et al., 2013). We summarise the current knowledge on the role of forests and trees in poverty dynamics, considering the full range of products and services that are sold, consumed, or used as production inputs, based on the conceptual framework of forest-poverty dynamics developed by Jagger et al. (this issue). That framework identifies four possible pathways : (1) helping people move out of poverty; (2) maintaining well-being levels through subsistence, food security, health, and cultural and spiritual values; (3) preventing declines by mitigating risks and stabilizing consumption, and (4) decreasing well-being by generating negative externalities that could significantly contribute to trapping or moving households into poverty. Our approach allows for a comparison of the relative strengths and weaknesses of each pathway based on current evidence. A distinguishing characteristic of this review is that we also incorporated evidence on the potential negative feedbacks of forest and tree-based systems on local communities (Lyytimäki, 2015), distinct from the negative effects associated with the process of deforestation or the imposition of strict forest protection rules that exclude local people (Byg et al., 2017; Poudyal et al., 2018). This review also treats gender as an important cross-cutting issue that has been relatively neglected by researchers and practitioners, a start towards addressing this additional knowledge gap.

2. Methods

This manuscript is an outcome of a series of workshops convened by IUFRO (International Union of Forest Research Organizations) for a Global Forest Expert Panel to examine the role of forests in poverty dynamics. IUFRO assembled 40 experts from a wide range of disciplines (including conservation biology, development studies, ecology, economics, forestry, geography, political science and policy studies, and sociology) and from different regions around the world. All panel members shared their knowledge and contributed to the final report (Miller et al., 2020a). Workshop discussions, specific searches in relevant databases, and input from 10 external peer-reviewers of an earlier version of this review (Razafindratsima et al., 2020) led to the identification of most of the studies included here. Additional studies were added in revising the review for publication as a journal article to ensure it includes up-to-date literature. Therefore, this article is a traditional literature review (as opposed to a systematic one; Jesson et al., 2011) based on expert knowledge that has sought to cast as wide a net as possible to identify relevant studies on forest and poverty dynamics. However, relying on expert knowledge, understanding, and reading of the literature comes with limitations, resulting, for example, from a selection bias depending on who these experts (and reviewers) are and whose knowledge and scientific writing count (Corbera et al., 2016). In our attempt to reduce at least partially these biases, we paid particular attention to the composition of the panel and considered material beyond peer-reviewed journal articles, both of which helped to tap into more diverse authorship. Taking a more traditional approach to literature reviews also helped as we were not limited by strict protocols of what knowledge can be considered (Haddaway et al., 2015).

Focusing on the four pathways mentioned above, we searched academic repositories, including Web of Science, Scopus, and Google Scholar, as well as national and international reports and statistics for evidence on whether, how, where, when, and for whom forests and tree-based systems play a role with regards to these four pathways. We also searched grey literature through relevant organizational websites for evidence of the roles forests and tree-based systems play in poverty dynamics. We limited the search to literature published since the year 2000. We considered the potential direct and indirect benefits of forests and tree-based landscapes to poverty and incomes. We included other dimensions of human well-being related to poverty, such as the effects of forest and tree-based systems on human health and nutrition, food security, and cultural and spiritual values. We also examined resilience to shocks through reviewing the effects of trees on household risk and vulnerability in well-being, including livelihood and income diversification as strategies to potentially reduce risk and variation, both economic and environmental. Additionally, we include evidence of ecosystem services provided by forests and tree-based systems that could affect poverty, income, and livelihood dynamics.

For each pathway, we also examined the evidence on who benefits, including, where possible, variation by gender, age, ethnicity, and wealth levels, and discuss the key contextual factors and mechanisms behind these pathways observed in the included literature. Our evidence comes primarily from reported case studies and syntheses in peer-reviewed academic literature due to the fact that forest goods and services, aside from timber, are generally either excluded or not entirely attributed to forests in the official economic statistics that are the basis for assessing national poverty rates (Bakkegaard et al., 2016). However, it should be noted that timber used by rural households for self-consumption, without entering the market, is also unaccounted for in official statistics. Therefore, peer-reviewed case studies provide the best available evidence on the roles forests and trees play in poverty dynamics.

Despite casting a wide net across this global knowledge base, the majority of studies included in our review focused on low and middle-income countries (LMICs). The findings presented here, thus, relate primarily to these countries, with more weight on regions with the highest poverty rates (sub-Saharan Africa), the highest poverty headcounts (South Asia), and the most dramatic reductions in the incidence of poverty in recent decades (China).

3. Evidence on how forests and tree-based systems affect poverty

3.1. Helping households move out of poverty

Forests and tree-based systems can potentially contribute to reducing the proportion of people living in poverty, as defined by national poverty lines, by enabling households to increase their incomes through the sales of forest and tree products (Belcher, 2005). It is difficult to evaluate whether, where, and for whom this has occurred without reliable longitudinal data. Angelsen et al. (2014) and Miller and Hajjar (2020) point to panel survey data as particularly valuable for understanding this role of forests, trees, and agroforestry. Lacking such long-term panel data, researchers typically examine contributions to household income, expenditures, or assets, rather than the role of forests in lifting people out of poverty over time (Miller et al., 2017). Based on this largely cross-sectional and descriptive literature, the general view that has emerged was that fundamental structural barriers generally prevent poor people from fully utilizing the management and sale of forest and tree products to move out of poverty (Belcher, 2005; Miller and Hajjar, 2020; Pérez, 2005; Wunder, 2001).

In one of the earliest reviews that concluded forests have a limited role to play in lifting people out of income poverty, Wunder (2001) argued that timber is the product most likely to generate enough profits to reduce poverty, but that those profits are largely captured by wealthy and politically powerful actors, not only through the exchange of wealth from LMICs to the Global North but also within the wealthier people in source countries where the resources originate. Such capture and related inequalities in benefits from trees and forests are often deeply rooted in colonial rule and subsequent land and forest management regimes. Over the longer term, the forest sector appears to have contributed more to the economic prosperity of European countries that have historically dominated forest exploitation and forestland conversion, such as in the Congo Basin, for example (Coquery-Vidrovitch, 2017; Hardin and Bahuchet, 2011). State bureaucracies and national elites are also entangled in the capture of benefits, reflected throughout a set of dominant strategies in the politics of land acquisitions, forest concessions, trade, and investment patterns (Ekoko, 2000; Karsenty and Ongolo, 2012). A global systematic review by Malkamaki et al. (2018) of socio-economic impacts of large-scale tree plantations, often established by actors from the global North, pointed out how these plantations often provide a burden rather than a benefit to local communities. Although benefits might occur over time, they likely do not reach those that existed from previous land uses for local people. Exceptions occur where local communities have secure tenure rights over forests, the ability to negotiate land transfers, and control over the value chain for processing forest products (Bray et al., 2007; Malkamäki et al., 2018). Samii et al. (2014) found that decentralized forest management, whereby responsibilities for concession allocation and management, for example, are devolved outside of central government control, effectively increased local incomes in the few cases that were rigorously evaluated. The timber sector contributed to the economic development of many countries in northern Europe and North America that now have some of the highest incomes in the world. However, such economic gain (for some) might not always be sustainable because it has led to a loss of ecosystem services, such as biodiversity and carbon storage. These same countries continue to profit from timber harvested in the tropics, thus contributing to the structural barriers that limit the ability of the poor in LMICs to leverage timber resources as a means to move out of poverty.

Non-timber forest products (NTFPs), which include product originating from forests or tree-based systems that are not timber – such as branches and deadwood for fuel, mushrooms, fruit and nuts, and bushmeat for food, and herbs for medicine, are generally more accessible to poor households but offer low returns to their labour (López-Feldman and Wilen, 2008; Wunder, 2001). Thus, although NTFP income flows disproportionately to the poor, it does not necessarily lift those households out of poverty, especially when forest resources are open access (and therefore susceptible to overexploitation and dissipation of rents) and when access to transportation, markets, and other public services are limited (Belcher et al., 2005; Shackleton et al., 2008). However, there are exceptions, which can be created by more equitable forest policies that favour small-scale production-to-consumption systems (Kamoto et al., 2013; Larson and

Ribot, 2007) or better market access (Scherr et al., 2003). For example, shea butter from the southern Sahel is a well-known case of a global market boom that offered rural women the opportunity to increase their household incomes (Mohammed et al., 2013), but it was difficult for them to capitalize on without complementary support such as access to credit facilities (Bawa and Atengdem, 2016; Laube, 2015). Likewise, the global demand for vanilla created an opportunity for smallholders in northeastern Madagascar to increase their income through agroforestry production, but only for those with sufficient social capital to obtain contracts with exporters and collectors (Hänke et al., 2018).

Payment for ecosystem service (PES) programs offer another possible mechanism for increasing incomes and reducing poverty of rural households with secure tenure over forest resources (Wunder, 2005). There is limited, but credible, evidence that this is possible with an appropriate design of the PES system. For example, in their assessment at the global level, Sills and Jones (2018) found a positive causal impact of participation in PES on income.

3.2 Maintaining human well-being levels

The rural poor secure their well-being, in part, by drawing on multiple benefits from forests and tree-based systems, including both final and intermediate goods and services that are traded in markets and consumed within the households. Standard measures of income and poverty, as reflected in official statistics, only credit forests for income from final goods and services traded legally in markets, including timber and some non-timber products. These statistics typically do not capture the large proportion of timber that is harvested, transported, or exported illegally (Kleinschmit et al., 2016), or the informal fuelwood and charcoal sector, which employ far more people than the formal timber sector in Africa (Mwampamba et al., 2013). Further, forests and trees also provide both direct and indirect inputs to production and to overall household well-being (e.g., fodder, pollination, food, and sacred places), which do not pass through markets and, therefore, are excluded from national income accounts (HLPE, 2017). There is a significant body of literature on the role of forests in maintaining well-being, which we review first by type of product or service.

3.2.1. Wood products

The harvest and processing of timber (from both natural forests and plantations) provide employment and income to millions of people worldwide. FAO (2014) estimated that in 2010, 54.2 million people worldwide were employed in forestry, logging, and secondary manufacturing (e.g., sawn wood, panels, and paper). Verdone (2018) estimated that smallholders produced USD 2-4 billion in timber products per year, an order of magnitude less than the single largest forest products company. However, they produced USD 76-309 billion/year worth of charcoal and firewood. Charcoal provides energy for over 80% of urban households in sub-Saharan Africa (Agyei et al., 2020; Zulu and Richardson, 2013), and the informal charcoal industry provides employment to over half a million people in rural areas of Kenya alone (Njenga et al., 2013). Many studies show that the harvest and sale of timber (Antinori and Bray, 2005; Sikor and Baggio, 2014) and other wood-related forest products are important to increasing household incomes (Humphries et al., 2020; Macqueen et al., 2020; Miller and Hajjar, 2020).

In addition to generating employment and income, harvesting timber and fuelwood for household use can reduce household expenditures on these products. By growing trees on their lands, either woodlots or agroforestry systems, farmers can reduce the time required to gather fuelwood (Njenga et al., 2017), with the additional public benefit of reducing pressure on natural forests (Iiyama et al., 2014). However, the ability of trees on farms to supply enough fuelwood for household consumption depends on the size of the landholding (Ndayambaje and Mohren, 2011). Thus, many people remain reliant on wood collected off-farm. Even when trees on farms produce sufficient wood, they may be more lucratively sold as timber, poles, or specialty products than used for fuelwood (Iiyama et al., 2014).

3.2.2. Non-timber forest products

The literature on the contribution of NTFPs to rural livelihoods is dominated by local-level case studies (Angelsen et al., 2014). Some studies have found high dependence on NTFPs (Debela et al., 2012; McSweeney, 2004; Pattanayak and Sills, 2001), but results can differ drastically even within the same region (Leßmeister et al., 2018). This is partly because the diversity of NTFPs and the level of dependency vary greatly with the local context. Belcher and Kusters (2004) also attribute this inconsistency to the lack of an agreed-upon definition of NTFPs and variation in focus, scale, approach, and methodology. For instance, studies vary in whether they include relatively low-value products collected in high volumes like fodder, mulch, and fuelwood. In addition, NTFPs are not as likely to be recorded in official economic accounts since they are often consumed without being sold in the market or are informally traded locally. Here, we focus on studies of NTFPs as a whole, although there is also a sizeable literature on wild animals in particular, as sources of both high-value exports and critical dietary protein in the regions where they are hunted (McIntyre et al., 2016; Swamy and Pinedo-Vasquez, 2014).

Numerous studies have found that poor rural populations are disproportionately dependent on NTFPs to meet their basic needs (Belcher et al., 2005; Belcher and Kusters, 2004; Boedecker et al., 2014; Wunder et al., 2014). NTFPs are generally managed as open access resources and can be harvested using low-cost and/or traditional technologies (Belcher et al., 2005). For rural dwellers with little financial and physical capital, the affordability and low barrier to entry of NTFP collection make the collection of these resources a viable livelihood strategy. NTFPs play multiple roles in rural livelihoods, including direct consumption as food or medicine and supporting production. For example, people who live near areas with more forest and tree cover have more diverse and nutritious diets independent of household income or poverty status (Hall et al., 2019; Ickowitz et al., 2014; Powell et al., 2015a). The micronutrients provided by forest foods improve health outcomes and prevent stunting, wasting, and impairments of cognitive development (Johnson et al., 2013; Ruel and Alderman, 2013; Vinceti et al., 2013). Some NTFPs, such as fodder, mulch, and poles for constructing fences, also serve as inputs to production. Both these inputs and final products may also be sold, helping generate cash to pay school fees, purchase food from markets, and acquire agriculture inputs such as seed and fertiliser (Arnold et al., 2011; Hall et al., 2019; Kar and Jacobson, 2012).

One particularly important role of forests is to function as a ‘natural pharmacy’ or source of medicinal plants that play an important role in health care for people living in remote, rural areas where modern medicine is not available. Medicines collected from the forest constitute a large proportion of the medicines used by rural populations in LMICs (Moran, 2000; ten Kate and Laird, 2002) and form an integral part of their primary health care systems because of affordability, access, and effectiveness (Colfer et al., 2006). The use of medicinal plants in traditional health care systems and their contributions to the well-being of forest-dwelling people are well-studied in most regions of the world (Colfer et al., 2006). Local communities may harvest and sell medicinal plants to generate some cash income; however, local people generally receive a low price for unprocessed medicinal plants. Forest-dwelling people in LMICs may derive little economic benefit from the commercial development of local medicinal plants, where much of the profit is instead directed to the pharmaceutical companies that research, process, and distribute the derived medical products.

3.2.3. Products from trees on farms

More than 43% of agricultural land globally has at least 10% tree cover on farms (Zomer et al., 2016). Agroforestry practices can directly contribute to increased incomes through sales of tree products (Hughes et al., 2020; Thorlakson and Neufeldt, 2012), increased yields (Amadu et al., 2020; Coulibaly et al., 2017; Kuntashula and Mungatana, 2013), or payments for sustainable land-use practices through payments for ecosystem services and certification programs (Castle et al., 2021). In some cases, agroforestry can have a negative impact on incomes when the biophysical or social contexts are not suitable. These negative effects can be seen in areas with high soil fertility, where monoculture produces higher yields and payments do not compensate farmers for the lower yields – e.g., some coffee certification schemes (Haggar et al. 2017), or where farmers are unable or unwilling to devote additional inputs to the agroforestry systems (e.g., Dai et al., 2017). Agroforestry and trees on farms can produce high-value tree crops, such as rubber, coffee, cacao, cashews, and macadamia and shea nuts, while also allowing for the production of high-value intercrops, such as pineapples, corn, tree crop, salacca, or rice (Kuyah et al., 2020; Miller et al., 2017; Somboonsuke et al., 2011).

Agroforestry can also increase both income and food security through diverse products grown in crop fields or in-home gardens (Cardozo et al., 2015; Kumar and Nair, 2004; Trinh et al., 2003). Crop diversity can significantly reduce the probability of household poverty by mitigating production risk, adding income sources, and increasing resilience. Examples of this are recorded from complex home gardens in Ethiopia (Michler and Josephson, 2017) or the diversification to the production of high-value crops, as shown in India (Birthal et al., 2015). In sub-Saharan Africa, fruit trees provide an important source of income for many families through the sale of tree products and increased crop or livestock production when incorporating fertiliser or fodder trees (Schreckenberg et al., 2006). Recent evidence from Uganda, using data from a national survey of nearly 1,400 households over 10 years, shows that households that increased the area they allocated to trees on farms – particularly fruit trees – saw a significant increase in total household food consumption, including forest and non-forest products (Miller et al., 2020b).

3.2.4. Forests and trees for food security and nutrition

Forests and tree-based systems contribute to food security and nutrition, especially for vulnerable groups, such as children and pregnant and nursing women (Kiptot et al., 2014). The avoided malnutrition and its health-related consequences indirectly contribute to poverty reduction as rural families generally do not have sufficient finance for medical bills or to purchase market-based foodstuffs, among others. Many rural populations that live in or around forested areas rely, to varying degrees, on harvesting wild foods to help meet their dietary needs (Boedecker et al., 2014; Rowland et al., 2017; Sunderland, 2011). Multi-country analyses in Africa provide compelling evidence for the positive linkages between forests and diets, demonstrating a positive relationship between tree cover and children's dietary diversity (Ickowitz et al., 2014; Rasolofoson et al., 2018). A global comparative analysis found that 77% of the surveyed rural households engaged in wild food collection (Hickey et al., 2016). This contributes to food security by allowing rural dwellers to access nutritious foods when they may not have other sources of sustenance (Boedecker et al., 2014), and by mitigating hardships brought on by internal and external shocks, such as droughts, conflict, illness, and/or failing crops (Clements et al., 2014; Pouliot and Treue, 2013).

Harvesting wild foods can increase dietary diversity and help combat micronutrient deficiencies, also known as "hidden hunger" (Fa et al., 2015; Ickowitz et al., 2014; Powell et al., 2015b). Micronutrient deficiency can have dire consequences for vulnerable groups such as young children, leading to childhood stunting and wasting with life-long consequences (Golden et al., 2011; Temsah et al., 2018). Although wild foods do not necessarily contribute a large percentage of calories to the diets of rural households, they have been found, in several instances, to contribute to a greater proportion of essential vitamins and minerals (Asprilla-Perea and Díaz-Puente, 2019, 2019; Powell et al., 2015b; Vira et al., 2015). In Gabon, for example, Blaney et al. (2009) found that although natural foods only contributed to 12% of the energy requirements of villagers in the Gamba Complex, they contributed an estimated 82% of protein, 36% of Vitamin A, and 20% of iron requirements.

Fruit trees, both wild and cultivated, are an important source of dietary diversity for many rural households. They have the advantage of being relatively easy to cultivate and manage (Willett et al., 2019). Fruits such as baobab, mango, papaya, and citrus are particularly vitamin-rich sources of nutrients (Vira et al., 2015). Based on a nationally representative panel survey of nearly 1,400 households in Uganda, Miller et al. (2020b) found that increasing the share of trees (especially fruit trees) on farms led to improved child health and nutrition outcomes (e.g., reduced child wasting and stunting). Agroforestry has been shown to increase food security and dietary diversity in many other contexts by increasing and diversifying production while improving the resilience of crops and farm livelihoods (Bostedt et al., 2016; Jamnadass et al., 2013; Kiptot et al., 2014; Waldron et al., 2017).

3.2.5. Forest and tree inputs to production in agriculture and fisheries

Many households derive inputs from forests and tree-based systems for production in other sectors, most notably agriculture and fisheries. These indirect benefits are particularly important to poor households who cannot afford to purchase substitutes for the free inputs provided by forests and trees (Chavarría et al., 2018), such as ecosystem services. The presence of trees and forests in agricultural landscapes showed an overall positive or neutral effect on crop yields in 52% of the case studies in a pan-tropical review of 74 studies, though there was significant variation by region (Reed et al., 2017). Although overall 36% of the studies reported negative effects of trees on crop yields (12% of the studies had mixed effects), only 16% of the studies reported negative overall livelihood effects, indicating the reduction in yields may be compensated for by other benefits (Reed et al., 2017). Although there have been numerous initiatives to promote these tree-based systems because of their benefits to both farmers and broader society, farmers must balance their expected benefits against the potential costs of competition for resources and negative effects on the microclimate, such as increased relative humidity and lowered air temperature in sub-humid zones (Kuyah et al., 2016).

The key ecosystem services from forests and trees that support crop production include nutrient cycling (Power, 2010), pollination (Garibaldi et al., 2011) and seed dispersal (Enríquez-Acevedo et al., 2020), natural pest and disease control (Karp et al., 2013), soil formation (Hurni et al., 2015), reduced erosion and leaching (Mbow et al., 2014), and climate and water regulation (Daily and Matson, 2008). In particular, ‘fertiliser trees’ (i.e., trees that are grown in agricultural fields or pastures to increase nitrogen availability) can offer an alternative or supplement to fertiliser application, which can reduce expenditure on inorganic fertilisers and increase income through higher yields (Ajayi et al., 2011; Akinnifesi et al., 2010). This has been demonstrated in Africa for both maize (Sileshi et al., 2007) and wheat (Sida et al., 2018).

Forests and trees support pollinators and natural predators of crop pests. Although many major crops are self- or wind-pollinated, wild pollinators such as bees, butterflies, birds, and bats directly affect the productivity of 75% of globally important crops (Potts et al., 2016). In a global assessment, Dainese et al. (2019) found that pollinator richness increased crop yield across a vast array of crop systems. The stability of pollination services declines in crop fields with increasing distance from forests and trees (Garibaldi et al., 2011). Incorporating forests and trees within agricultural landscapes creates heterogeneity in the habitat and supports diverse natural predators of crop pests (Chaplin-Kramer et al., 2019; Kebede et al., 2019; Maas et al., 2016), especially in perennial crops (Pumariño et al., 2015). For instance, forest cover in farmland improved pest control by increasing natural predators such as bats and birds in Costa Rica (Guenat et al., 2019) and Western Kenya (Karp et al., 2013).

Forests and trees can also increase crop yield and resilience by improving microclimate conditions in agricultural landscapes (Pramova et al., 2012). For instance, trees on farms can buffer extreme climatic fluctuations such as temperature spikes that have negative impacts on crop growth (Hatfield, 2016). Shade trees have been found to enhance production by regulating temperature and humidity fluctuations in coffee agroforestry systems in Latin America (Lin et al., 2008) and India (Nesper et al., 2017). Trees in agricultural landscapes can also enhance understory growth by reducing air and soil temperature and by regulating water retention and gas exchange (Lott et al., 2009). This is one way that tree-based ecosystems can increase resilience to climate change and other shocks (Quandt et al., 2019; Thorlakson and Neufeldt, 2012).

In livestock systems, trees provide both shade and fodder. These systems include grazing livestock on pastures with trees, allowing livestock to graze on the trees or shrubs, and supplying tree cuttings as fodder for livestock. Fodder trees, when used as a protein supplement, improve milk and meat production, livestock growth, and livestock health and reproduction (Franzel et al., 2014). For example, in Ethiopia, livestock productivity and nutrient balances improved with forest proximity (Chavarría et al., 2018; Wood et al., 2018). Increased productivity ultimately leads to improved incomes and food security. In this regard, Franzel et al. (2014) estimated that households increased their annual net returns between USD 13-334 in Zimbabwe, USD 30-114 in Kenya and Uganda, and USD 68-503 in the Philippines.

Forests and trees can also benefit fisheries. Fish and other organisms (e.g., freshwater prawn, crayfish, and crabs) are an important source of protein for the poor, who consume less but are more dependent on (and have fewer substitutes for) these products in their diets, as compared to wealthier populations (HLPE, 2014; Jones et al., 2006; Kent, 1997). Forests contribute to the maintenance and regulation of aquatic food webs by regulating flow extremes, controlling sedimentation rates, regulating instream temperature, and contributing energy flow through terrestrial resource subsidies in the form of terrestrial fauna entering the aquatic food web (HLPE, 2014). For example, in the Amazon Basin, fish are, in many cases, the most important source of protein consumed by rural people. In freshwater streams and rivers, fish feed on fruits and seeds deposited by riparian vegetation on which their survival depends (Horn et al., 2011). McIntyre et al. (2016) report that hundreds of millions of people globally benefit from the low-cost protein and commerce that freshwater fisheries provide, particularly where alternative sources of protein and employment are scarce (Lo et al., 2019).

A growing body of literature highlights the contributions of ‘blue forests,’ notably mangroves, to local community well-being, livelihoods, and food security (Himes-Cornell et al., 2018), including employment of the millions of people who are artisanal, or low technology, fishers (Hutchison et al., 2014). Mangroves provide habitat, spawning and nursery grounds, and nutrients for a variety of fish and shellfish, including for many commercial species (FAO, 2017; Hutchison et al., 2014). Fishing sector and rural communities around the world depend on the fish and shellfish in mangroves as a source of income and food security. Mangroves also contribute to aquaculture, both as open-water estuarine mariculture (e.g., oysters and mussels) and as pond culture (mainly for shrimps) (FAO, 2017). Because of its high economic return, shrimp farming has been promoted to boost national economies and alleviate poverty in several countries, although the resulting damage to mangroves may have significant negative impacts on the fisheries sector (Hossain et al., 2013).

3.2.6. Non-material contributions

Although poverty rates are often based on income lines, poverty is widely recognized as a multi-dimensional concept (Jagger et al., this issue). Non-material factors such as culture, religion, and spiritual values are difficult to quantify but clearly important to human well-being. Their loss is, therefore, a form of impoverishment.

Forests and trees are significant to spiritual and cultural traditions central to the identity of forest-proximate communities, especially Indigenous people (Asselin, 2015; Daniel et al., 2016; Oteng-Yeboah et al., 2011). Information on the cultural significance of forest resources can be gleaned from anthropological, ethnobotanical, and ethnoecological studies (Alexiades, 2003; Cocks, 2006; Toledo, 2002). These cultural values manifest in ways ranging from forests being objects of animist-based beliefs to traditional forest products marketed globally, such as artisanal arts and crafts. For example, in Ghana and Nigeria, forest products are the materials used to make musical instruments essential for rituals and ceremonies (Kakudidi, 2004; Mogue Kamga et al., 2020; Van Andel, 2006). Across the world, people conserve forests in sacred groves that hold strong cultural and religious importance to local people (Liljeblad and Verschuuren, 2018; Ormsby and Bhagwat, 2010; Sheridan, 2009).

Forests are culturally important to the self-identification and quality of life of many Indigenous people. They symbolize cultural cohesion in a rapidly changing environment and, hence, cultural integrity (Asante et al., 2017). Intimately linked with ancestry and cultural heritage, forest symbols strengthen social and cultural identity. The cultural values of forests also extend beyond Indigenous populations. For example, in the western Brazilian Amazon, social movements and a state government have emphasized cultural connections to the forest among descendants of migrants who came to the region to tap rubber from the native *Hevea brasiliensis* trees (Gomes et al., 2012). In 1998, the state of Acre elected a new government that emphasized 'florestania' or forest citizenship, thus recognizing the centrality of forests to the culture and identity of rubber tappers. To support both the ecosystem services and the cultural values associated with rubber tapping, the government offered a subsidy for rubber as a mechanism to simultaneously increase rubber-tapper incomes, incentivize protection of the forests with rubber trees, and recognize the cultural value of rubber-tapping (Jaramillo-Giraldo et al., 2017; Sills and Saha, 2010).

In many regions, forests are considered sacred and are governed by a set of traditional norms and rules (Munyi and Mutta, 2007; Ngoufo et al., 2014; Rutte, 2011). Such forests are traditionally managed by Indigenous communities. Preserved forest patches are usually close to human settlement, thus forming an integral part of traditional rural communities (Ray et al., 2014). They provide the venue for social, cultural, and religious ceremonies and a range of products for traditional ceremonies, from food and beverages to costumes and musical instruments. For example, sacred forests in south-eastern Nigeria and coastal Kenya are important sites for the coronation of paramount rulers, basically chiefs of chiefs, and other traditional rites and celebrations (Daniel et al., 2016; Kibet and Nyamweru, 2008; Umazi et al., 2013).

Many religions that originated in China, Japan, Central and South Asia (including Buddhism, Shinto, Daoism, and Hinduism) integrate nature as a critical component of their belief systems (Dudley et al., 2009). Sacred forests provide essential spiritual services to Tibetan Buddhists as naturally forested Holy Hills where village gods and spirits reside (Taylor and Kaplan, 2005). According to ancient Shinto beliefs, a god can descend to a high pine on an elegant mountain top to exist in a large old tree (Kasulis, 2004). Over 15 tree species have been identified in Shinto for religious use, including trees in shrines that have been managed for centuries (Omura, 2004)

Traditional annual rituals to consecrate the sacred forests and honour the gods and spirits provide an essential mechanism to integrate widely scattered households into a close-knit community (Liu, 2006). Sacred forests provide similar spiritual services to the Dai people who live in southwest Yunnan Province of China, northwest Vietnam, northern Thailand, and upper

Laos (Taylor and Kaplan, 2005). To the extent that cultural practices contribute to a shared sense of belief among communities, they are essential to collective community capabilities.

The maintenance of religious forests may also generate ecosystem services. For example, religious forests in Nepal's hilly regions have positive impacts on soil conservation and microclimate preservation (Acharya, 2003; Niroula and Singh, 2015). In other cases, particular plant species are preserved by religious beliefs as they are thought to represent a deity, such as the case of *Ficus religiosa* in Hinduism (Gairola, 2020; Krishna, 2017).

3.3. Preventing poverty declines by mitigating risks and stabilizing consumption

Forests and tree-based systems play important roles in stabilizing consumption across seasons (*i.e.*, gap filling) and reducing vulnerability to shocks (*i.e.*, managing risks). Rural households who depend on agriculture for their livelihoods typically face highly variable revenue flows and labor demand across seasons. Poorer households are more likely to fill those seasonal gaps by collecting and selling NTFPs (Arnold et al., 2011; Leßmeister et al., 2018; Wunder et al., 2014).

Vulnerability to environmental changes and natural hazards (e.g., due to global climate change) is understood as a function of exposure, sensitivity, and adaptive capacity (Adger, 2006). Poorer households may be more vulnerable because their homes and livelihoods are relatively more exposed (e.g., to coastal flooding); because their livelihoods are relatively more sensitive to perturbations (e.g., rain-fed agriculture); or because they have fewer options for adaptation (e.g., relatively limited access to credit lines or savings). Forests and tree-based systems can mitigate these factors by reducing exposure, providing a means to diversify livelihoods, thereby making them less sensitive to environmental perturbations, and facilitating adaptation to environmental change, thereby stabilizing consumption over time.

First, forests can reduce exposure to environmental perturbations. For example, in coastal regions, mangroves buffer human settlements from tropical cyclones and storm surge (Sierra-Correa and Kintz, 2015). Also, on steep slopes, forests help prevent landslides in response to extreme precipitation events (de Jesús Arce-Mojica et al., 2019). Agroforestry systems can stabilize the microclimate by tapping into deep water sources and serving as windbreaks (Place et al., 2016). Trees in the landscape allow more water to infiltrate the soil, thus stabilizing downstream water flows (Pattanayak and Butry, 2005).

Second, livelihood diversification is a common strategy for reducing sensitivity to shocks (Wunder et al., 2014). Forests and tree-based systems provide options for diversification even to households who otherwise do not have sufficient financial, physical, or human capital to add new activities to their livelihoods portfolios. For example, open access forests can be a source of NTFPs with different seasonality patterns and responses to environmental perturbations (Pattanayak and Sills, 2001). Agricultural livelihoods can be diversified through the adoption of tree-based systems (Krishna, 2011; Kristjanson et al., 2019). Public demand and initiatives to conserve forests are providing new ways for poor households to leverage forest landscapes to diversify their incomes, including income from wildlife conservancies (Bedelian and Ogutu, 2017), ecotourism (Andam et al., 2010), and payments for environmental services (Pagiola et al., 2005).

Third, forests and trees can also provide a safety net that helps households cope with shocks and adapt to environmental change. They effectively offer insurance in the form of forest products that can be consumed or sold (Paumgarten, 2005; Shackleton and Shackleton, 2004; Wunder et al., 2014). This is especially relevant to the rural poor who lack access to other forms of insurance and who rely on activities that are subject to weather and other environmental shocks that affect entire communities, limiting the ability of households to help each other (Fisher et al., 2010; McSweeney, 2004; Noack et al., 2019; Paumgarten and Shackleton, 2011; Takasaki et al., 2004).

Although it is clear that access to forests and tree-based systems can help reduce vulnerability, it is less clear how significant this is for poverty alleviation (Mbiba et al., 2019). Wunder et al. (2014) found that only 10% of households across multiple countries used environmental resources, predominantly the collection of NTFPs in forests, as their primary safety net. However, forests and trees can be particularly important for rural populations in remote areas. For example, for people without access to financial services, trees may act as stores of wealth, effectively acting as a bank account (Angelsen et al., 2014; Thorlakson and Neufeldt, 2012; Wunder et al., 2014).

3.4. Decreasing well-being by generating negative externalities

Forests and trees can also generate negative externalities for forest-proximate populations (Lyytimäki, 2015). For example, the role of forests as a habitat for wild animal populations can lead to negative outcomes, including crop-raiding and livestock predation (Bista and Song, in review; Hill, 2018) and transfer of diseases from wildlife to livestock and humans (Baudron and Liégeois, 2020). High evapotranspiration rates in forests may also mean that they compete for water with downstream users (Sun et al., 2006), even as upstream forests can perform important water regulating services (Wu et al., 2021). In addition, the effects of invasive tree species can also be considered a negative externality of forests (McGarry et al., 2005; von Dohren and Haase, 2015). Many of these negative externalities of forests impose costs on some people but benefit others. Thus, Byg et al. (2017) argued for a ‘disaggregated accounting’ of both forest services and disservices, and their distribution across people and places. For example, some alien tree species may disrupt subsistence agriculture for some, while providing NTFPs like fruits and nuts, or wood for firewood or conversion to charcoal. Net outcomes depend on people's ability to manage these species to neutralize their negative impacts (McGarry et al., 2005).

3.4.1 Crop raiding and livestock depredation

Crop raiding and livestock depredation happen wherever people live close to forests but especially near protected areas with high wildlife densities (Hill, 2018; Karanth and Ranganathan, 2018). Crops and livestock in the buffer zones of protected areas are convenient sources of food for some wildlife. Elephants, which are the largest crop-raiding mammal, destroy crops and may also cause human injuries and even death. Human-elephant conflicts occur primarily near protected areas in Africa and South Asia. For example, Neupane et al. (2017) found that elephants are responsible for more than 40% of crop-raiding, causing the annual loss of 25% of crop production in Nepal's Terai region. Harich et al. (2013) report that 84% of farmers experience crop damage from elephants around the Bia Conservation Area in Ghana.

Primates can also cause serious crop damage, and it is difficult to guard against their opportunistic crop-raiding behaviour (Sunderland-Groves et al., 2011). Baboons, chimpanzees, and numerous other primate species can inflict serious damage on crops (Mackenzie et al., 2015; Mohammed et al., 2017; Mwakatobe et al., 2014; Tweheyo et al., 2005). For example, Tweheyo et al. (2005) found that 73% of people living around the Budongo Forest Reserve in Uganda reported crop damage by primates, and 79% of the residents consider baboons to be the most destructive.

Livestock predation by wildlife is another major problem for forest-proximate people, leading to losses. For example, loss resulting from livestock predation represents as high as two-thirds of household cash income for villages outside the Serengeti National Park in Tanzania (Holmern et al., 2007). The species most commonly responsible for predation are large felids (e.g., lions, tigers, pumas, cheetahs, leopards, snow leopards, and jaguars) (Inskip and Zimmermann, 2009). For example, in the buffer zone of the Chitwan National Park (Nepal), Dhungana et al. (2019) found that more than 87% of livestock lost during 2007-2016 were goats taken by leopards. Moreover, people in disadvantaged social groups suffered disproportionately more attacks in the buffer zone of the Chitwan National Park because they live closer to the forest and do not have the means to construct suitable protection facilities (Lamichhane et al., 2018). Wang and Macdonald (2006) also reported that attacks on livestock in the Jigme Singye Wangchuck National Park in central Bhutan caused an average 17% loss in cash income by affected households.

Even though the most prominent and well-publicized cases of human-wildlife conflict are often those around protected areas, conflicts can happen anywhere in forested landscapes. Michalski *e*t al. (2006) reported that jaguars and pumas were the main animals attacking cattle in a fragmented forest landscape in the southern Brazilian Amazonia, with damages of up to USD 885 per year per farm. Bista and Song (in review) found that local residents suffered significant economic loss from wildlife in the Middle Hills of Nepal, where forest conditions had improved significantly from community forestry. On the other hand, around the Nilgiris Biosphere Research and Bhadra Tiger Reserve in the Western Ghats of India, Puyravaud et al. (2019) found that deforestation increased the frequency of crop-raiding by elephants.

There are also numerous indirect costs of human-wildlife conflict (Barua et al., 2013). Crop damage contributes to food insecurity among the rural poor. The potential of wildlife-caused human injury or mortality stokes fears in local residents, damaging psychosocial well-being. For example, Jadhav and Barua (2012) argue that the fear of an elephant attack exacerbates the mental illness of marginalized people, imposing greater health damage than the physical threat. To mitigate wildlife impacts, farmers engage in extensive guarding, sometimes day and night, and divert limited financial resources to purchase materials for fences and stalls. For instance, school-age boys may be deployed to guard crops during peak crop-raiding time, compromising their performance at school (Mackenzie et al., 2015). These indirect costs can cause long-term damage to the welling-being of the poor, but they are not well documented in human-wildlife conflict studies.

3.4.2. Water competition

Forests generally consume more water than other vegetation types because of their high leaf area per unit ground area (Gray and Song, 2012) and long growing seasons for some evergreen tree species. In areas with limited precipitation, the high water consumption by trees reduces water availability for agricultural and domestic use (Li et al., 2016; Sun et al., 2006). Similarly, trees on farms compete with crops for water, light, and inputs, including fertiliser, land, and labour (Dai et al., 2017). However, the net effects of trees on farms depend on the balance between increased competition and improvements in the microclimate and soil fertility (Kuyah et al., 2016).

Forests, especially high productivity forest plantations, are major water users and thus compete with other downstream uses of water (Calder, 2007). Zhang et al. (2018) identified a lack of water as a major factor contributing to cropland abandonment in a rural forest community in China. This may be especially true of the fast-growing and non-native species that grow in industrial plantations, such as ponderosa pine (*Pinus ponderosa*) plantations in the forest-steppe ecotone in western Patagonia (Licata et al., 2008).

This competition for water must be seen in the context of the overall relationship between water availability and forests and trees (Creed and van Noordwijk, 2018). On the one hand, natural forests contribute to the resilience of water supply through conservation of soil and water resources, providing freshwater during dry seasons, and mitigating floods during wet seasons in many parts of the world. On the other hand, water consumption by forests reduces freshwater availability in the streams (Kim et al., 2014). A systems approach that integrates hydrological processes at all scales is needed to understand the role of forests in water availability and the subsequent impact on people's livelihood under a changing climate. If properly managed, forests can help enhance the resilience and quality of water supplies.

3.4.3. Effects of invasive tree species

Some tree species that are planted can also become invasive and compete for both water and growing space. This is particularly true of species that have deep roots, a high transpiration rate, and a long growing season. For instance, Le Maitre et al. (2019) estimated that forests of invasive alien species in the Western Cape of South Africa used as much as 970 m^3/ha/year of water, having a significant negative effect on the water supply system. Guava (*Psidium guajava*) and its sister species strawberry guava (*Psidium cattlenianum*), native species to tropical America, have become invasive in many parts of the world. These tree species can drastically change the character of the ecosystems they invade, including cropland and pastures (DeSisto et al., 2020; Patel, 2012; Rajaonarimamy et al., 2017; Walsh et al., 2008).

3.4.4. Other negative effects of trees

Woody encroachment (also known as "bush encroachment" or "woody thickening") is displacing more open ecosystems throughout the dry topics of Africa and to a lesser extent in Australia and Latin America (Liu et al., 2015; Skowno et al., 2017; Stevens et al., 2017). It is associated with negative impacts on biodiversity (Parr et al., 2014, 2012; Ratajczak et al., 2012) due to loss of species that require open habitat, as well as reduced productivity of grazing land and the extra costs incurred by pastoralists or ranchers for 'debushing' or thicket clearance (Stafford et al., 2017). These impacts can have severe consequences for livelihoods during drought years as the thickening bush reduces water availability for both humans and animals (Angassa and Oba, 2008).

4. Gender in forest landscapes

Although gender issues arise across the various pathways and roles described above, they merit a separate discussion here for several reasons. First, there remains a paucity of literature exploring how gender affects poverty dynamics in the context of forest landscapes (Shyamsundar et al., 2020). Second, studies that have explored aspects of this question argue that taking gender into consideration in relation to forest landscapes matters because how, why, and where men and women access, use, and manage forests and trees differ (Kristjanson et al., 2019; Mai et al., 2011; Mwangi et al., 2011; Razafindratsima and Dunham, 2015). Interventions aimed at enhancing the sustainable use and management of forests and agroforestry practices that do not take these differences into account can exacerbate gender inequalities and miss opportunities for more significant impacts in terms of both effectiveness and equity (Kristjanson, 2020). An earlier review of literature focusing on forests and gender identified persistent gender gaps (disproportionate differences between women and men) across regions in access to services, access to markets and value-addition activities, land and tree tenure voice and agency, and hiring labour (Colfer et al., 2016). In addition to these, gender differences in the capacity for addressing climate change have been recognized as an issue that not only affects productivity but also widens existing gender gaps in many places. These capacity differences include less bargaining power, assets, and resources identified as essential for adaptation to a changing climate (Pérez et al., 2015). In some areas, these gender-related challenges have been exacerbated as men migrate from rural areas in search of employment, leaving women to assume the spectrum of agricultural and forest management roles, often without the resources or agency to do so successfully (Giri and Darnhofer, 2010; Jaquet et al., 2015; Slavchevska et al., 2016).

There is evidence that NTFPs play a particularly important role for women in poverty alleviation. For example, CIFOR's pan-tropical Poverty Environment Network (PEN) study found evidence of distinct male and female roles in relation to the collection of forest products that vary across regions (Sunderland et al., 2014). In Africa, women are the main collectors of subsistence-oriented forest products. In Latin America, however, men were found to dominate firewood collection. Men were also more involved in fuelwood collection in Africa more often than previously assumed. In all regions, men were more involved in hunting, wood harvesting, and mineral extraction than women. They found that in Latin America, men earn seven times more income than women from unprocessed forest products, while in Asia, earnings are similar for men and women, and in Africa, the share of income from forests is greater for women. With respect to income from processed forest products (e.g., furniture), the share of overall income was higher for men (61%) than women (25%) across the three regions (Sunderland et al., 2014). Women were also found to collect more forest products than men from common property resources in Latin America and Asia, but not in Africa (Jagger et al., 2014; Sunderland et al., 2014). However, this is not always the case; for instance, relatively few differences between men and women exist regarding the role of NTFPs in household coping strategies in South Africa (Paumgarten and Shackleton, 2011).

In evaluating the agroforestry literature to identify studies that disaggregate effects by gender, age, socio-economic level, and literacy, we found that the primary equity component studied is gender. The importance of gender considerations for agroforestry practices and interventions have been extensively discussed for Sub-Saharan Africa and, to some extent, South and East Asia and the Pacific, and the evidence shows mixed differential effects of agroforestry between women and men (Bostedt et al., 2016; Kiptot et al., 2014). Positive effects include agroforestry providing income-generating opportunities for women, reducing women's labour burdens, and improving dietary diversity for women and children (Kiptot et al., 2014; Place et al., 2005). Harvesting from forests is often dangerous and exhausting; collecting wood on-farm reduces the distance women have to travel and affords more time for leisure (Njenga et al., 2017; Sunderland et al., 2014). Women are often responsible for managing livestock, so available shrubs also reduce the time required to gather fodder, allowing women more time for leisure activities and to prepare nutritious food for their families (Kiptot et al., 2014). Women also directly earn money through the sale of milk; and the dairy income they have control over often goes directly towards their children's education and providing nutritious food to their families (Kiptot et al., 2014). Additionally, in some communities, women might benefit from selling fruit and fruit products (Kiptot et al., 2014). Many agroforestry studies that consider nutrition outcomes highlight the importance of women and women's empowerment in decision-making as key factors determining household nutrition and dietary diversity along with agroforestry practices.

Additional labour burdens for women can arise, however, in relation to agroforestry practices if the responsibility for managing and harvesting on-farm trees falls primarily on them. Women often lack control over profits from agroforestry practices, and their unequal access to information, program benefits, technology, capital, and markets can limit returns to their efforts (Kiptot et al., 2014; Place et al., 2005). There is also evidence of considerable variability in how the incorporation of fertiliser trees affects different population sub-groups, such as women, smallholder farmers, and poorer or more marginalized households (Coulibaly et al., 2017; Kuntashula and Mungatana, 2013; Place et al., 2005). In many cases, women are restricted in their ability to participate in agroforestry programs due to social norms or program design. When they can participate, they often experience fewer benefits than their male counterparts (Hegde and Bull, 2011; Place et al., 2005). Men also often exclude women and control income from relatively high-value tree crops such as rubber and coffee (Kiptot and Franzel, 2012).

5. Conclusions

This global review of the role of forests and other tree-based systems in four potential poverty pathways has found that these relationships are strongly context-dependent. Natural resource endowments, cultural, religious, economic, political, and institutional settings all influence the contribution of forests and tree-based systems to poverty outcomes. We found that there was more evidence on the effects of forests and tree-based systems on poverty pathways in studies undertaken in Sub-Saharan Africa, followed by South and East Asia, the Pacific, and Central America. The strongest evidence for significant positive contributions to poverty outcomes are associated with high-value, non-timber forest products, including foods, medicinal plants, and agroforestry products. Although there is limited literature examining movements of people out of poverty as a direct outcome of forests and tree-based system interventions and investments, there is a larger body of literature examining their effects on income, health and nutrition, risk reduction, ecosystem services, and other dimensions of well-being. Gender and the impacts of failing to address gender gaps play a role in determining the distribution and magnitude of poverty-related impacts in forest landscapes.

Evidence from around the world shows that the goods and ecosystem services that forests and trees provide play important roles in maintaining the livelihoods of the poor and helping to keep households from falling into, or further into, chronic poverty. They help poor rural households secure and stabilize their socio-economic and cultural status. Their numerous resource benefits (food, fodder, soil fertility, water retention, carbon sequestration, tourism potential, etc.) remain largely non-monetized and unrecognized by official reports and policymakers at all levels. Continued and strengthened efforts on policies and programs that reward local communities for their conservation and protection of forests, on-farm trees, and environmental services are badly needed. There is also no escaping the need for initiatives such as health insurance, efficient energy alternatives (to wood, charcoal, and traditional cookstoves), and other basic social safety net programs needed to boost forest-related contributions to sustainable poverty alleviation goals.

Despite ample evidence that forest and other tree-based systems play a critical role in supporting well-being through subsistence, food security, cultural and spiritual values, and mitigating risks by smoothing income across seasons and years, we found little evidence of many poor people permanently moving out of poverty due primarily to forests and tree-based efforts. The levels of income generated on small farms and within communities, especially adjacent to protected forests, are often too small to boost households out of poverty. At the same time, there are some negative externalities associated with forests that can contribute to transient poverty or sending households deeper into poverty, such as crop-raiding, livestock depredation, and reduction of freshwater resources. Therefore, forests and other tree-based systems will only advance UN Sustainable Development Goals on the global scale with significantly greater investment interventions and policies aimed at enhancing ecosystem services and livelihoods via sustainable forest and tree landscape targeted efforts, particularly those that recognize and meet the needs and strengthen the rights, of women, poor and marginalized and Indigenous People.

The contrast between the widespread dependence of the poor on forests and trees for their livelihoods and well-being and their limited ability to use those same resources to exit poverty, begs an explanation. Possibilities that deserve more consideration include the influence of international investment and trade on the allocation of benefits from forests and the influence of the rules governing access to forests on the global distribution of prosperity. More research on the dynamics between forests and inequality across countries is merited, as is a systematic review to gain a broader vision supported by a more careful accounting of the balance of evidence.

Acknowledgements

We are grateful to IUFRO (International Union of Forest Research Organizations) for putting together the Global Forest Expert Panel and for inviting us to participate in the panel, during which the ideas for this manuscript were developed and implemented. We thank Daniel Miller, Jennifer Zavaleta Cheek, Pamela Jagger, Stephanie Mansourian, Christoph Wildburger, and an anonymous reviewer for their helpful feedback that improved earlier versions of this manuscript.

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