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# Agroforestry and non-state actors: A review

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ABSTRACT

Agroforestry, or the intentional integration of trees on crop or pastureland, is a sustainable land use system that provides ecosystem services including climate change mitigation and private benefits for smallholders. While existing reviews of agroforestry adoption focus on government policy, there is increasing interest from, and opportunities for, non-state actors to accelerate agroforestry adoption. The purpose of this critical review is to identify points of entry for non-state actors to increase smallholder incentives for agroforestry adoption in low and middle income countries. We identify opportunities for non-state actors to address key market failures in all stages of the agroforestry system. We find that non-state actors have advantages of proximity and institutional knowledge that provide opportunities for direct and indirect intervention to increase agroforestry adoption.

## 1. Introduction

The benefits of agroforestry (defined as intentional incorporation of trees onto crop or pasturelands) for smallholder farmers in low and middle income countries (LMIC) are wide-ranging and well-documented (Garrity et al., 2010; Jose, 2009; Mbow et al., 2014; Miller et al., 2020, 2017; Sileshi et al., 2008; Waldron et al., 2017, 2015). Research has focused on how agroforestry can help alleviate poverty through diversification of income, increased crop yields, and substitution of agricultural inputs (Cacho et al., 2003; Ellis, 1992; Lundgren and Raintree, 1983; Nair, 1998; Pandey, 2007; Pratiwi and Suzuki, 2019; Quinion et al., 2010; Steppler and Nair, 1987). More recent research has highlighted how agroforestry systems can provide a range of ecosystem services, such as soil enrichment, improvements in air and water quality, and biodiversity benefits (Barrios et al., 2012; Jose, 2009; Sileshi et al., 2007). A growing body of work has begun to demonstrate how agroforestry can advance climate change mitigation through carbon storage (Chapman et al., 2020; Duguma et al., 2019; Griscom et al., 2017; Syampungani et al., 2010).

The benefits of agroforestry systems are to some degree achieved on 43% of agricultural land with at least 10% tree cover in 2010, sequestering approximately 36.29 Pg Carbon (Zomer et al., 2016). As a proven sustainable land use practice, global efforts are underway to achieve higher levels of agroforestry to advance global climate change mitigation (IPCC, 2019), sustainable development (World Bank, 2020), and conservation goals (Bhagwat et al., 2008; Schroth and Harvey, 2007; Waldron et al., 2012). Indeed, agroforestry is a sustainable land use practice that has the potential to contribute to nine of the Sustainable Development Goals (Wekesa et al., 2018), and an intervention that can reduce degradation of human modified lands (Willemen et al., 2018). As more players, many of which are non-state actors (i.e., intergovernmental and non-governmental organizations, academic institutions, private corporations), seek to expand the benefits of agroforestry, there is a need for greater understanding of the complex barriers to adoption.

Smallholder farmers must assess the tradeoffs of alternative land uses when determining land use practices, such as profitability of the practice and whether the land use practice is culturally aligned. But for smallholder farmers that are likely interested in agroforestry practices and where adoption is constrained, non-state actors have an opportunity to aid in alleviating constraints to help spur large-scale agroforestry adoption. Three recent policy guides attempt to address challenges for

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increasing agroforestry adoption among smallholders, but these guides primarily provide recommendations for state actors, such as national governments (Bernard et al., 2019; Buttoud, 2013; Place et al., 2012). While state actors play an important role in increasing adoption via subsidies, regulatory policies, and other mechanisms, non-state actors play a central role in wide-ranging efforts to reach smallholder farmers. For example, in Niger non-governmental organizations implemented a capacity building program with local agricultural communities to regenerate five million hectares through agroforestry systems (Reij et al., 2009). With agroforestry identified as an intervention for climate mitigation and adaptation by the Intergovernmental Panel on Climate Change (IPCC, 2014), there are a growing number of opportunities for non-state actors to engage in efforts to catalyze wide-scale adoption of agroforestry systems among smallholder farmers. In addition to helping advance global goals to combat climate change, non-state actors are particularly well suited to address poverty and other local objectives. But for agroforestry systems to meet their potential, a review of barriers and opportunities for non-state actors to advance agroforestry adoption is needed.

Non-state actors have a distinct advantage - namely, they can often be nimbler and more flexible than state actors. For instance, this is increasingly evident for climate change mitigation and adaptation efforts, an area where reliance on national governments can lead to inaction or slow progress. Non-state actors have helped set agendas, created norms and frameworks to support climate action, provided financing, monitored progress, created and disseminated knowledge, and implemented policies or programs at the local level (Haufler, 2009). Recognizing the importance of non-state actors, the Paris Climate Agreement included 8000 non-state observers in the conference, and established formal mechanisms through the Non-State Actor Zone for Action to report actions set out in nationally determined contributions to the Paris Agreement (Bäckstrand et al., 2017).

Here, we build on the large body of research examining the constraints to wide-scale agroforestry adoption among smallholder farmers in LMICs, and critically examine the literature to identify how non-state actors can increase sustainable agroforestry adoption by leveraging their comparative advantage relative to state actors (Kant and Lehrer, 2005) within the agroforestry system (input, production processes, and output). We identify both direct and indirect opportunities for non-state actors to help smallholder farmers adopt agroforestry practices, and address market failures in the form of information asymmetries, transaction costs, challenges with public goods and common property, and uncompensated positive externalities from agroforestry systems. Examining opportunities for non-state actors to accelerate agroforestry adoption among smallholder farmers in the tropics where market failures have inhibited adoption is useful because functioning agroforestry markets create incentives for smallholder farmers that improve livelihoods (Russell and Franzel, 2004). By focusing our efforts on interventions that address existing market failures and allow smallholders to capture unrealized private gains from agroforestry, we identify points of entry that align the goals of non-state actors and smallholders. We investigate three interlinked questions in our critical review. First, what are the market failures that would justify intervention by non-state actors? Second, what are mechanisms that address these failures that could be initiated by non-state actors? Finally, what is the strategic and socially acceptable role of non-state actors to implement these policy solutions?

## 2. Methods

We conduct a critical review of peer-reviewed and grey literature (Grant and Booth, 2009) on agroforestry systems for smallholder farmers in LMICs guided by two frameworks (details below). We focus on this population because they will likely experience the largest welfare gains from ecosystem services and poverty alleviation provided by agroforestry systems (Thornton et al., 2019). Further, climate and population pressures in LMIC countries will impose high demands on productivity and mitigation / adaptation measures on agricultural lands (Zomer et al., 2016).

Our critical review is guided by two frameworks: Kant and Lehrer's (2005) conceptualization of agroforestry systems as consisting of input, production, and output stages, and Biermann et al.'s (2010) characterization of non-state actor agency for earth system governance. In particular, we examine market failures that hinder widespread agroforestry adoption within the three stages of agroforestry systems, focusing on those that can be addressed by non-state actors. Kant and Lehrer's (2005) characterization of the agroforestry system in three stages of production (inputs, production processes, and output) allows us to systematically examine market failures from seed inputs to products. Here, *inputs* are all of the fixed and variable resources (e.g. land, labor, credit, seeds, fertilizer, animals) necessary in the production process (Kahan, 2008). *Production processes* is a series of repeated steps that includes, for example, growth promotion, pest control, and management of mature trees. *Outputs* include both extractive products (e.g. cash crops, timber, carbon credits) and non-extractive value (e.g. improved soil health, fertilizer, cooling). Bierman et al.'s framework helps identify where non-state actors have a comparative advantage within these steps, as they argue non-state actors can intervene in *direct* (i.e., making decisions that change behavior) or *indirect* (i.e., influencing the decision of state actors) ways. Direct interventions occur outside of the state, while indirect interventions require the involvement of governments and therefore place non-state actors in an advisory role.

For our review, we draw on the definition of non-state actors by Arts (2003) as "all those actors that are not (representatives of) states." We identify three categories of non-state actors that emerged from our review: intergovernmental and non-governmental organizations (hereafter IGOs and NGOs), academic institutions, and private industry. This typology is then used to link direct and indirect action to relevant non-state actor categories based on our synthesis. The categories of non-state actors are not comprehensive, and omission does not mean the non-state actor is irrelevant or unable to take action, but that other types of non-state actors did not emerge in our review.

Importantly, applying these conceptual frameworks and lenses to our review of the agroforestry system presents an important advance, as research has largely focused on a single component of the system, such as tenure security (Borelli et al., 2019; Coleman, 2019; Otsuka et al., 2000; Robinson et al., 2018), input supply constraints (Cornelius and Miccolis, 2018; Graudal and Lillesø, 2007; Lillesø et al., 2011), and compensation for environmental services (Cole, 2010; Marais et al., 2019; Minang et al., 2014; Rosenstock et al., 2019). Yet the sustainable and wide-scale adoption of agroforestry by smallholder agricultural households depends on a functioning input, production, and output chain.

## 3. Market failures and solutions in the three stages of agroforestry systems

### 3.1. Stage 1: inputs

Agroforestry input constraints can be characterized into three main types: common property (Borelli et al., 2019; Otsuka et al., 2000), capital market distortions (Chavan et al., 2015; Dorward et al., 2009); and asymmetric information (one side of a transaction lacks information) and transaction costs associated with key inputs like seeds (Cornelius and Miccolis, 2018; Lillesø et al., 2018, 2011). Interventions designed to affect input constraints often attempt to address price or delivery of inputs to farms (Ellis, 1992). Table 1 provides an overview of market failures, policy mechanisms to address each failure, and whether non-state actors are best suited to take direct or indirect actions to address the market failure.

**Table 1**
Non-state actor policy interventions to address market failures in the input stage.

| Market failure | Policy mechanisms | Type of intervention | | Non-state actor categories | | |
|---|---|---|---|---|---|---|
| | | Direct | Indirect | IGOs and NGOs | Academic institutions | Private industry |
| Common property: Lack of land tenure security limits long-term land investments (Borelli et al., 2019; Jarrett et al., 2017; Kang and Akinnifesi, 2000; Place et al., 2012; Russell and Franzel, 2004). | Formalize rights of smallholders (FAO, 2017; Place et al., 2012). | | ✓ | ✓ | | |
| | Create a public landholding registry and reconcile overlapping tenure claims (Robinson et al., 2018). | | ✓ | ✓ | | |
| | Increase monitoring and evaluation of tenure governance (Borelli et al., 2019; Robinson et al., 2018). | ✓ | | ✓ | | |
| | Build local capacity and respond to the needs of marginalized groups (Borelli et al., 2019; Coleman, 2019; Robinson et al., 2018). | ✓ | ✓ | ✓ | | |
| Distortions in the Capital Markets: lack of access to credit to reduce risks and smooth income (Chavan et al., 2015; Dorward et al., 2009; FAO, 2017; Leakey et al., 2007). | Extend government agricultural support to agroforestry, including lower interest rates ( Callo-Concha et al., 2017). | | ✓ | ✓ | | |
| | Provide international finance through local intermediaries like microfinance institutions ( Gromko and Calo, 2017) | ✓ | | ✓ | | ✓ |
| | Provide support for farmers associations that have greater market power (Dorward et al., 2009). | ✓ | | ✓ | | |
| Information asymmetries & transaction costs: quality is a hidden attribute of seeds/seedlings that limits a consumer's ability to distinguish between high and low quality ( Cornelius and Miccolis, 2018; Lillesø et al., 2018; Place et al., 2012). | Informal quality certification system (Maredia et al., 2019; Nyoka et al., 2011). | ✓ | ✓ | | | ✓ |
| | Support entrepreneurs through the development of quality seed sources (Leakey et al., 2007; Lillesø et al., 2011; Place et al., 2012). | ✓ | | ✓ | ✓ | |
| | Participatory domestication programs to develop genetically improved species of indigenous plants (Jamnadass et al., 2019) | ✓ | | ✓ | | |

### 3.1.1. *Common property: land tenure insecurity*

Land tenure security is widely considered a foundational enabling condition for smallholder adoption because it can incentivize long-term land investment, such as planting trees (Borelli et al., 2019; FAO, 2017; Jarrett et al., 2017; Kang and Akinnifesi, 2000; Place et al., 2012; Russell and Franzel, 2004). Land tenure security is such an important element for agroforestry programs that a manual on tenure and agroforestry by the FAO and the International Centre for Research in Agroforestry (ICRAF) states, "there are few agroforestry success stories in an uncertain land tenure context" (Borelli et al., 2019, p. 2). An exhaustive list of tenure related barriers and policy solutions is beyond the scope of this paper, although recent reviews have highlighted interventions directly and indirectly related to agroforestry adoption (Miller et al., 2019; Tseng et al., 2020). We focus on solutions associated with two broad sources of tenure insecurity: (1) substance of rights (what property rights exist?) and (2) assurance of rights (how likely is it that property rights will be upheld and enforced?) (Robinson et al., 2018; Sjaastad and Bromley, 2000). This distinction is useful because non-state actors can play a direct role in the assurance of rights, while being limited to an indirect role on the substance of rights.

The substance of rights can be broadly defined as the statutory or customary rights to land ownership - in other words, rights have substance if the right exists for the landholder (Robinson et al., 2018). In 2012, an estimated 70% of land in LMICs lacked statutory rights (Borelli et al., 2019). While security can exist under informal or customary systems, the process of formalizing rights of smallholders can, under the right conditions, increase the incentives for longer term land investments (FAO, 2017; Place et al., 2012). Importantly, non-state actors are often limited to indirectly affecting statutory rights, usually through advising on existing policies or advocating for policy changes.

There are several examples of non-state actors successfully advocating for statutory rights for smallholder farmers, such as through titling reform, (i.e., granting of formal rights to land). For example, the World Wildlife Fund created an enabling policy environment for 1996 legislation in Namibia that granted rights to wildlife on communal lands through media, policy briefs, collaboration with local universities, and supportive economic data (Jones, 2010). While titling can lead to long-term land investments, non-state actors should be aware that the process presents its own set of challenges including the risk of formalizing the exclusion of marginalized groups, increasing conflict within or between communities, and the inability to reach a common understanding between all parties (Coleman, 2019). Furthermore, titling does not always lead to sustainable outcomes when, for instance, farmers respond to increased land values by removing trees to increase crop coverage (Otsuka et al., 2000).

In cases where titling reform is unlikely or the outcomes are uncertain, non-state actors can focus on areas where land tenure security exists but does not lead to long-term investments because farmers lack assurance of rights - that is, the expectation that rights will be enforced or upheld. Non-state actors can take indirect action to improve assurance through, for instance, advising governments on monitoring and evaluation of existing enforcement systems, assisting in creating publicly available land registries, or by strengthening customary institutions (Robinson et al., 2018). Non-state actors with close connections to local communities can also play a direct role as both an educator on land rights and a liaison to government officials (Naughton-Treves and Day, 2012). In the case of customary land tenure, non-state actors can facilitate dialogue within or between communities to resolve disputes and increase assurance (Borelli et al., 2019). While there is wide agreement that land tenure security should be a policy priority to achieve greater agroforestry adoption, any efforts to increase security should carefully examine risks of unintended social or environmental damages (Borelli et al., 2019; FAO, 2017; Jarrett et al., 2017; Kang and Akinnifesi, 2000; Masuda et al., 2020; Place et al., 2012; Tseng et al., 2020). The need to respond to local communities provides a logical entry point for non-state actors to advocate for marginalized groups that often lack political power.

In addition to the rights to the land, agroforestry programs must also

consider tree tenure - that is, the rights to own trees and their products (Nair, 1993). Regulatory barriers to tree tenure include public ownership of trees by the state, prohibitions on the harvesting of timber or tree products, or permits that are out of reach for the rural poor (Borelli et al., 2019). In some cases, state ownership is the result of traditional practices that view trees as communal property (Kant and Lehrer, 2005). Other tree tenure regulations can be imposed in reaction to rising deforestation, which can have unintended consequences like driving farmers into woodlands for fuelwood instead of planting supply (Place et al., 2012). ICRAF has been successful in negotiating with policymakers on forest laws in Indonesia that aim to provide stronger rights to rural farmers and indigenous groups (Colchester et al., 2005). Here, non-state actors can provide valuable legal insights and an understanding of local communities to advocate for reforms.

#### 3.1.2. Distortions in capital markets: lack of access to credit

Lack of access to credit is a persistent challenge for the livelihood of smallholder farmers in LMICs (Von Pischke et al., 1983). Credit plays a crucial role in the uptake of innovations like agroforestry that can increase productivity among smallholder farmers (Foster and Rosenzweig, 2010; Magruder, 2018; Mwangi and Kariuki, 2015) and is particularly important in this context because of the opportunity costs associated with converting cropland to agroforestry systems while trees mature (Kang and Akinnifesi, 2000). Credit allows smallholder farmers to smooth consumption by offsetting costs in the gestation period before financial benefits from outputs are realized (e.g., tree products, reduction of fertilizer and pesticide use) (Ruben and Clercx, 2003). A primary barrier is that both potential borrowers, creditors, and investors lack critical information necessary to make informed decisions, which ultimately depresses the availability and demand for credit. Lenders often lack information about potential borrowers, thus making it challenging to assess risk which can lead to high interest rates that smallholders are unable to repay (Besley, 1994). Furthermore, investors lack information on complementary activities like insurance and enforcement of property rights, which can lead to a cycle of underinvestment (Dorward et al., 2009). Borrowers also often lack information about access to credit due to a lack of institutional support for agroforestry in agricultural policy (Rahman et al., 2008).

Further, many existing government policies that promote access to rural credit specifically target crops (Buttoud, 2013) or monoculture tree plantations (Place et al., 2012). For example, with the rapid growth in the demand for palm oil, a Malaysian government agency provided fertilizer on credit to smallholders that is deducted from income on fruit delivered to specified mills (Cramb et al., 2017). In effect, this subsidy incentivized monoculture rather than multi-species production because the former requires greater nutrient inputs (Liu et al., 2018). Monoculture tree plantations have been linked to lower soil productivity, increased pests and diseases, vulnerability to wildfires and storms, and social tensions due to encroachment of large private landholders on smallholder farms (Liu et al., 2018). Constraints on credit can therefore have undesirable cascading effects. By contrast, when palm oil is integrated into a diverse agroforestry system it can provide a range of economic and environmental benefits (Bhagwat and Willis, 2008). In the Malaysian case, the government program could be reformed to provide farmer training or financial support for local seed dealers instead of fertilizer on credit to overcome the monoculture bias. Governments can also establish low interest rates (Callo-Concha et al., 2017) and credit programs designed specifically for agroforestry (Rahman et al., 2008). Non-state actors can elevate the economic potential of reforms by supporting diverse grassroots coalitions, or through an advisory role with national governments. In India, ICRAF advised the national government on programs including credit, extension, and market information systems specifically designed for agroforestry (Chavan et al., 2015).

There are cases in which the macroeconomic context makes interest rates out of reach for smallholder farmers (Follis and Nair, 1994). In these cases, non-state actors' close connection to local communities can help to directly channel informal or international sources of credit. In Cameroon, for example, farmer's associations have played an important role in providing informal credit for agroforestry systems (Molua, 2005). Non-state actors can play a role in working within local communities to develop and support farmer's associations (Dorward et al., 2009). While international credit is a potential solution, large impact investors are often discouraged by transaction costs and minimum investment levels. A report in Costa Rica, for example, highlighted a potential solution to these limitations through microfinance aimed at smallholder agroforestry projects (Gromko and Calo, 2017).

#### 3.1.3. Information asymmetries & transaction costs: farmers and seed dealers lack information and conditions required for a functioning market

In order to achieve higher rates of adoption, farmers must be convinced of potential livelihood benefits from agroforestry (Dawson et al., 2011). Several frameworks for behavior change interventions exist (e.g., (Reddy et al., 2017)), but here we focus on three specific barriers highlighted in the literature around quality seed inputs that have hindered widespread agroforestry adoption (Bernard et al., 2019; Cornelius and Miccolis, 2018; Graudal and Lillesø, 2007; Nyoka et al., 2011; Place et al., 2012). These include: (1) asymmetric information that lowers farmer's willingness to pay because farmers are unable to determine the quality of seeds or seedlings, (2) high transportation costs associated with supplying seeds to rural smallholders (Cornelius and Miccolis, 2018), and (3) low economies of scale from fewer seeds demanded for a perennial product (Graudal and Lillesø, 2007).

The focus on high quality genetic material, or germplasm, is important due to its role in providing farmers with the promoted benefits of agroforestry adoption, such as commercially viable tree products, animal fodder, and natural fertilizer. For instance, in the northern states of India, higher economic returns from quality poplar germplasm developed in collaboration between an agriculture supply company and Indian universities was critical in the widespread adoption of agroforestry systems among smallholder wheat and rice farmers (Chavan et al., 2015; Dhillon et al., 2013). This example highlights many roles non-state actors can play in reducing information asymmetries. Non-state actors may work with state actors to develop quality seed sources (Leakey et al., 2007; Lillesø et al., 2011; Place et al., 2012). As the example of India's Poplar trees demonstrates, collaboration between academia and the private sector on the development of new and improved species of germplasm can produce quality germplasm that increases farmers' interest in agroforestry. Non-state actors can also partner directly with local communities to develop native seed sources. For example, ICRAFs participatory domestication programs in Cameroon work with local communities using simplified breeding practices applied to a wide range of indigenous tree species including the pygeum (*Prunus Africana*) valued for its medicinal uses and allanblackia (*Allanblackia*) domesticated for edible oil (Jamnadass et al., 2019). Survey results found positive association between the ICRAF domestication programs and livelihood benefits and sustained adoption among participants (Tchoundjeu et al., 2010).

Another possible solution to overcome asymmetric information is to establish quality standards and monitoring (Lillesø et al., 2018). Nyoka et al. (2011) recommend applying an informal quality certification system developed by the Food and Agriculture Organization (FAO) for staple crops in which seed dealers rather than government certified agencies certify the quality of the seeds, as the latter is often difficult to implement and can drive prices out of reach for smallholders. A similar quality certification system in Tanzania and Ghana demonstrated a higher willingness to pay for certified crop seed (Maredia et al., 2019). Informal quality certification systems also allow non-state actors to provide services to seed dealers in the absence of government capacity for a formal program. Although not directly related to agroforestry, at a global scale the Forest Stewardship Council certification of sustainable forestry practices has successfully influenced rhetoric, laws, and enforcement on sustainable forestry (Sundstrom and Henry, 2017) and

may serve as a case study.

Finally, a common intervention is for state or non-state actors to provide seeds directly to farmers at no cost (Place et al., 2012), although there is considerable debate about the effects of direct supply interventions. Lillesø et al. (2018) argue that government or NGO distribution crowds out seed and seedling entrepreneurs, while Cornelius and Miccolis (2018) argue that there are cases in which market constraints are strong enough to require government provision of seeds. A report synthesizing 50 years of experience supporting tree seed supply (Graudal and Lillesø, 2007) recommended state actors develop guidelines and supportive regulatory frameworks, while non-state actors provide training for entrepreneurs, establish trade associations and breeding programs, and manage gene conservation.

### 3.2. Stage 2: production processes

The components of agroforestry (animals, crops, and trees) can be combined in a wide range of production processes. The three categories adopted by the FAO are agrisilviculture (trees combined with crops), silvopastoral (trees combined with animals), and agrosilvopastoral (trees, animals, and crops) (FAO, 2015). Unlike the input and output stages which describe a transaction or series of transactions, the production stage takes place over the course of many years. The longer timeframe of the production stage is linked to market failures that are easily overlooked by state and non-state actors alike (Table 2).

#### 3.2.1. Information asymmetries: knowledge requirements

Knowledge requirements are a critical barrier for smallholder farmers (Cornelius and Miccolis, 2018; FAO, 2017; Place et al., 2012). Many agroforestry techniques tend to be knowledge intensive (Matocha et al., 2012), and trees grown for extractive outputs often require specialized training (Russell and Franzel, 2004). State and non-state actors can help farmers overcome knowledge barriers by directly providing information and education through local agents (Arvola et al., 2020; Place et al., 2012). A study on the dissemination of agricultural innovations in Sub-Saharan Africa emphasized the need for simplicity in innovations to achieve higher adoption (Macours, 2019). Interventions should balance the trade-offs of systems that provide increased benefits but demand higher skill level requirements compared to systems that may have fewer benefits but can achieve wider adoption with fewer knowledge requirements. For example, research conducted by universities in Sri Lanka on multilayered tree gardens identified local farmers' preference for including upper canopy timber trees that informed tree pruning interventions to improve productivity within existing practices (Sinclair and Walker, 1998). As this example demonstrates, balancing trade-offs often requires highly localized knowledge and awareness of systems that may exist within local cultures. Working within communities, non-state actors can formalize existing knowledge that increases likelihood of adoption (Coe et al., 2014). For instance, a review of agroforestry projects in Bolivia revealed that projects in which indigenous knowledge was integrated with outside knowledge resulted in greater outcomes for ecosystem services and climate change adaptation (Jacobi et al., 2017). A study in the Sahelian region of West Africa found that membership in community-based organizations that develop skills and disseminate management best-practices was a significant factor in agroforestry adoption (Binam et al., 2017). Recognizing the benefits of integrating communities into agroforestry projects, ICRAF works with local stakeholders in an approach known as "nested communities of practice" that is being used in East Africa (Winowiecki and Sinclair, 2020). In tribal districts of Western India, NGOs have successfully increased adoption of agroforestry through women's self-help groups that included low-cost inputs and training for nursery raising and grafting (Bose, 2015).

#### 3.2.2. Information asymmetries: risk and discounting

The long time horizon for trees to mature and produce benefits poses a significant barrier to adoption. Farmers often choose not to invest because of the risks associated with a long growth period (Arvola et al., 2020; Kang and Akinnifesi, 2000; Rahman et al., 2008) and preference for near term benefits (Hosier, 1989). Public and NGO investment in research and dissemination of information about the benefits and risks of agroforestry practices can aid in overcoming risk aversion and incentivize adoption (Arvola et al., 2020; Place et al., 2012), especially if the information is location specific and actionable (Geertsema et al., 2016). As discussed in the input stage, access to credit can smooth consumption over a longer period of time and reduce associated risks (Benjamin and Buchenrieder, 2016). Credit can constitute its own set of risks for smallholder borrowers, especially with distant lenders without

**Table 2**
Non-state actor policy interventions to address market failures in the production stage.

| Market failure | Policy mechanisms | Type of intervention | | Non-state actor categories | | |
|---|---|---|---|---|---|---|
| | | Direct | Indirect | IGOs and NGOs | Academic institutions | Private industry |
| Information asymmetries: knowledge requirements for agroforestry create barriers to entry (Cornelius and Miccolis, 2018; FAO, 2017; Place et al., 2012). | Build on local knowledge to promote systems that balance higher benefits with simple knowledge requirements (Coe et al., 2014; Jacobi et al., 2017). | ✓ | | ✓ | | |
| | Develop systems that are simple and easy to adopt ( Macours, 2019). | ✓ | | ✓ | ✓ | ✓ |
| Information asymmetries: farmers choose not to invest because of risks and discounting associated with a long time horizons to realize benefits (Arvola et al., 2020; Kang and Akinnifesi, 2000; Rahman et al., 2008). | Conduct research and dissemination of actionable knowledge in local contexts (Geertsema et al., 2016; Place et al., 2012). | ✓ | | ✓ | ✓ | |
| | Increase access to credit to provide consumption smoothing (Benjamin and Buchenrieder, 2016). | ✓ | | ✓ | | ✓ |
| | Promote fast-growing tree species (Kronick, 1984; Lillesø et al., 2018). | ✓ | | ✓ | ✓ | ✓ |
| | Establish supportive institutions for agroforestry akin to staple crops (e.g., insurance, research, extension, loans, support prices, tax concessions) (Callo-Concha et al., 2017; Lambert et al., 2012; Rahman et al., 2008). | | ✓ | ✓ | | |
| Policy failure: lack of ongoing support for farmers to ensure long-term success (Cole, 2010; Kant and Lehrer, 2005). | Use longer-term funding sources to maintain longevity and consistency of implementation activities (Borgström et al., 2016). | ✓ | ✓ | ✓ | | |
| | Develop local institutions that will maximize the likelihood of sustainability (Cole, 2010; Scherr, 1992). | ✓ | | ✓ | | |

social ties to the community (Chauke et al., 2013). Another way to reduce risk is to research and promote tree species that are fast growing (Kronick, 1984; Lillesø et al., 2018), although trade-offs with other beneficial traits that provide higher value outputs and ecosystem services should be considered.

Existing government policies can also profoundly increase perceptions of risk. For instance, government subsidies that exclude agroforestry can lead to high perceptions of risk because farmers bear all the risk of adopting new practices (Jacobson and Ham, 2019). Farmers will perceive lower risks of agroforestry adoption with increased support from government institutions akin to those commonly provided to staple crops (e.g. insurance, research, extension, loans, support prices, tax concessions) (Callo-Concha et al., 2017; Rahman et al., 2008). A study in southeast Nigeria found that extending interventions typically targeted at staple crops, such as access to credit and regular contact from an extension agent, were associated with higher rates of agroforestry adoption (Lambert et al., 2012). While reforming monoculture institutions is limited to government intervention, non-state actors can play an important role in advocating for agroforestry as a tool that can achieve similar goals of soil fertility and farm productivity, while also providing environmental co-benefits.

#### 3.2.3. Policy failure: short-term funding and management

Long-term, consistent institutional backing can provide needed support throughout the lifetime of agroforestry projects (Cole, 2010; Kant and Lehrer, 2005), as interventions focused on ecosystem co-benefits typically require longer term management to be successful (Borgström et al., 2016). The short-term focus of project managers driven by funding concerns has been shown to lead to declines in adoption (Jacobson and Ham, 2019). Non-state actors should communicate the long timelines of agroforestry projects to their donors, and commit to long-term projects in local communities. International funding through the Green Climate Fund (GCF) is focused on long-term sustainability and could provide a more stable source of funding for agroforestry projects and investments (GCF, 2020). Non-state actors can also support the development of local institutions that will maximize the likelihood of long-term viability (Cole, 2010; Scherr, 1992), where institutional structures, capacity, and other factors are developed to create resilient institutions that last long after non-state actors disengage from an area.

### 3.3. Stage 3: outputs

Early research and investment into agroforestry was largely the domain of forestry and focused on export products like teak (Nair, 1993). Since then, agroforestry *outputs* have become a development-driven goal, shown to increase crop diversification and decrease volatilities (Pratiwi and Suzuki, 2019). Direct economic benefits are recognized as an essential condition to increase adoption of sustainable agricultural practices (Piñeiro et al., 2020). In addition to traditional outputs such as tree fruits, timber, and rubber, this section also considers the market failures associated with non-extractive outputs (e.g., carbon storage). Table 3 provides an overview of the market failures associated with the output stage along with a range of non-state actor interventions.

#### 3.3.1. Policy failure: regulatory barriers

Legalizing the removal of forest resources is a difficult undertaking that can have unintended consequences. In Brazil, federal law regulates the 53% of the Brazilian Amazon that is privately owned, but adherence has been low due to weak enforcement and the profitability of other land uses (Miccolis et al., 2019; Santiago et al., 2018). A 2012 revision to the forest law included more lenient preservation requirements that allowed for agroforestry on forest land if native species were incorporated, but whether the revisions have led to declines in deforestation or increases in reforestation remains unclear (Miccolis et al., 2019). Recent spikes in deforestation largely due to agricultural expansion point to the importance of political will to ensure that lighter regulations do not lead to declines in conservation (Sax, 2019). In the absence of strong national support for sustainable agriculture, non-state actors can work within local communities to increase adoption through information on agroforestry techniques that can provide private benefits to farmers (Tremblay et al., 2015). For example, Brazilian farmers noted the influences of Ernst Götsch, a researcher and farmer, for applying successional

**Table 3**
Non-state actor policy interventions to address market failures in the output stage.

| Market failure | Policy mechanisms | Type of intervention | | Non-state actor categories | | |
|---|---|---|---|---|---|---|
| | | Direct | Indirect | IGOs and NGOs | Academic institutions | Private industry |
| Policy failure: regulatory barriers restrict agroforestry practice (Borelli et al., 2019; Place et al., 2012; Russell and Franzel, 2004). | Adapt laws to allow for the marketing of agroforestry products (Borelli et al., 2019; Place et al., 2012; Russell and Franzel, 2004). | | ✓ | ✓ | | |
| Information asymmetries: pricing and lack of market power leads to opportunistic middlemen and low returns for farmers (Russell and Franzel, 2004); and limited access to marketing opportunities (Cornelius and Miccolis, 2018; Kant and Lehrer, 2005; Leakey et al., 2007; Russell and Franzel, 2004). | Increase capacity through farmers associations that can provide administrative and management services ( Arvola et al., 2020; Russell and Franzel, 2004; Shiferaw et al., 2011) | ✓ | | ✓ | | |
| | Promote market information systems through mobile phones (Ogutu et al., 2014; Russell and Franzel, 2004). | ✓ | | ✓ | | ✓ |
| | Develop public-private partnerships and grow markets for agroforestry products (Graudal and Lillesø, 2007; Jarrett et al., 2017; Leakey et al., 2007). | ✓ | | ✓ | | ✓ |
| | Create facilitative institutions that create linkages between smallholder farmers and agribusinesses ( Russell and Franzel, 2004). | ✓ | | ✓ | | ✓ |
| | Support centralized sources of supply, information, and marketing (Leakey et al., 2007). | ✓ | | ✓ | | ✓ |
| Positive externalities: uncompensated benefits of environmental services (Godsey et al., 2015; Haile et al., 2019; Place et al., 2012). | Communicate local environmental services to farmers to increase value perception (Marais et al., 2019). | ✓ | | ✓ | ✓ | |
| | Develop payment for environmental services pathways (Haile et al., 2019; Matocha et al., 2012). | ✓ | | ✓ | | |
| | Include agroforestry as a strategy in domestic REDD+ efforts to reduce deforestation (Minang et al., 2014). | ✓ | | | | ✓ |

planting of a mix of nutrient fixing trees with short cycle crops to restore degraded lands (Miccolis et al., 2019).

There are also examples of deeper engagements where non-state actors have played a pivotal role in shaping policy and laws in support of agroforestry systems. For example, ICRAF played an important advisory role throughout the development and passage of India's National Agroforestry Policy (NAP) (Pal Singh et al., 2016). The landmark policy is implemented by the Ministry of Agriculture with the goal of overcoming barriers to adoption (Dhyani, 2014) and mainstreaming agroforestry in the agricultural sector (Pinjarkar, 2014). In addition to simplified regulations for harvesting and transport of agroforestry products, the policy holistically addressed market failures and policy constraints in all three stages, including institutional credit and insurance, creation of a national level agency to promote and manage agroforestry, and improvements to land records for stronger land tenure security (Chavan et al., 2015). The NAP is a first of its kind policy and could be a future model for other countries, and provides a case where non-state actors, along with others, played a pivotal advisory role in the formation of policy.

#### 3.3.2. *Information asymmetries: pricing and limited access to markets*

Agroforestry among smallholders is often characterized by low volumes of trade and limited access to information on pricing, leaving farmers at the mercy of opportunistic middlemen (Russell and Franzel, 2004). In these cases, farmer associations can provide administrative and management services, as well as higher volumes of trade for increased market power (Arvola et al., 2020; Russell and Franzel, 2004; Shiferaw et al., 2011). A contemporary tool to overcome asymmetric information is the use of mobile phones by smallholders to receive updates on market pricing (Russell and Franzel, 2004) at lower costs (Ogutu et al., 2014). Non-state actors can facilitate access to mobile phones, subsidize mobile phone credits, link buyers and farmers directly, or in general help overcome barriers to information asymmetries using existing well-established and familiar technologies.

Another well-documented constraint is the lack of marketing opportunities and institutional support for tree products produced by smallholder farmers (Kang and Akinnifesi, 2000; Leakey et al., 2007; Lillesø et al., 2011; Place et al., 2012; Steppler and Nair, 1987). Public-private partnerships can provide a direct connection between farmers and large international or regional companies (Graudal and Lillesø, 2007; Jarrett et al., 2017). Daimler-Benz, for example, sources raw materials for its C-class cars from smallholder agroforestry in Brazil (Leakey et al., 2007). Non-state actors can also play an important role in facilitating the linkages between farmers and local businesses without providing services directly to avoid crowd-out effects. This can be done through physical centers and workshops in rural areas that provide information on how to successfully commercialize agroforestry products (Russell and Franzel, 2004). Non-state actors can also provide support for commercial enterprises that combine input supply with output processing, which can offer farmers a centralized source of supply, information, and marketing (Leakey et al., 2007). Holistic support for farmers that provides knowledge needed at each stage of the supply chain that incorporates local knowledge can also provide reassurance for farmers that perceive high risk in converting cropland to agroforestry.

#### 3.3.3. *Externalities: uncompensated benefits of environmental services*

Agroforestry systems produce a wide range of environmental services that extend beyond the farm. Most smallholder farmers are uncompensated for these positive externalities leading to a quantity of agroforestry that is below the socially optimal level (Godsey et al., 2015; Haile et al., 2019). A potentially low-cost intervention by non-state actors is to increase perceived private value of agroforestry through knowledge sharing on benefits of fertilizer replacement, income diversification, and resilience to extreme weather conditions (Marais et al., 2019).

Non-state actors can also aid in supporting payment for ecosystem services (PES) programs, which can provide payments to farmers in exchange for the ecosystem and climate change mitigation services (Benjamin et al., 2018). PES programs are designed around compensating farmers for the uncompensated positive externalities, and the myriad of public benefits provided by agroforestry systems at regional (water quality, soil health, adaptation) and global (biodiversity, carbon sequestration) scales. For instance, Reducing Emissions from Deforestation and Forest Degradation Plus (REDD+) is a mechanism created by the UNFCCC through which countries can receive PES and support local agroforestry programs. While not considered forests under REDD+, agroforestry systems are recognized as a complementary strategy and part of broader initiatives to address agricultural impact on deforestation (Minang et al., 2014). In Brazil, the government pays farmers for reforestation or agroforestry through the Amazon Fund, established in 2008 as part of Brazil's domestic REDD+ policy that raises funds internationally for restoration projects in the Amazon (Amazon Fund, 2013). Despite the large funding inflows, there is evidence that without ongoing institutional support, connection to on-the-ground implementation is weak (Pinsky et al., 2019). The funding mechanism is further constrained by the dismantling of governance committees of the Amazon Fund by the federal government (What is the Amazon Fund? [WWW Document], 2019). Here, non-state actors can support links between broader funding streams to develop institutions and systems to support implementation, funding to farmers, and other avenues that ensure positive externalities are compensated.

Non-state actors can also play an important role in directly financing agroforestry programs. There are a wide range of new financial instruments that are connecting investors interested in natural capital and smallholders that can provide environmental services (TNC, 2019). For example, Forest and Landscape Restoration receives multilateral funding, but has also increasingly drawn capital from private equity firms seeking to make impact investments in programs such as agroforestry (Liagre, 2015). Further, non-state actors can aid in linking farmers to both carbon markets and programs of the GCF. The carbon sequestered in agroforestry systems along with the wide range of ecosystem services are areas in which there is a growing market that can compensate farmers for the positive externalities (Atangana et al., 2014).

## 4. Discussion

Our critical review of the literature indicates non-state actors can play *direct* and *indirect* roles in catalyzing or supporting agroforestry adoption among smallholder farmers in LMICs, filling a unique gap that state actors may be unable to address at scale. We found that market failures within the three stages of the agroforestry system hindering adoption by smallholder farmers can broadly be categorized into issues stemming from common property, information asymmetry, uncompensated positive externalities, distortions in capital markets hindering sufficient credit, and market failures stemming from existing regulatory barriers. These market failures are also not independent, as each type of market failure can create multiple barriers to agroforestry adoption within and across each stage of the agroforestry system.

While agroforestry systems are complex and vary by context, our review suggests there are a wide range of opportunities for direct intervention by non-state actors. This is especially true in the production and output stages, which are less dependent on changes in the legal or regulatory environment to reduce barriers to agroforestry adoption, and are instead focused on the production of agroforestry products, including non-extractive benefits in the form of ecosystem services. We find differentiation between the role of the state and non-state actors, with fewer instances of both *direct* and *indirect* opportunities for intervention in the analysis. Consistent throughout all stages, we see that non-state actors have a comparative advantage to centralized state intervention of proximity to communities in which they work, as well as institutional knowledge where they may serve as a bridge between state and non-state actors to address market failures. A key hindrance of non-

state actors, however, is that they may not have the resources to be consistently engaged with smallholder farmers given funding constraints, organizational or institutional priorities, or other factors. While this analysis has highlighted *direct* intervention of non-state actors, *indirect* opportunities for addressing market failures can complement state efforts. The three policy guides previously mentioned (Bernard et al., 2019; Buttoud, 2013; Place et al., 2012) provide comprehensive recommendations for state actors, such as national governments, and our own review highlights instances where non-state actors may work with state actors in an advisory role or through complementary activities.

Realizing widespread adoption of agroforestry among smallholders that practice monoculture presents opportunities to address climate change, sustainable development, and biodiversity conservation goals. But the potential benefits permeate across spatial scales: agroforestry can provide a range of benefits to farmers (e.g., income diversification, increased crop yields, input substitution), local communities (e.g., soil enrichment, increased water quality, adaptation to a warming climate), and and beyond through global ecosystem services (e.g., habitat refugia for biodiversity conservation, carbon sequestration for countries aiming to achieve their nationally determined contributions to the Paris Climate Agreement). Recognizing and accounting for benefits at all scales is important for broader adoption, and can serve as a means to motivate policies that support agroforestry programs. For instance, the potential for agroforestry systems to store carbon speak to multiple audiences. At a national level, countries such as India have recognized that increasing agroforestry as part of their reforestation efforts is the only feasible pathway to achieve the goal of 33% forest coverage due to land pressures from a large and growing population (Dhyani, 2014). Globally, confining tree planting to uninhabited areas limits reforestation efforts to 11% of global area available for reforestation and does not provide local communities with ecosystem, biodiversity, and socio-economic benefits (Erbaugh et al., 2020). Thus, meeting global reforestation and restoration targets likely will require practices such as agroforestry.

A comprehensive review of agricultural practices found that agroforestry was the least evaluated program type (Piñeiro et al., 2020). While our review examined both the peer-reviewed and grey literature, our analysis is limited to documented market failures and interventions and thus does not include innovative efforts that are ongoing and remain undocumented. This literature is expanding with articles covering the linkage between agroforestry adoption and community-based forest management (Laichena, 2021), farmer organizations and commercialization of wood products (Hintz et al., 2021), the proposed application of an Agroforestry Accounting System (Campos et al., 2021), and land tenure reform on the shifting of forest management to communities (Trejos and Flores, 2021). Although we attempted to include studies from a variety of regions, India and Brazil are overrepresented in our review, and thus warrants caution when generalizing specific cases to other countries. Additionally, our analysis begins with the assumption that non-state actors will be taking action where agroforestry provides net benefits to specific contexts, but as with any practice, there are documented cases where agroforestry adoption included trade-offs. In Kenya, for example, fast-growing tree species combined with maize on hillside farming consumed more water than if practiced separately (Jackson et al., 2000). Both state and non-state actors engaged in agroforestry programs should be mindful of whether the advocated agroforestry system is appropriate for the landscape and population. For instance, planting trees in native grasslands may have adverse effects on native species (Veldman et al., 2015). Further, the climate and biodiversity benefits of agroforestry are relative to monoculture crop systems, and are not assumed to be greater than forests or native tree plantations.

As interest in agroforestry systems for smallholder farmers continues to grow, state and non-state actors alike should work together to create incentives and environments that promote sustainable agroforestry systems where smallholder farmers are most likely to benefit. Our study outlines specific areas for direct and indirect action by non-state actors, and future research should work to evaluate, across a wider array of countries and contexts, models that can be replicated to address the myriad of market failures that hinder agroforestry adoption within its complex supply chain.

## Author contributions

Conceptualization: JB and YJM. Methodology: JB and YJM. Refining concepts and arguments: JB, DSB, SCCP, TK, JTS, NHW, and YJM. Writing - original draft: JB. Writing - Reviewing & Editing: JB, DSB, SCCP, TK, JTS, NHW, and YJM. Supervision: YJM.

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The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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