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Governing agriculture-forest landscapes to achieve climate change mitigation

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ABSTRACT

This introduction to the special section on "Governing Agriculture-Forest Landscapes to Achieve Climate Change Mitigation" reviews external interventions to improve forest conditions and reduce deforestation, and by extension, influence carbon storage in agriculture-forest landscapes. The review is based on a careful survey of 123 cases of project-based and policy interventions to influence land use and forest cover outcomes. We propose that outcomes of interventions can be explained in terms of rights, incentives, and technologies related to land use and apply this framework to examine 12 types of interventions in agriculture-forest landscapes. The analysis of the identified 123 cases raises concerns about consistency of data and comparability of cases. Our preliminary evidence suggests limited association between the stated objective of an intervention and its success. This evidence also suggests that smaller scale and effective enforcement may be positively associated with improved forest outcomes. But the effectiveness of interventions across different agriculture-forest landscapes varies and available evidence does not permit easy generalizations. The variable effects of interventions across different agriculture-forest landscapes point to the need to better understand the forms and functions of interventions and to problems associated with assessing their relative efficacy.

1. Introduction

This introduction to the special issue reviews policy and programmatic interventions[1] used in agriculture-forest landscapes to sequester carbon by reducing deforestation without adversely affecting other social and ecological outcomes related to livelihoods. Our review identifies 12 major types of interventions in such landscapes and presents a framework for analyzing them. The framework focuses on rights, incentives, and technologies related to land use. These three dimensions of interventions substantially affect actors' choices and outcomes in agriculture-forest landscapes. Together, the introduction and the papers in this special section advance the understanding of how to govern agriculture-forest landscapes to reduce deforestation and thereby improve climate change mitigation outcomes.

Climate change mitigation in terrestrial systems is necessary to avoid the worst effects of climate change and halting deforestation is argued to be one of the most cost effective mitigation measures globally (Foresight, 2011; Stern, 2006). Yet 73% of deforestation can be attributed to agriculture (Hosonuma et al., 2012) and deforestation is likely to continue with projected increases in food demand. Sixty percent more food production is estimated to be needed in 2050 compared to 2005/07 (Alexandratos and Bruinsma, 2012). While agricultural intensification can reduce pressures on forests at global scales (Vermeulen et al., 2011; Burney et al., 2010), at local scales intensification often drives further expansion. Improved governance is therefore necessary to "hold the boundary" and balance competing policy objectives of food production, economic development, climate change mitigation, and ecosystem conservation, (Ewers, 2006; Godfray et al., 2011; Newton et al., 2013). Understanding the effectiveness of governance interventions is thus essential to influence outcomes in agriculture-forest landscapes.

We define agriculture-forest landscapes as places where forests and agricultural land use coexist in a mosaic pattern. The boundary between forest and agriculture is fuzzy in space and time. In contrast to the notion of agriculture-forest landscapes as frontiers

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[1] For the purposes of this paper, we define an intervention as an externally structured effort to influence outcomes in a social–ecological system (Folke et al., 2005; Lebel et al., 2006). For a careful discussion, see Büscher (2013).

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(Bryant et al., 1997; Maertens et al., 2006), we emphasize the interspersed nature of agricultural and forest land uses, the potential for different kinds of land cover change, and the possibility that such mosaics may be durable rather than fleeting forms of land use. Whereas existing work on frontiers examines their characteristics (Fairhead and Leach, 1996; Rudel et al., 2002), the ebb and flow of agriculture in relation to forests (Angelsen, 2010; Morton et al., 2006), and the relationship of land cover change to specific factors such as migration, technology adoption, or road building (Rudel et al., 2002; Perz, 2003; Nepstad et al., 2001), the ensuing discussion is a comparative assessment of how external interventions shape agricultural and forest outcomes.

This overview paper addresses two questions: (1) Through what policy and programmatic interventions do agents such as government agencies, civil society organizations, donors, and corporate actors seek to avoid deforestation and sequester carbon while maintaining food security and livelihoods, and (2) What do we know about the effects of these different interventions? We investigate these questions through a review of 86 papers that provide empirical information on interventions in agriculture-forest landscapes, and a meta-analysis of 123 cases derived from these papers. Brief reviews of four in-depth studies of agriculture-forest interventions in the special section follow. These studies examine five of the twelve interventions, providing a situated analysis of how they function.

Our analytical approach, using information from the reviewed studies, suggests that agriculture-forest interventions can be mapped along three dimensions: rights (and institutions) that reflect social agreements, incentives and rewards, and technologies. Section 2 discusses how different interventions relate to rights, rewards, and technologies. Section 3 examines the relationships between features of interventions and their outcomes through a meta-analysis of reviewed papers. Section 4 summarizes the papers comprising the special section. The empirical evidence in Sections 2–4 points to the need to better understand the form and function of an intervention, coupling between interventions and outcomes, and problems with attributing impacts or assessing the relative efficacy of interventions.

2. Analyzing governance interventions in agriculture-forest landscapes

Managing agriculture-forest landscapes to reduce deforestation and sequester carbon is at its core about modifying and redirecting the effects of pressures for deforestation. The amount of carbon stored on a per hectare basis in the biomass and soils of tropical forests far exceeds the carbon in the biomass and soils of agricultural systems (Palm et al., 1999). Cultivated tree crops such as oil palm or rubber (which we treat as agricultural crops here), or rangelands can provide significant levels of carbon sequestration, but their contribution to carbon sequestration must be compared to carbon levels in the existing landscape (cf. Fox et al., this issue). Pressures for deforestation include timber harvesting and illegal logging (Ebeling and Yasué, 2009); fire (Nepstad et al., 1999); road building and settlement (Rudel, 2007); shifting cultivation (Styger et al., 2007); and conversion of forests to agricultural land (Godfray et al., 2011, Golden Agri-Resources, 2012, Green Bond and Principles, 2014, Kissinger, 2011, Kotto-Same et al., 1997) including for commodity crops, livestock, and biofuels (Kaimowitz et al., 1999; Romijn, 2011).

Interventions to counter land use changes are undertaken by land users, governments, civil society organizations and market actors. Our analysis of the identified studies suggests that such interventions are a mix of changes in: (a) resource rights to agricultural land and forests, often through policy and institutional changes reflecting sociopolitical choices; (b) incentives and rewards to change land use behavior, and (c) technological mechanisms, including those for agricultural intensification. Broadly speaking, these three major forms of influences embodied in interventions represent political, economic, and agronomic or agro-ecological logics. Other logics may also help characterize interventions in agriculture-forest landscapes, but we found that for the purposes of this paper, the three logics were adequate.

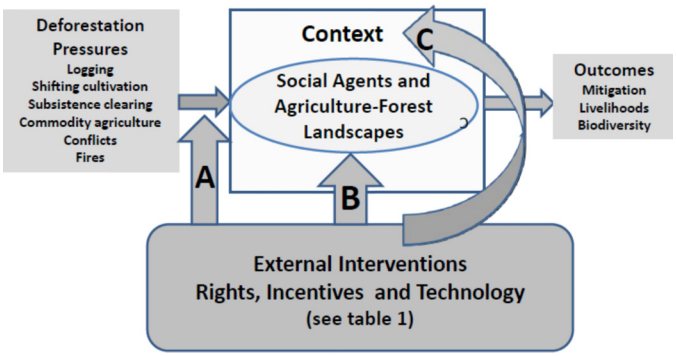

Fig. 1. Distal and proximate effects of external interventions in agriculture-forest landscapes.

Fig. 1 represents the conceptual relationships among deforestation pressures, contextual features, and forest outcomes as influenced by external interventions. The thin, horizontal arrows represent how deforestation pressures, landscapes, their context, and outcomes are connected in the absence of external interventions. Deforestation pressures may be direct, such as logging, fires, and conversion for agricultural uses or for ranching. Or, they may manifest themselves by influencing the incentives related to activities that lead to deforestation: e.g., through road building, conflicts, violence, and changes in relative prices of agricultural and forest sector commodities (see Geist and Lambin, 2002).

The three vertical arrows (A–C) represent interactions between external interventions and deforestation pressures. Some interventions attempt to directly curtail deforestation pressures (arrow A). Logging bans, fire management, tree planting/reforestation, and agricultural intensification are examples. Other interventions (arrow B) seek to influence agents in landscapes. Among them, we include rewards or incentives to decision makers and practitioners, tenure reforms in the forestry and agriculture sector, protected and CBNRM area creation, incentives to producers, and zoning of lands to restrict agriculture, grazing, or harvesting activities. These interventions redefine social agreements or agents' incentives (or both) and thereby attempt to influence social and ecological outcomes. Finally, macro-level changes in forest and agriculture policies, product supply chains, and national standards and voluntary certification schemes are more distal ways to influence agent behaviors and trajectories of land use (curved arrow C). The key question for reducing deforestation is therefore how to deploy interventions embodying changes in rights, incentives, and technologies to yield more positive results.

Producers, governments, NGOs, donors, and market actors have used a range of mechanisms to affect land use and land cover change. Table 1 presents a classification of interventions based on the causal relationships they target and their focus on rights, incentives, or technology. We list 12 major intervention types, and identify how they seek to counter deforestation pressures, their key focus/constitutive influence dimension, and the number of cases encountered. The subsequent discussion briefly introduces the interventions; a comprehensive treatment is beyond the scope of this paper.

Table 1
Summary table for mitigation interventions.

Agriculture-forest landscape interventions	Target of intervention	Key constitutive influences	Number of cases
Fire management	Directly counter deforestation	Technology	3
Logging bans	Directly counter deforestation	Rights	5
Tree planting	Directly counter deforestation	Technology	16
Agricultural intensification	Directly counter deforestation	Technology	3
Protected areas	Agents and landscapes	Rights	7
Zoning (for land use)	Agents and landscapes	Rights	3
Decentralization, CBNRM	Agents and landscapes	Rights	21
Standards/certification	Agents and landscapes	Incentives	4
PES	Agents and landscapes	Incentives	20
Supply chains	Agents and landscapes	Incentives	2
Agriculture/forest policy	Macro-social and institutional context	Rights, incentives	35
Titling/land tenure	Macro-social and institutional context	Rights	10

Note: The regional distribution of the cases is as follows: Asia – 72; Latin America – 41; and sub-Saharan Africa – 10.

2.1. Resource rights interventions

Formal resource rights interventions can occur through legislative actions, policy reforms or managerial actions. Policy reforms can create new rights to resources such as the rights to create management plans, or to buy or sell land. They can alter land uses directly by changing *types of rights*, e.g. conservation vs. extraction-oriented actions related to forests, or can reallocate rights by excluding groups of users. These shifts in turn affect deforestation by changing the political–economic relationships among actors, their relative access to assets, and their choices over resource use. Policy changes can also encompass mechanisms that go beyond changes in rights by including new incentives or encouraging the adoption of new technologies, and by affecting both proximate and underlying pressures leading to deforestation. At the aggregate level, these choices and actions are reflected in how land and forests get used and in forest cover and land use outcomes.

Whether it is control over technical aspects of land use interventions (Bhattarai and Conway, 2008), mechanisms to sequester carbon (Asquith et al., 2002), or changes in zoning (Clement and Amezaga, 2009), a key element of rights-based interventions is reallocation of resource rights, sometimes from one social group to another. Many rights-related interventions also influence land uses more indirectly, for example by underwriting improvements in conflict-management skills, rule enforcement, or capacities to monitor and impose sanctions (Castella et al., 2006; Clement, 2010).

2.1.1. Forest and agriculture policy reforms

Forest and agriculture policy reforms cover an immense variety of interventions including subsidies and taxes through which to influence commodity prices, but they require substantial mobilization of interests and resources. These reforms help constitute the formal macro-institutional context within which land use occurs, and can reset the incentives for land uses that negatively affect forest cover (Brockett and Gottfried, 2002; McGinley and Cubbage, 2011). They are especially effective when governments command high levels of resources, maintain a presence in regions and areas far from the capital, and there is complementarity between policy reforms and underlying social and cultural conditions (Niroula and Thapa, 2005; Pacheco et al., 2010).

2.1.2. Titling/land tenure

Interventions that rely on tenure changes and clarification are premised on the assumption that more secure land and resource tenure motivate landowners to manage resources more efficiently (Angelsen and Kaimowitz, 2001). In many settings, land tenure reforms have been a mechanism to resolve competing claims for land and reduce forest clearing as a means for *de facto* claims to forested land (Angelsen, 2010). Reforms to improve land tenure security have had divergent impacts, sometimes successfully discouraging forest land clearing as a means to establish land rights (Alden Wily, 2008; Osborne, 2011), but also sometimes motivating agricultural expansion by increasing land values (Angelsen, 2010; Phelps et al., 2013).

Land tenure reforms can be pursued to improve security of ownership and rights through *de jure* recognition of *de facto* arrangements (Pacheco et al., 2012). They can also involve redistribution of land from large estates and state-held lands to smallholders, particularly via state-led colonization schemes (Pacheco, 2006). With these reforms has also come the expansion of legally recognized categories of land ownership, such as the formalization of communal land tenure (ownership rights legally shared by a group of people), customary use rights to land, and the establishment of land areas owned by indigenous peoples (Alden Wily, 2008).

2.1.3. Protected and conserved forests

Initiatives to protect forests through land classification or by combining conservation and development goals (Wells and Brandon, 1992; Canavire-Bacareeza and Hanauer 2013) have grown rapidly since the 1950s. Although protected areas are a centerpiece of efforts to protect forests and biodiversity, debates about their success continue (Hughes and Flintan, 2001; Naughton-Treves et al., 2005; Porter-Bolland et al., 2012; West et al., 2006). Differences in the assessment of protected area successes result at least in part from variations in scale and location of studies, methods used, and outcomes upon which analysts focus. However, a spate of recent global and national studies uses sophisticated analytical approaches to show that protected areas have successfully reversed or at least slowed deforestation in many contexts, and in some cases helped improve local incomes (Andam et al., 2008, 2010; Ferraro and Hanauer, 2014; Nelson and Chomitz, 2011). But their success in safeguarding biodiversity or in reducing deforestation in other countries and regions remain less clear.

Research arguing that that protected areas improve neither biodiversity nor livelihoods highlights complications from factors operating at supra-local levels: Projects may fail to link incentives for agricultural intensification to forest conservation. Forest conversion may be driven by macro factors outside the scope of a specific project or intervention. Migration, infrastructure development, fires, drought, and market demand for forest products may lead to conversion despite formal classification into protected areas (Fisher and Hirsch, 2008). These possibilities have led some scholars to refer to protected areas as paper parks (Wilkie et al., 2001).

2.1.4. Zoning and spatial planning

Zoning and spatial planning seek to influence outcomes by permitting or prohibiting particular uses of land in specified zones.

They have been used especially to designate land for agricultural development versus protected or utilized forest areas, including efforts to retain forest buffers in agricultural lands; restrict agricultural practices, including new forest clearing or burning in shifting cultivation; encourage tree-based plantations (including cacao, coffee, oil palm, pulp); and change incentives for agricultural production (Castella et al., 2006). Their effectiveness depends on implementation effectiveness, how they connect with other interventions, and contextual conditions (see, for example, Meyfroidt et al., 2014).

2.1.5. Decentralization and CBNRM

A substantial body of work on decentralization characterizes it as efforts by central governments to formally cede some decision making powers to actors and institutions at lower levels in a political-administrative and territorial hierarchy (Ribot et al., 2006). Devolving powers to lower levels involves the creation of a realm of decision making in which a variety of lower-level actors can exercise some control. But there are wide variation in implementation and relevant institutional structures, with concomitant differences in accountability and perceived legitimacy of leaders, decision making, and outcomes (Ribot et al., 2010).

Decentralization reforms need effective local level resource governance. Local resource governance, often through communities, existed in many places prior to present-day decentralization efforts, and both decentralized and community-based governance of natural resources rely on (1) local level decision makers and organizations who can make decisions and exercise powers; (2) clear roles and tasks for local level decision makers, and (3) institutionalized arrangements for the carrying out resource management roles. A more elaborate discussion of conditions for effective local governance is available in Ostrom's seminal work (Ostrom, 1990, 2009). Decentralized resource governance hinges on the logic that actors closer to the location of resources and resource users can make more effective decisions about resource management and benefit allocation (Mather, 2007; Skutsch and Ba, 2010). In practice, a number of empirical studies focused on local level and decentralized forest governance have found supporting evidence for this conclusion (Persha et al., 2011; Somanathan et al. 2009)

Changes in rights to resources usually accompany efforts to manage forests and land use through decentralization reforms. These changes are associated with new decision makers being charged with the conventional goals of more effective forest protection, and improvements in material benefits for local users and stakeholders (Cronkleton et al., 2012). Depending on the flexibility of implementation and the nature of accountability relationships, such reforms can improve both forest and livelihood outcomes (Chhatre and Agrawal, 2009; Clement and Amezaga, 2009).

2.1.6. Logging bans and moratoria

Governments deploy logging bans and moratoria for multiple reasons, but the typical rationale for a sweeping ban on timber harvests is rapid depletion of forest resources, often illegally (Kaimowitz, 2003). When governments have adequate monitoring and enforcement capacities on the ground, logging bans can be effective. In studies of six Asia-Pacific countries, logging moratoria in different years reduced allowable harvests and timber production (Waggener et al., 2001). The experience has been similar in Bangladesh in the 1970s and 1980s when a succession of logging bans reduced deforestation, and in parts of China (Sarker et al., 2011; Wakeel et al., 2005, West et al., 2010; Weyerhaeuser et al., 2005).

But logging bans also have perverse effects and much research has documented their ineffectiveness when enforcement is weak or policy is uncertain (Bray et al., 2003; McElwee, 2004). Even when recorded timber harvests fall, negative effects on livelihoods, unemployment, and spatial leakage of timber harvesting cannot be ruled out (Kaimowitz, 2003). Such negative consequences are particularly likely with informal alliances between enforcement agencies and illegal harvesters.

2.2. Incentives and rewards-based interventions

Beginning from the 1990s, a number of studies have outlined a class of interventions that use financial incentives to support sustainable land use (Pagiola et al., 2002; Boyd et al., 2007a). Examples include payments for carbon sequestration (or maintenance of forest cover or watershed services), sustainability labeling and disclosure statements, and access to financing, such as debt for nature swaps and green investment. All involve transfers of funds from a party interested in an environmental value. Their implementation often requires information and institutional innovations to ensure performance (Calvo-Alvarado et al. 2009).

2.2.1. Payment for environmental services (PES) (watershed, zero deforestation, carbon)

PES programs are a rapidly proliferating set of fund or market-based incentive-oriented interventions in which individuals or communities are paid by a specified buyer, via a contract mechanism, for land use activities that maintain the flow of a clearly defined environmental service relative to a pre-determined baseline (Cranford and Mourato, 2014; Engel et al., 2008). A broad definition of PES can include many conservation approaches that have been underway for decades. However, the relevant elements of the current generation of PES programs are primarily focused on provisioning of watershed services such as flood control and water quality, and carbon sequestration as for example through Reducing Emissions from Deforestation and forest Degradation (REDD+) and other terrestrial mitigation initiatives (Boyd et al., 2007b). Such initiatives hinge on establishing a competitive market price for environmental services so that the economic benefits of conserving forest land approach the expected gains from alternative land uses.

PES is potentially promising as a tool for GHG mitigation from agriculture and for forest conservation (Ferraro and Kiss, 2002). But, there are also many concerns over its implementation (including an assumption of effective governance and equitable property-rights that is often missing in real world contexts), unintended social equity and livelihoods impacts, difficulties in valuing and marketing environmental services, and monitoring and enforcement costs (Corbera and Schroeder, 2011; Mahanty et al., 2013). Other critics have drawn attention to the continuing dearth of evidence about impacts of PES interventions and problems of motivational crowding (Pattanayak et al., 2010).

2.2.2. Voluntary standards and certification

The use of voluntary certification and standards is based on the idea that environmentally aware consumers will purchase sustainably produced goods and that producers therefore have an interest in being certified as meeting recognized sustainability standards (Washburn and Miller, 2003). Certification of agricultural products (e.g. beef, oil palm, coffee) that have had a record of expansion into forest areas and timber can potentially encourage compliance with various sustainability guidelines, protect old growth forests, conserve natural habitats, and encourage local employment (Cashore, 2004; Cauley et al., 2001).

Research on certification's impacts has been more frequent in the industrialized world; boreal forests account for the larger expanse of certified forests globally (Cashore et al., 2006). But whether sustainability standards and certification are a substitute

or a complement to rights-based governance interventions continues to be a matter of discussion (Alexandratos and Bruinsma, 2012; Blackman et al. 2014; Buscher, 2013; Cauley et al., 2001; Damania and Hatch, 2005; Gulbrandsen, 2004). Their criteria and indicators may be as or more important for helping to establish new policy as for the additional numbers of certified farmers they create. Industry adoption of sustainability standards, such as the Roundtable for Sustainable Palm Oil, has raised questions about conflicts of interest and not yet successfully demonstrated consistent outcomes. Support by government agencies for certification standards, third-party monitoring, widespread availability of certification, forest law enforcement, and security of land tenure have all been advanced as core elements in enhancing the effectiveness of standards and certification (Ebeling and Yasué, 2009).

2.2.3. Sustainable commodity supply chain interventions

With increasing demands from an expanding, more prosperous global population, the sustainable supply of agricultural commodities will require productivity increases through intensification and improved outputs (Meyfroidt and Lambin, 2011; White and Dasgupta, 2010). Interventions to increase the sustainability of the supply chains for agricultural commodities and their production have increased in number and complexity in recent years and typically seek to avoid deforestation. Interventions may be internally driven, such as voluntary corporate social responsibility programs that seek to achieve sustainability standards, or zero logging in high carbon forests (Golden Agri-resources and SMART 2012), or externally driven such as consumer campaigns, regulations, or taxes that seek to change commodity-related practices (Friedman, 1999; Khor, 2011; Newton et al., 2013). Interventions that seek to improve the sustainability of commodity chains run the full gamut of what has been discussed in other parts of this section, including certification, standards, moratoria, jurisdictional policy changes, and intensification, with the distinctive element being their application to market transactions and the involvement of corporate actors and consumers at multiple levels beyond the agriculture-forest landscape. They also include corporate sustainability policies (Bitzer et al., 2008), carbon insetting (Banerjee et al., 2013), sustainability labeling, redirecting production of commodities to low carbon areas outside of forests, and monitoring by government or third parties such as Greenpeace for compliance with standards. Interventions also include the burgeoning area of "green" finance, investments guided by principles intended to support the environment (Green Bond Principles, 2014).

2.3. Technological interventions

Interventions based on technical approaches to improve forest outcomes related to carbon storage, tree cover, and forest condition (without negatively affecting social and livelihood outcomes) have a long history (Schramm and Warford, 1989). Such interventions include agricultural intensification and tree planting – often in combination with zoning and spatial planning, and fire management. In general, technical interventions and social and institutional changes to support these interventions need to be undertaken together.

2.3.1. Agricultural intensification

Land sparing and agricultural intensification are among the more visible, if contested, approaches for enhancing the contribution of the agricultural sector to terrestrial mitigation. The basis for land sparing is that if more crops can be produced from a given area, the enhanced productivity can reduce the conversion of forest for agriculture and reduce carbon emissions (Phalan et al., 2011) if (a) the "spared land" sequesters more carbon/emits less GHGs than cultivated farm land, (b) the additional yield does not result from inputs whose production creates higher emissions, *and* (c) other interventions are used to protect natural habitats elsewhere. This approach is in contrast to what has come to be termed land sharing, in which environmental and agricultural production objectives are combined on the same land (Minang et al., 2014, Müller et al., 2013, Nelson and Agrawal, 2008, Ostrom., 1990, Ostrom., 2009, Pacheco, 2006, Perfecto and Vandermeer, 2010).

Land sharing and land sparing both have their defenders (Fischer et al., 2008; Balmford et al., 2005). Modeling-based approaches as well as reviews of existing studies of agricultural intensification suggest that land sparing combined with intensification can indeed enhance mitigation and biodiversity conservation (Villoria et al., 2013). But some caution is warranted about the long-term benefits of a land sparing approach (Lin et al., 2008; Tscharntke et al., 2012). Rudel et al. (2009) found little evidence of land sparing at the country level through agricultural intensification between 1970 and 2005. And interventions to conserve forests against agricultural expansion have also had limited successes, and only with explicit efforts to favor conservation and support intensification (Phelps et al., 2013).

2.3.2. Fire management

Fires are potent, direct drivers of changes in the landscape, whether caused by natural or human agents. They are a dominant form of disturbance in some temperate and boreal forest systems in particular (Stocks et al., 1998), and have a strong association with deforestation in tropical forests as well (Nelson and Chomitz, 2011). Many indigenous groups have long practiced fire management (Bowman et al., 2009; Posey, 1985), and effective management of fires is associated with lower incidence of wildfire hazards in some forest ecosystems (Boer et al., 2009).

Much of the available evidence about the usefulness of fire management comes from temperate forests (Cochrane, 2003). Existing research suggests that there is feedback between tropical deforestation and fires (with forest edges being more vulnerable to wildfires) as also between climate change, forest fires, and deforestation (Nepstad et al., 2001; Siegert et al., 2001).

2.3.3. Tree planting

Tree planting is a direct intervention to improve forest cover, and can focus on specific tree species, or combine agriculture and forest-based activities in an effort to increase both environmental and economic outcomes. This category includes agroforestry, provided the intervention assures high carbon sequestration than the previous land use. As off-farm tree resources decline and farmers' incentives for forest-resource related incomes improve, they can undertake tree planting autonomously. But changing relative prices favoring forest products are no guarantee of autonomous tree planting–lack of information, insecure tenure, and inadequate access to technology can all discourage tree planting.

One example of tree planting comes from rotational community woodlots (Ramadhani et al., 2002). Fast growing trees planted in such woodlots require higher capital investments and effective management – often not available to poor farmers. But when accessed, capital and management inputs can lead to high yields from rotational woodlots, even compared to agricultural crops (ICRAF, 1998; Nyadzi et al., 2003). Scholars of industrial scale plantations have nonetheless raised concerns about their equity as well as ecological impacts (Lohmann, 2001).

2.4. Summarizing the different interventions

Fig. 2 summarizes the interventions according to their relative emphasis on rights, incentives, or technologies. The nearness to

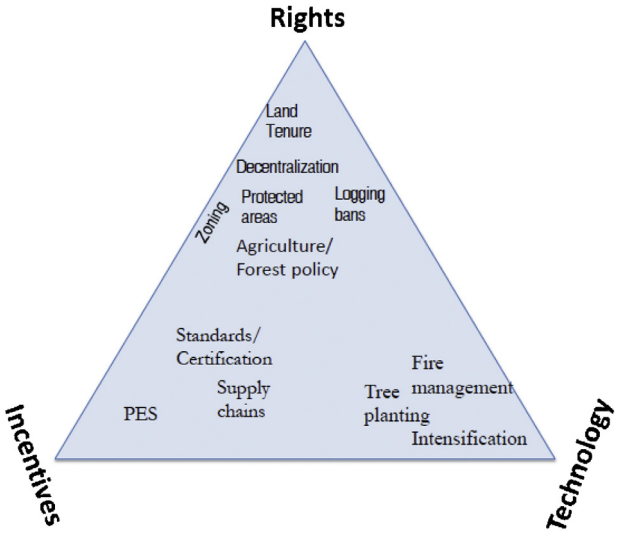

Fig. 2. Situating agriculture-forest landscape interventions in terms of relative importance of rights, incentives, and technology.

each of the vertices of the triangle indicates the relative emphasis of the intervention on rights vs. incentives vs. technology.

The figure also makes it evident that real-world interventions are a mix of different levels of rights, incentives and technical mechanisms even if the emphasis varies. Changes in rights, incentives, and technical improvements can also complement each other. Consider as an example community-based natural resource management in the buffer zone of a protected area. Such interventions typically transfer some resource rights to local users, provide them with incentives to limit extraction of benefits from core zones of protected areas, and provide technical support for sustainable harvesting.

At the same time, interventions in agriculture-forest landscapes do not produce effects in a social or political–economic vacuum. As Calvo-Alvarado et al (2009) emphasize, the recovery of tropical dry forests in Guanacaste, Costa Rica and possibly in other parts of Latin America is not just a consequence of forest conservation policies or payments for environmental services, but also the context in which policies are implemented (see also Lambin and Meyfroidt, 2010, Alves-Pinto et al., 2013).

3. Relationship between features of interventions and forest outcomes

Interventions in agriculture-forest landscapes are designed by stakeholders with multiple and at times divergent objectives. Improving ecosystem outcomes, economic and material benefits, forest cover, and carbon sequestration are commonly stated objectives, but they are not necessarily convergent. Multiple and ambitious goals, short time horizons, and limited resources have meant that outcomes of interventions often fall short of expectations and fail to secure local support and engagement.

Existing empirical work on the effectiveness of many of the interventions highlighted here, for example recent work on decentralization (see Ribot et al., 2006; Edmunds and Wollenberg, 2003) or PES (see Pattanayak et al., 2010), has yielded a range of results and all too often little agreement. Reasons likely have to do with variations in social, macro-policy, political–economic, and cultural environments within which interventions are implemented and with which different features of interventions interact in uncertain or unpredictable ways (Pfaff et al., 2013). But also, the intervention types themselves do not follow a blueprint. Consider timber certification. There are multiple standards; implementation varies by timber concessions; and monitoring and enforcement are applied with varying intensity depending on implementation capacity of governments.

3.1. Findings from the meta-analysis

Our goal in conducting the meta-analysis of 123 interventions in forest-agriculture landscapes was to assess whether basic features of interventions are associated with observed patterns of forest outcomes. To identify the 123 cases, we undertook keyword searches from November 2010 to June 2011 on ISI Web of Science combining a term for the region (Africa, South Asia, Southeast Asia, East Asia, and Latin America) with a term for the substantive focus ('forest,' 'agriculture,' 'land use,' and 'deforestation,' together with 'decentralization,' 'policy,' and 'project'). Of the just over 400 papers identified, 86 contained sufficient information about the intervention's goal, implementation process, geographic scope, and forest outcome to be included in the analysis. (The online appendix A provides more detailed information on our search strategy, a full list of the identified references, and the number of cases that each paper yielded).

Although the meta-analytic approach we use is ill-equipped for generalizations about the magnitude of the relationships between interventions and outcomes, or even to enable causal inference, it is a useful starting point to investigate potential causal links between different types of external interventions, the socio-economic processes they engender, their effects on incentives of decision makers, and how these combine to produce forest outcomes.

We focused in our meta-analysis on forest cover outcomes because they were the most consistently reported across the cases. We coded the information in the studies into three categories of forest cover outcomes based on whether they had improved, declined or not changed. Across the cases, we found no statistically significant association between the stated goal of the intervention, and reported forest cover outcomes (Pearson $Chi^2 = 0.59$, $P = 0.44$). This lack of an association between the intended-goal-observed-outcome relationship remained broadly consistent after the cases were grouped by the driver of deforestation (specifically, shifting cultivation, biofuel production, or logging, and by legal vs. illegal activities) although the number of cases within each of these subcategories became very small.

The absence of an association between specified goals and outcomes may point to several issues: imprecise goal setting and drift over time, implementation problems, potential biases in reporting and interpretation including difficulties in comparison owing to inconsistent data in the reviewed studies, and possibly the interactions between specific features of the political–economic context and of the interventions (Niroula and Thapa, 2005; Ramadhani et al., 2002).

However, we found that the scale of the intervention was related to observed patterns of outcomes, with smaller-scale interventions being more likely to have positive forest outcomes. We categorized cases into three broad scale categories depending on whether the interventions was targeted at the country (nationwide intervention), province, or smaller than a district level in scale. Table 2 presents the distribution of forest condition outcomes.

Another key finding concerns the role of enforcement. In general, more effective enforcement was associated with better forest outcomes and lack of enforcement mechanisms had a significant association with worse forest outcomes or no change in outcomes. Table 3 presents the distribution of the cases for forest outcomes in relation to enforcement.

The analysis suggest that although positive outcomes can also occur when effective enforcement is absent, high levels of effective

Table 2
Scope of Case/Intervention and Forest Cover/Condition Outcomes.

Scope of case/intervention	Forest cover/condition outcomes		Total
	Negative or no change	Positive change	
Small	9	32	41
Medium	18	22	40
High	14	13	27
Total	41	67	108
Pearson $Chi^2 = 7.52$, $P = 0.023$			

enforcement are more strongly associated with positive outcomes. Specific cases substantiate this general pattern. For example, Müller et al. (2013: 904) examine multiple policy options for reducing deforestation and find that only enforcement of land use legislation ameliorated the effects of deforestation drivers.

Given the differences among the reviewed studies – in terms of data, methods, analytical approaches, types of interventions, location, and the disciplinary affiliations of authors – common patterns (related to scope and enforcement) are likely worth greater attention than the absence of such patterns. Thus, the associations between specific features of interventions and outcomes as described in this section point toward potentially fruitful areas for future, more systematic analyses of causal links.

4. Contributed papers

The ensuing articles in this special section examine specific mechanisms or interventions that address what are currently seen as critical issues in the governance of agriculture-forest landscapes and protection of forests from agricultural conversion: tenure; a comparison of reward-based incentives vs. regulation and sanctions; agricultural investment and intensification; and decentralized, multi-stakeholder participation in land use decisions. As such they provide a more situated analysis of how these levers work than is feasible through a general review of the literature.

4.1. Resource and land tenure

To understand the effect of tenure on deforestation, Robinson et al. (this issue) examined 36 papers (118 cases) that used remote sensing data on forest cover change over time. The authors found that tenure *security*, indicated by the absence of conflict, was a better predictor of avoided deforestation than the form of tenure. Form was classified as communal/customary, private, protected public, and not-protected public forests and land. Tenure security, however, depended on the legal and socioeconomic context of the intervention. The positive effects of clearer and more secure property rights could be superseded by "how communities at the forest-farm interface internalize [tenure] concepts" and the socioeconomic context of their decisions, especially in terms of relative forest-agriculture product prices, access to markets, and technological change. No one form of tenure was clearly better than another in leading to positive outcomes, although protected public lands were slightly more likely to result in positive forest outcomes than private, communal or unmanaged public land. Robinson et al. concluded that clear and secure rights are a necessary, but insufficient condition for incentives-based forest policies like REDD+, and not "perfect safeguards" against the loss of forest cover. Strengthening tenure invariably involves strengthening legal and social institutions to facilitate and enforce claims.

Table 3
Enforcement effectiveness and forest cover outcomes.

Enforcement effectiveness	Forest cover/condition outcomes		Total
	Negative or no change	Positive change	
Low	27	14	41
Medium	3	14	17
High	0	14	14
Total	30	42	72
Pearson $Chi^2 = 23.90$; $Pr = 0.000$			

4.2. Incentives and rewards

The paper by Börner and Wunder (this issue) contributes to the literature on payments for ecosystem services. Payments and other rewards to land users have received increasing attention because of successful interventions to pay producers of ecosystem services and interest in Reduced Emissions from Deforestation and forest Degradation (REDD+). Börner and Wunder used a spatially explicit model of detection of deforestation in Brazil to explore how a mix of incentives (carrots) and enforcement (sticks) can achieve cost-effective reductions in deforestation without sacrificing equity. They argued that regulations alone have not sufficiently slowed deforestation in Brazil; "in 2006, the aggregated non-forest land uses on private properties exceeded the 20% limit in 749 out of 760 municipalities." Their analysis focused on how to enhance the tons of carbon sequestered per unit operational cost, considering costs to policy implementers and land managers (costs of liability establishment, administrative processes and legal coercion), spatial patterns of deforestation (distance, patchiness, unequal access to land), clarity of tenure, budget constraints, and revenues from fines.

Börner and Wunder concluded that enforcement is less costly than payments, but that both carrot and stick approaches are needed to achieve distributional equity. A pure enforcement approach would cause land users to forego roughly two-thirds of the annual growth in value from agriculture in the Amazon states, with losses borne primarily by large-scale producers. Indigenous and traditional populations would have little to no welfare loss with improved enforcement. A payments approach would reduce land user costs, but require higher spending by the state. Although their focus is on the analysis of enforcement vs. incentives, they are in agreement with Robinson et al. that clarifying and enforcing land rights is a necessary enabling condition for PES interventions.

4.3. Decentralization reforms

As discussed in Section 2, decentralized governance is a key policy instrument for reducing deforestation. The paper by Oosterzee et al. (this issue) examines how institutional arrangements at the landscape level can enable better management of agricultural and forestry drivers, flexibility in balancing climate change mitigation, livelihoods and biodiversity goals, and integrate fragmented or conflicting policies. Oosterzee et al. described the evolution of integrated natural resource management in Australia, including for the case of the "Degree Celsius Wet Tropics Biocarbon Sequestration and Abatement Project." They documented regional natural resource management bodies' representation of community interests, connectivity among decision makers, and

use of knowledge and capacities. The entities adaptively managed forest-crop-grassland landscapes for reduced net GHGs, biodiversity, sustainable agriculture, water quality and community benefits. Climate change mitigation was achieved using avoided deforestation and degradation, reforestation with native species, and reduction in nitrogen fertilizer use. Their case also shows the vagaries of national politics, however, as a shift in national leadership recentralized control.

4.4. National agricultural policies

Finally, Fox et al. (this issue) focused on agricultural investments by governments. National government's agricultural investment policies and support to farmers are among the more direct policy levers to influence incentives and create enabling conditions for farmers' crop and livestock choices. Their paper analyzes how agricultural policies for the expansion of rubber in Lao and southern China have affected land use change and smallholder well-being. The authors showed the dynamism of a regional landscape in flux, from swidden agriculture and its decline to the rise of rubber and reduction of natural forest. They documented the variable and uncertain nature of above ground biomass, below ground biomass and soil carbon stocks in these systems.

This paper also shows that land use interventions must be understood in terms of actual impacts in particular landscapes, e.g., tons of carbon saved or income generated, and not to assume that a particular land use category or land use always has the same impacts. National policy definitions of swidden agriculture as non-forest and rubber as forest overlooked how these systems functioned as carbon stocks. They suggest that robust comparisons of land use impacts on carbon for informing REDD+ policy are not yet available, and site-specific, cost-effective carbon stock assessments are needed for the region. Impacts also varied by country contexts. For example, China's investment in smallholder capacities for rubber resulted in better benefits for smallholders in contrast to Lao where smallholders often lost land rights and pursued livelihoods as laborers in rubber plantations.

Fox et al. conclude that managing land use change by determining carbon stock thresholds, in tandem with other impacts that land use changes may have, such as burning or welfare impacts, is as or more important than seeking to maintain a hard line between forest and agricultural land. They observe that managing longer fallows and other aspects of swidden agriculture may provide equally important welfare and carbon gains. Where investment in plantations occurs, policies should help smallholders benefit by providing extension, credit, transport and marketing services. But overall, they raise grave concerns about "parachuting" REDD+ policies into landscapes where the impact of such policies is highly uncertain." They conclude that REDD+ and other interventions must mesh well with existing market and policy environments to be effective.

5. Discussion

The empirical evidence detailed in the preceding discussion forms the foundation to highlight three issues: the relationship between form and function of interventions; the tightness of coupling between interventions and outcomes; and the factors that shape the relative effectiveness of interventions. These issues are of enduring relevance for improving forest and carbon sequestration outcomes.

5.1. Function vs. form

The reviewed interventions, the meta-analysis, and the detailed case studies demonstrate the difficulty of meaningfully interpreting interventions or their effects from their form alone, and highlight the importance of focusing on how interventions function in specific contexts. In part, the difficulties arise because of limited availability of consistent information across the reviewed cases–indeed, the meta-analytic approach only allows the creation of coarse categories. But the same inference is also evident in the more detailed case studies by Fox (this issue) and Oosterzee (this issue). In the broader literature, even when specific studies rigorously attribute average effects to particular types of interventions – for example for protected areas – the generalizability of these findings to other locations and jurisdictions requires caution.

The point is valid more generally. It affects how interventions and polices are selected, designed, implemented, and communicated. Robinson et al.'s observation that tenure security is more predictive of positive forest outcomes than the form of tenure is buttressed by the meta-analytic result that highlights the importance of enforcement across the studies. It points to tenure security as the key feature of tenure policy for forest outcomes, understandable given that land rights in forests have in many places been historically unclear, contested, or subject to multiple tenure regimes, often leading to negative effects on forest cover.

Although the importance of function over form is driven home by the contrast of tenure security with tenure type, the same distinction can be made in assessing the effectiveness of other interventions. Different instances of decentralization show that the processes through which decentralization is expected to produce its effects can be invigorated or diminished depending on how the reforms are pursued and the countervailing political and economic interests working against them (Nelson and Agrawal, 2008; Sandbrook et al., 2010). Adequate opportunities for meaningful participation, guarantees of decision making on key issues, institutionalized accountability mechanisms, and sufficient resources are central to effective decentralization. Equally important, however, is understanding how these opportunities measure against the influence of powerful centralizing forces, such as national government offices, the military, donors, or large corporate interests that may actively work against local interests. Extant designs of decentralization interventions often neglect one or more pillars of decentralization, pursuing form at the expense of function. Charges of ineffectiveness of some protected areas by labeling them "paper parks" attempt to highlight similar processes (Alcorn, 1993; Wilkie et al., 2001). Attending to function over form is clearly one way in which to guard against the complacency of shibboleths such as "privatization," "tenure," "decentralization," and "CBNRM," which encompass enormous variety.

5.2. Attributing impacts to interventions: Tightly coupled or loosely connected?

Bluntness and variability of instruments, interactions with political, social, and economic contextual factors, variations in implementation, and multiple types of deforestation pressures mean that interventions are almost never tightly coupled with specific outcomes. This makes outcomes difficult to attribute to interventions precisely or reliably. The meta-analysis and articles in our special section demonstrate that interventions to manage agricultural-forest landscapes tend to be only loosely coupled to desired outcomes, making predictions about impacts of future interventions and improvements in their design difficult to predict. Indeed, policy itself often works in fragmented, piecemeal fashion and hopes of silver bullets to solve perceived problems are likely misplaced. Simple causal analysis is therefore likely inappropriate for understanding interventions or designing policy, confirming that policy sciences in this arena requires more systems-oriented analysis and an adaptive learning approach (Lindblom, 1959).

5.3. Relative effectiveness of instruments and interventions

The 12 intervention types reviewed in this paper have been used in different spatial and social contexts to counter deforestation pressures. Their effectiveness depends not only on their content, but also on what they add to an existing set of policy, economic, and technical conditions. Interventions also generate other outcomes, affecting livelihoods, biodiversity, participatory processes and the like. Indeed, few policy interventions are so precise as to produce only a single intended effect. Evaluating their relative effectiveness to draw generalizations about priority interventions is therefore difficult. Prioritization requires not only an assessment of the programmatic impact, but also counterfactual analyses of how other possible interventions in that same context might have fared. The multiplicity of desirable outcomes and the multiple criteria against which outcomes can be evaluated can quickly lead to dizzying analytical complexity and questionable interpretations. Yet informed choices from a menu of possible mitigation instruments require knowledge of the relative effectiveness of interventions, including outcomes other than the primary goal of improved forest condition. Clearly far more information is needed about how deforestation-related interventions function and their effectiveness across settings in agriculture-forest landscapes.

6. Conclusion

In a recent paper, Ostrom argued against the common presumption that one can "make simple, predictive models of social–ecological systems (SESs) and deduce universal solutions, panaceas, to problems of overuse or destruction of resources" (Ostrom, 2007). We agree. Our review of 12 types of interventions to address deforestation, and thereby terrestrial emissions, leads us to the same general conclusion about the nature of interventions and their effectiveness in the face of different deforestation drivers.

While we cannot robustly assess the relative effectiveness of interventions, we can draw some conclusions. Tenure security, accompanied by supporting social and legal institutions, matters more than the form tenure takes. Enforcement seems to be consistently associated with positive forest outcomes and is predicted to cost less than environmental payments. Land use categories should be assessed for their actual carbon sequestration and not based just on general assumptions related to agriculture and forests.

Our review suggests that analytical attempts to identify average effects of a particular type of intervention across forest-agriculture landscapes to provide policy guidance may conceal as much as they reveal. Such an approach treats different instances of a given intervention as being substantively similar, as being implemented in roughly the same way, as producing more or less similar effects (or at least that average effects can stand for the specific effects) and for similar reasons, and as having effects that can be abstracted from the context of the intervention and its implementation. The three different sources of empirical information included in this introduction – a focused review of the literature, an analysis of the effects of interventions, and brief summaries of four studies in the special section – all suggest that these assumptions about interventions and how they work need to be examined anew. It is self-evident that a protected area differs from a payment for environmental services scheme or from an agricultural intensification project even if all three aim to reduce deforestation. But, additionally, a given protected area is different from other protected areas. Any one payment scheme differs from other payment schemes. And a given intensification project differs from others. These differences are evident whether one compares interventions and outcomes in different countries, landscapes, across different time periods, or indeed, within the same country (Andrews, 2013).

Thus, even within a general type, specific interventions differ in form, function, and effects. Understanding how interventions work requires close attention to the specific form of the implemented intervention, to the variations between different instances of a given intervention type, and knowledge about how the distinctive features of an intervention connect to features of the policy and socio-political context. Such knowledge requires a judicious combination of both qualitative familiarity and quantitative data. As importantly, it requires moving beyond simple causal analyses to the use of methods suited to the analyses of complex systems and exploration of non-linear causal relationships – both exciting new avenues of future work.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.gloenvcha.2014.10.001.

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