A MULTI-LEVEL APPROACH FOR ASSESSING THE TRENDS AND IMPACTS OF FOREST CERTIFICATION

by

PARAG KADAM

(Under the Direction of Puneet Dwivedi)

Abstract

Forest certification has become one of the most widely used market-driven mechanisms for forest management and conservation, but it is not clear yet whether the different standards are having any impacts on the discourse and environmental outcomes. The goal of this dissertation is to explore the changes in the forest management (FM) standards of Forest Stewardship Council (FSC) and Sustainable Forestry Initiative (SFI) and the environmental impacts of these two most widely used forest certification systems in the world. The central questions are a) where FSC and SFI FM standards have made changes to be convergent with the international sustainable forest management (SFM) protocols, b) whether SFI-FS has impacts on forestry best management practice (BMP) implementation rates, and c) whether FSC-FM impacts on biodiversity outcomes. The scale of the study area in the latter two, local and global respectively, is dependent on the availability of comparable long-term on-the-ground data of not only the environmental outcomes (i.e., BMPs and threatened species) but also certification locations and areas. By using a mix of qualitative and quantitative methods as well as incorporating the political ecology and socio-economy variables into the analyses, the results of this dissertation show that FSC and SFI have clear convergences with the international SFM protocols in ecological and socio-economic spheres of standards. Moreover, both FSC and SFI have positive associaions with the environmental outcomes, albeit with some constraints and contexts.

INDEX KEYWORDS: Best Management Practices, Biodiversity, Environmental impact, Forest certification, Sustainable forest management.

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DEDICATION

To
my family,

And to
the people around the world who unconditionally accepted me into one.

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CHAPTER 1

INTRODUCTION

Forest governance, today, is considered to be a collection of processes through which the forests, their participatory management, and the general forestry resource utilization are governed (Fernández-Blanco et al., 2019). Forest governance specifically covers planning, decision-making, implementation, and monitoring. Forest governance emerges from the interactions in space and time between human and natural systems comprising of natural resources, actors, norms of interaction between them, rules among the actors regarding the management of natural resources, and the actual practices that constitute that management. Arts and Buizer (2009) outlined how discourse on biodiversity, sustainable development, and governance within the global forest policy arena is characterized by different coalitions, rules of the game, and power relations. Particularly, the researchers argue that the discourse on governance shifted in the 1990s from the government to governance “due to processes such as increasing state failure, market liberalization, internationalization, decentralization and individualization” (Arts and Buizer, 2009, page 1) and new policy instruments like certification programs, carbon trading schemes, etc. driven by networked partnerships of public and private stakeholders. New rules of the game like multi-stakeholder participatory dialogue and requirement of free, prior, and informed consent (FPIC) became mainstream due to these changes in the global forest policy arena, which empowered stakeholders like NGOs and indigenous groups. Since the Agenda 21 of United Nations Conference on Environment and Development held in Rio in 1992 – where globalization of forestry stakeholders was heralded most prominently – designing and implementing ‘principles, criteria, indicators, and verifiers’ of what constitute good forestry practices in multi-level systems (inter-/national/regional to local forest management unit/FMUs) has been deemed crucial for instituting sustainable forest management (SFM) (Prabhu et al., 1998).

Forest certification is a non-state, market-driven mechanism for recognizing the sustainability of forest management practices of forest management entities based on their compliance with a set of standards, assurance of which is provided by third-party independent certification body audits. Within the typology of forest governance, this mechanism for conservation sits in the center of the spectrum of public-private-civil society initiatives (see figure 1 from Delmas and Young, 2009). The original purpose of forest certification in the early-1990s was to mitigate tropical forest deforestation in light of direct-action campaigns by environmental non-governmental organizations (Bartley, 2007). This mechanism of forest governance has led to a widespread dialogue and on-the-ground changes in forestry practices over the last 30 years (Pappila, 2013). Today, forest certification has become one of the most critical forest governance systems worldwide, with the certified area supplying 31% of the world's total roundwood (US Endowment for Forestry and Communities, 2017). The Forest Stewardship Council (FSC) was the first major certification scheme that emerged from the coordinated efforts of non-governmental organizations (NGOs), environmental groups, and industry in 1993 (FSC 2014). Since then, market competition has created another global certification system – the Programme for the Endorsement of Forest Certification (PEFC) (PEFC, 2020). FSC and PEFC task themselves with the standardization of forest management practices, supply chain mixing requirements, and related trademark requirements for appropriate consumer signaling. In North America, the PEFC has endorsed the Sustainable Forestry Initiative (SFI) (SFI, 2019), the American Tree Farm System (ATFS) (ATFS, 2020), and the Canadian Standards Association (CSA) (CSA, 2021).

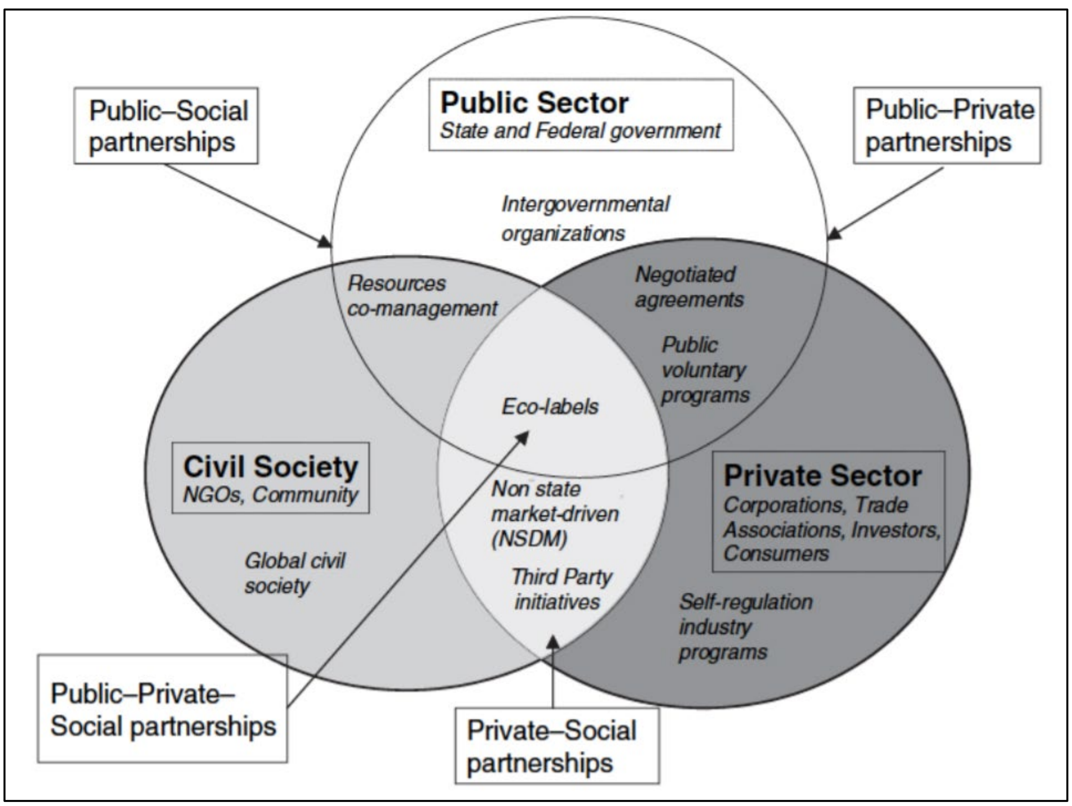

Figure 1. Types of forest governance systems and their place within the public-private-civil realm. From (Delmas and Young, 2009)

Globally, the FSC has certified 228.4 million hectares in over 130 countries (FSC, 2021a), each under a nationally unique set of verifiers but with globally common principles and criteria. FSC's approach to standardization includes developing voluntary forest management standards through a balanced, deliberative multi-stakeholder voting. FSC has three chambers in its General Assembly, viz. environmental, social, and economic, each with one-third weights of votes – which are further sub-divided into the global north and global south sub-chambers where stakeholders vote on the process of standardization (FSC, 2020a; van der Ven and Cashore, 2018). SFI has followed suit with this tripartite governance model. In terms of area certified, with 152 million hectares area certified to forest management standards, SFI is the world's second-largest single certification scheme; it is the largest in North America (Fernholz et al., 2021). The theory of change of both FSC and SFI certification schemes purports to materialize responsible and sustainable forest management through direct standard system and indirect social dialogue (Romero and Putz, 2018). The goal of this dissertation is to explore the trends in the standardization of SFM to understand the role of the two most widely used forest certification systems in the world, followed by analyses of the environmental impacts of those forest certification systems.

Both FSC and SFI offer three types of certification standards in total. The Chain of Custody standard ensures that certified forest products don't mix with non-certified ones throughout the supply chain, while the Forest Management Standard covers an area-based certification. The complexity of standards and the cost of implementing them are two of the primary hurdles among certificate holders to implementing an area-based forest management standard (Cashore, 2002). Attempting to mitigate these challenges, both FSC and SFI offer a responsible sourcing standard – viz. FSC Controlled Wood and the Fiber Sourcing Standard (SFI-FS), respectively – covering requirements for the certified mills to implement procurement practices and responsibly mitigate risk, if applicable (Kadam et al., 2021a).

Forest certification systems face loss of trust and legitimacy through internal resource constraints and external stakeholder constraints (Naka et al., 2000). FSC's growth strategy is to include a more significant role for forest managers and the industry, while PEFC and SFI aim to attract environmental groups and social organizations. This is how they compete for legitimacy – by changing their governance approaches (van der Ven and Cashore, 2018). In light of the issues of 'private governance' (Mayer and Gereffi, 2010), it is critical to understand not only how the discourse in standards has developed but also whether they are impacting the environment positively or negatively. Each of the following chapters in this dissertation are devoted to exploring these research questions.

Within the global forest policy regimes of sustainable forest management (SFM), international protocols outline a series of standardized criteria and indicators agreed upon by participating countries to achieve sustainable forestry – falling more towards the public-private part shown in Figure 1. The objective of Chapter 2 is to compare five major SFM systems [three protocols (International Tropical Timber Organization, Montreal Protocol, and Forest Europe) and two certification schemes (FSC and SFI)] to better situate the past and present interlinkages between protocols and certification schemes. Our study reviews the historical levels of convergence between protocols and certification schemes, exploring the degree of any substantive changes in global forest governance since 1990. For certification schemes, I focus on only the international forest management standards, covering general principle and their criteria, as opposed to national level standard documents with indicator level detail for developing a broader understanding of potential overlaps between protocols and certification schemes. I find that FSC may have been instrumental in other global SFM systems changing the ecological types of criteria & indicators in the last 30 years. Changes in SFI's standards correspond to its institutional changes from a purely industry-driven system to being an independent organization. Our results show that considering ecological and socio-economic institutional elements towards understanding trends and developments in all the five standards is important for SFM standard development.

Earlier research in understating the impacts of forest certification has been focused on processes instead of outcomes, using data received after third-party audits (Johansson and Lidestav, 2011). The main reason for this is that comparable long-term on-the-ground data of environmental outcomes as well as the performance of certified and non-certified management entities have been difficult to obtain (Blackman et al., 2017). The objective of chapter 3 is to analyze how the increase in overlaps of wood sourcing areas of certified and non-certified mills in Georgia, United States, is related to the change in rates of forestry best management practices (BMPs) of harvested sites. There is enough history of assessing spatial dependence in landowners' characteristics and motivations in the United States (Poudyal et al., 2019) to warrant considering possible spatial dependence. Using long-term spatial data, I employ regression modeling methodology, which incorporates potential spatial neighborhood dependencies between the mills in Georgia. I aim to understand the spatial dimensions of the impact of increasing SFI-FS certified fiber sourcing on the BMPs in relation to the non-certified fiber sourcing from 2002 to 2019 (the period for which BMP data is available and comparable). The spatial analyses found an overall positive effect of overlapping SFI-FS sourcing overlaps and an overall negative effect of overlapping non-certified sourcing overlaps. The spatial model could identify certified overlaps, elevation, and harvest intensity as the most important lagged/indirect effect variables creating a local neighborhood effect. Our result will be crucial not only for the SFI to strategize development constructively but also for stakeholders to recognize and critique the forest certification system.

Forest certification operates in a heterogeneous set of variable assemblages. Agreement exists that forest certification mechanism is strengthened by parallel forest governance from governments or people (Cerutti et al., 2011). The objective of the chapter is to assess the importance of FSC certification presence to biodiversity management outcomes (percent threatened species) in the face of complex politico-ecological and economic systems on the global level. Using a novel machine-learning algorithm of the generalized random forests, this study analyzes the heterogeneity in the impacts of FSC's Forest Management (FSC-FM) certifications on biodiversity loss in 91 countries from 2008 to 2019. I consider possible sources of heterogeneity in the analyses of the impact, such as the socio-ecological factors as well as politico-economic ones. I find that FSC-FM certification has positive effects where population densities and tree cover loss is high but require enabling conditions of higher perception of corruption control and lower extraction of non-forestry natural resources (oil, coal, and natural gas).

The three dissertation chapters provide a multi-perspective look at the major forest certification systems covering both the global changes in the certification standards in relation to the sustainable forestry protocols over time as well as their impacts on the environment. The two impacts chapters use novel statistical modeling methodologies which are geared towards the particular geographical scales of the respective study areas, one local and the other global. Moreover, our methodologies are also relevant to the respective scope of certification standard systems, viz. a responsible sourcing standard and a forest management standard. I hope that the results of this work are helpful for policy makers not only in the FSC and SFI institutions but also for governments, industries, NGOs, and civil society in relevant countries while strategizing the future of the market-driven mechanism of forest certification.

CHAPTER 2

MAPPING CONVERGENCE OF SUSTAINABLE FOREST MANAGEMENT SYSTEMS: COMPARING THREE PROTOCOLS AND TWO CERTIFICATION SCHEMES FOR ASCERTAINING THE TRENDS IN GLOBAL FOREST GOVERNANCE[1]

[1] Parag Kadam, Puneet Dwivedi, Caroline Karnatz, Accepted by [Forest Policy and Economics]. Reprinted here with permission of publisher, [10/05/2021].

Abstract

At the global level, two Sustainable Forest Management (SFM) systems, i.e., protocols and certification, have grown significantly in standardizing forest management practices. Protocols are driven by multi-stakeholder groups that outline a series of standardized criteria and indicators agreed upon by participating countries. On the other hand, forest certification involves market-driven multi-stakeholder standardization, assessment, and recognition of a forest management entity's compliance with standards established by the respective certification program. In this study, we compare the trends in numbers and types of changes that have taken place over two consecutive periods (1995-2005 and 2005-2015) through case studies for three protocols (International Tropical Timber Organization (ITTO), Forest Europe (FE), and Montreal Process (MP)) and two certification schemes (Forest Stewardship Council (FSC) and Sustainable Forestry Initiative (SFI)). A qualitative review of the respective systems' institutional histories is followed by a graphical representation of the observed changes. We then compare the relative quantitative changes in the categories of criteria and indicators in the standards of the selected systems. We find that FSC may have been instrumental in other SFM systems changing the ecological types of Criteria & Indicators (C&Is) in both periods. Changes in SFI's standards correspond to its institutional changes from a purely industry-driven system to being an independent organization. Furthermore, we find that ITTO has been more reactive in changing their C&Is as compared to MP and FE, which may have played a vital role in the standardization discourse. Nevertheless, based on our results, we argue that considering socio-economic institutional elements towards trends and developments in all the five standards is important. The selected five SFM institutions can use our findings regarding the trends in the standardization of global forest management to achieve their respective goals for ensuring the sustainability of forest resources worldwide.

Keywords

Sustainable forest management, Standardization, Stakeholder coordination, International forest governance

2.1. INTRODUCTION

Sustainable Forest Management (SFM) promotes responsible forest resource use while recognizing critical contributions of forestlands to human well-being in the form of economic, environmental, and social values (United Nations, 1987). At the global level, two SFM systems, i.e., protocols and certification, have grown significantly in standardizing forest management practices.

Protocols outline a series of standardized criteria and indicators (C&Is) agreed upon by participating countries to achieve sustainable forestry. Different countries are members of different international forestry protocols which are designed by international, national, and sub-national institutions to collect data related to forest trends through monitoring of various factors, e.g., water, biodiversity, silvicultural systems, cultural benefits, and several others (Gulbrandsen and Humphreys, 2006). The mission of the protocols has been to provide policymakers at the national scale with informed strategies to operationalize and improve SFM (Gulbrandsen and Humphreys, 2006; Washburn and Block, 2001).

Forest certification involves standardization, assessment, and recognition of a forest management entity in compliance with standards established by a certification program. Forest certification schemes are recognition and verification systems that aim to assess the performance of individuals or groups of individuals on the level of individual forest management units (FMUs) against a set of standards developed in concert with multiple stakeholders (van der Ven and Cashore, 2018). The most prominent forest certification schemes employ third-party verification, promote the legitimacy of forest management entities and forest products companies in the public sphere, and are driven by environmental awareness of consumers in the market who demand sustainable forest products (Johansson and Lidestav, 2011).

In the 1970s, the role of civil society and non-governmental organizations (NGOs) was limited in forest resource management rulemaking as there was a high probability that persons deemed to be forestry professionals came either from government or industry (Westoby and Simmons, 1989). The rate of deforestation in the Amazon increased from about 12 thousand km^2/year in the 1970s to almost 30 thousand km^2/year in the 1990s, and the forests in SE Asia and the Congo followed a similar trajectory as well (Rosa et al., 2016). During this time, local and international NGOs associated with social and environmental concerns saw a rapid rise in numbers as well as in their ability to be heard by governments (Berny and Rootes, 2018). They actively campaigned through social coalitions and movements for changing the practices of the industry to be more responsible and accountable (Bartley, 2007). Globalization of some NGOs like Friends of the Earth (FoE) and Greenpeace in the 1970s was a result of the growing emphasis on the need for transnational as well as multi-stakeholder cooperation and collaboration while facilitating decentralization of decision-making agency was felt in the context of management of natural resources, in general, and forest resources, in particular (Lemos and Agrawal, 2006).

Since then, there has been a 37.5% reduction in the global rate of deforestation from 160 thousand km^2/year in the 1990s to 100 thousand km^2/year between 2015 and 2020 (FAO and UNEP, 2020). The net loss of forest area has shown a 39.7% reduction from 78 thousand km^2/year in the 1990s to 47 thousand km^2/year in 2020. Despite these reductions in annual rates, a total of around 4.2 million km^2 of forestland has been lost to other land-uses since 1990, and the primary forest area has decreased by 810 thousand km^2 since 1990 (FAO and UNEP, 2020). The latest report on the State of the World's Forests notes that forests currently cover 40.6 million km^2 of land worldwide, although only five countries carry half and ten carry two-thirds of that land (FAO and UNEP, 2020).

Approaches to tackle deforestation constitute various multi-level and multi-system forest governance mechanisms driven by different societal interests. Since the 1990s, rather than a genuinely global forest governance system, a variety of fragmentary forestry regime 'complexes' with multi-actor partnerships, mechanisms, and programs have arisen attempting to hybridize regulation and control of forest use and conservation (Fernández-Blanco et al., 2019; Lemos and Agrawal, 2006; Rayner et al., 2010). Krasner (1982) defines an international regime as a "set of implicit or explicit principles, norms, rules and decision-making procedures around which actors' expectations converge in a given area of international relations" (page 186). Biermann et al. (2009) state that the fragmentation of forest governance is "a patchwork of international institutions that are different in their character (organizations, regimes, and implicit norms), their constituencies (public and private), their spatial scope (from bilateral to global), and their subject matter (from specific policy fields to universal concerns)" (page 1). In spite of their multi-stakeholder nature, it must be noted that public state actors and their authority are still crucial in the international forest policy regime complexes; moreover, Giessen et al. (2016) argue that the co-governance model of public and private actors is just an intermediate step before enough political momentum, in regard to state interests and capacities, is reached.

In today's fragmentary global forest management regime (Arts and Buizer, 2009; Dimitrov, 2003; Fernández-Blanco et al., 2019; Humphreys, 2012), there exists a need for comparing and differentiating the chronological developments in protocols and certification schemes driven by their respective goals and missions. This can help us streamline an understanding of global forest governance across multiple strategies. This is especially true as these two systems have become the default for global forest governance to achieve local, regional, national, and international policy goals.

In this context, this study analyzes five major three protocols (International Timber Trade Organization- ITTO, Montreal Protocol - MP, and Forest Europe - FE) and two certification schemes (Forest Stewardship Council - FSC and Sustainable Forestry Initiative - SFI)] to contextualize global changes in the standardization discourse of forest management practices over the last thirty years. The objective of this study is to identify convergence and dissonance between the five major standards over time by comparing the respective number of changes in their words and conceptual framing. We also contextualize those changes in the institutional histories to understand the trajectories of global forest governance discourse. It is not an exhaustive analysis as we do not include all the SFM standards that have ever existed but studying these five major standard systems can give a glimpse at the trajectory of global forest governance. First, we discuss the institutional histories of the five SFM systems. Second, we argue that standard development includes additions, removals, and restructuring of C&Is and in terminologies within those C&Is. Finally, our analysis of these changes in the five standards is discussed, considering the potential dynamics which may have shaped them over time.

2.2. HISTORIES OF SELECTED MAJOR SFM INSTITUTIONS

Jeon et al. (2019) discuss how institutional design and operational structures are relevant to the adoption of particular forest-related/focused policies by comparing the Association of Southeast Asian Nations (ASEAN) and MP. Furthermore, Fernández-Blanco et al. (2019) found that synergies are observed among vague institutional elements built on concepts like Sustainable Development and SFM while conflictive relations are camouflaged; instead, the conflictive relations crop up when institutional elements are of concrete subject matter, viz. trade vs. conservation elements, carbon credits vs. forest certification for sustainable management, etc. This makes understanding the dynamics of institutional histories important to assess the trends in the standardization of SFM practices.

2.2.1. INTERNATIONAL TROPICAL TIMBER ORGANIZATION (ITTO)

ITTO was founded by 64 countries belonging to the United Nations Conference on Trade and Development (UNCTAD) in 1983. It included producer and consumer countries in the context of tropical timber and had a mandate to tackle global resource management issues. The world's first International Tropical Timber Agreement (ITTA) designed to include forest conservation was ratified in 1985 between the ITTO members, but legal recognition was not gained until 1994 due to slow progress on the side of producer countries.

Gulbrandsen and Humphreys (2006) note that ITTO is dominated by trade interests based on its emphasis on 'sustainable timber production' as opposed to 'sustainable forest management.' They argue that ITTO shows a lack of leadership towards going beyond industry interests and is more reactive than initiative in international forest politics. Cadman (2011), along with Gulbrandsen and Humphreys (2006), state that while some NGOs undertook direct action campaigns, including export bans and timber boycotts, others looked to ITTO as a potential vehicle for change, and they began to lobby ITTO members to outline and enforce sustainability requirements on tropical timber. In 1987, ITTO had begun its legacy of authoring influential SFM literature by publishing the report *No timber without trees* to underscore subpar SFM practices in ITTO member countries, but a report from the International Institute for Environment and Development (IIED) found that less than one percent of global timber comes from sustainable sources was instrumental in pushing ITTO to look at SFM more closely (Humphreys, 2014).

In 1990, ITTO adopted its Year 2000 Objective, in which all tropical timber would be sustainably sourced by the year 2000, and in 1992 ITTO published *ITTO Guidelines for the Sustainable Management of Tropical Natural Forests,* a critical SFM landmark which functioned as the first internationally agreed-upon set of SFM criteria and issued its definition of SFM. In 1993, ITTO published additional SFM guidelines, and the corresponding C&Is were updated in 1998. In 2000, ITTO collaborated with the African Timber Organization (ATO) to design regional SFM C&Is. Though ATO was defunct as of 2013, its C&Is are still in use alongside ITTO in some countries. ITTO also supported regional SFM initiatives, such as the Yaoundé Declaration in Central Africa (2002), by supplying funds and SFM expertise to develop C&Is. ITTO also published guidelines for restoration and degraded forests (2002) and best practices for law compliance (2005) as well as a revised set of C&I complete with reporting format (2005). The current ITTA was adopted in 2006 and placed a premium on human welfare in relation to forests in addition to the economic and ecological value of forests. In 2009, ITTO and the International Union for Conservation of

Nature (IUCN) collaborated to issue guidelines for biodiversity conservation, and in 2013 ITTO, Food and Agriculture Organization (FAO), and International Technical Tropical Timber Association (ATIBT) combined to promote SFM in the Congo Basin. The following year, ITTO established the Independent Market Monitor for use in the European Union, and ITTO's knowledge-sharing initiatives have been formally ongoing since 2013. ITTO continues to collaborate with tropical countries and regions to implement C&Is, such as Thailand (2018) and Ghana (2018).

2.2.2. THE MONTREAL PROCESS (MP)

The MP was launched as a working group in 1994 to develop an array of C&Is for the then-unaddressed boreal and temperate forests. Gale and Cadman (2014) note that the development of C&Is in the MP standardization as well as in the Helsinki process standardization (later 'Forest Europe') was rapid in comparison to the failed negotiations to establish a global forest convention that occurred during and after the Rio Earth Summit of 1992. Relating the structure of policy networks to policy outcomes, they find the normative components of SFM standardization that emerged from Montreal process negotiations as more 'economistic' in nature when compared to the 'eco-social' SFM norms that emerged from FSC negotiations (see Section 2.4) which took place around the same time. The authors also state that the forest policy networks in Canada and the United Kingdom could be described as "closed, clientelistic, and resistant to new actors articulating new ideas" (page 173). By the beginning of the 1990s, Canada's forest policy networks were going through economic recession, mill closures, and severe pressure from United States-based Coalition for Fair Lumber Imports for de-subsidizing imports (the 'softwood lumber dispute') while the environmental movement was calling for boycotts of environmentally controversial forest products (Cashore, 1997; Maser, 1990). Standardizing SFM on a national level via the MP allowed Canada to move from 'old' sustained yield to 'new' SFM conceptualizations by implementing hierarchical PC&Is, deflect criticism from NGOs and civil society (both domestic and international), and provide a 'coherent and defensible alternative to FSC' (Gale and Cadman, 2014). Canadian delegates started negotiating with forestry officials from North America and Europe, holding their first meeting in October 1993, which led to the first set of C&Is. The European representatives decided to pursue a separate Helsinki Process for developing C&Is for temperate and boreal forests in Europe. Gale and Cadman (2014) argue that the rapid progress in the development of C&Is was because the working groups included a small number of closely related and like-minded forestry diplomats, the international expertise of Canada's chief negotiator (Jagmohan Maini), and already established templates of PC&Is.

In terms of actual standardization events, the MP guidelines began with the Santiago Declaration in 1995, which established the scope and definitions of its C&Is in assessing SFM in boreal and temperate forests. The Santiago Declaration recognized the value of an internationally accepted understanding of SFM in boreal and temperate forests in addition to acknowledging the need to consider the differing characteristics of member countries' forest types, culminating in seven criteria and 67 indicators (MP, 1995). Its C&Is were designed to be implemented at the national level and apply to all forests and ownership types (MP, 1999). In 2003, the MP published its first Country Forest Report, which contained reports from each member country measuring their forests against the MP C&Is. No country could provide information on all seven criteria and 67 indicators, and the report cited difficulties in reporting data stemming from discrepancies in collection methods, appropriate data collection, and data interpretation (MP, 2003a). In 2003 the MP issued the Québec City Declaration, which outlined the MP vision for the future (2003-2008) and included additional goals, such as increased communication and collaboration with other C&I processes and the endorsement of a global set of criteria (MP, 2003b). C&Is were revisited and revised in 2007 and 2009. In 2009, the MP also implemented its Strategic Action Plan, which outlined five initiatives to enhance boreal and temperate forest SFM through 2015. The second Country Forest Report was also published in 2009, which highlighted how the MP and its member countries responded to four key issues of climate change, bioenergy, biodiversity, and water (MP, 2009). The MP's most recent declaration, the Yanji Declaration, was issued in 2017 and reaffirmed member countries' commitment to the MP and SFM promotion and implementation (MP, 2017).

2.2.3. FOREST EUROPE (FE)

Although Europe hosts an abundance of boreal and temperate forests, the European countries opted to develop a regional system distinct from the MP. Facilitated by the Ministerial Conference on the Protection of Forests in Europe, FE is a leading SFM entity in Europe. Originally called the Helsinki Protocol, the organization adopted the name FE in November 2009. FE hosts periodic ministerial-level conferences designed to address problems in European SFM and adopt resolutions, and its first activities predate the Rio Earth Summit (European Commission, 2021). In 1990, the organization issued the Strasbourg Declaration, recognizing the contribution of forests to ecological and economic well-being. Its 1993 Helsinki Protocol expanded the contributions of forests to socio-cultural values and acknowledged the importance of biodiversity conservation, climate change, and cooperation with countries in transition to market economies

(FE, 2021a). Its subsequent conference, the 1998 Lisbon Declaration, saw the establishment of socioeconomically focused C&Is. In 2003, the Vienna Declaration expounded the necessity of biodiversity, introduced C&I for climate change mitigation, and emphasized the economic and socio-cultural dimensions of SFM. Subsequent declarations have emphasized issues of energy, water, wood and wood products, climate change, and the development of a green economy (FE, 2021a). FE guidelines are designed to prioritize and promote SFM implementation and to be generalized, guiding political principles that can be adapted to suit local and national parties. C&Is articulate a series of voluntarily adopted recommendations for national stakeholders and decision-makers and emphasize economically viable, environmentally sound, and socially equitable approaches to SFM that complement preexisting SFM measures (FE, 2016). Areas of focus include afforestation, reforestation, communication, and stakeholder participation.

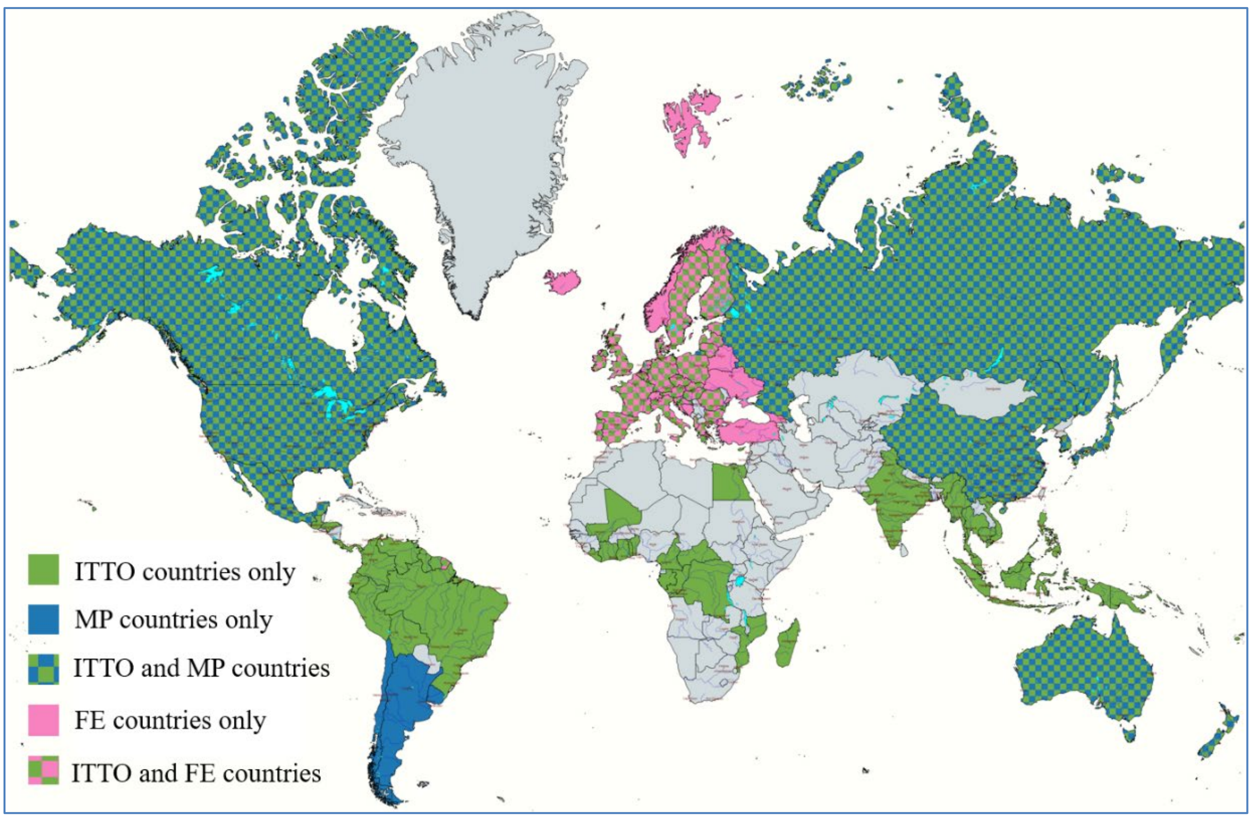

Figure 2. Geographical coverage of the three international protocols selected in the study. Overlapping countries are also shown in the figure. ITTO: International Topical Timber Organization, MP: Montreal Process, FE: Forest Europe.

Figure 2 shows the current geographical coverage of the selected protocols for this study. ITTO member countries, being divided into producing and consuming blocks, shows overlap with the countries which are part of MP and FE protocols. The discourse of SFM standardization clearly shows more temperate and boreal focus, with multiple protocols being actively engaged in the related countries.

2.2.4. FOREST STEWARDSHIP COUNCIL (FSC)

First lobbying efforts for forest certification and labeling scheme came from FoE in 1985 based on consumer awareness of the impacts of procuring tropical timber in the United Kingdom and Europe. They started their own 'Good Wood' program, and related labels started showing up from 1988 onward, which was the same time when the IIED report was published (Humphreys, 2014). Stiglitz (2003) observes that FoE had proposed a global forest certification scheme to ITTO in 1989, but ITTO Council rejected the same with a statement that it was "a veiled attempt . . . to encourage the current campaign of boycott against the import of topical timber products" (page 63). This prompted FoE to withdraw from the process and encouraged other NGOs to begin forming coalitions to develop the proposed certification system, the most prominent among which were the World Wide Fund for Nature (WWF) and the Rainforest Alliance[1] (Cadman, 2011). The WWF began negotiating with the forestry industry in 1991 to organize a trade network leading to the formation of the world's first global forest certification program in 1993 after the Earth Summit – the Forest Stewardship Council (FSC). Cadman (2011) notes that ITTO's lack of leadership in taking up the certification issue, predicting that 'the concept would leave the ITTO behind'. The birth of multi-stakeholder, multi-level certification can be situated in the results of Fernández-Blanco et al. (2019), who found that conflictive relationships exist in the context of concrete subject matter especially trade versus conservation interest groups; this was also noted by Ven and Cashore (2018). These have shaped the competitive dynamics between the industry and NGO-driven forest certification schemes. Cadman (2011) argues that current competitive dynamics have originated from and shaped by NGOs response to consumer skepticism regarding companies 'self-certifying' their forest products and the strategies of NGOs to keep industry in more effective dialogue than adopting direct action campaigns. Gulbrandsen and Humphreys (2006) argue that even though ITTO has increased its interest in forest certification since 1994, like the FAO, they have tended to treat the subject as a more technical and less political process.

FSC's approach to standardization includes developing voluntary forest management standards through a balanced, deliberative multi-stakeholder voting. FSC has three (environmental, social, and economic) chambers in its General Assembly (GA), each with one-third weights of votes which are further sub-divided into the global north and global south sub-chambers (FSC, 2020a;

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[1] Rainforest Alliance started its own SmartWood certification program in 1989.

van der Ven and Cashore, 2018). FSC employs global principles and criteria (P&Cs) developed by the FSC International but facilitates the development of locally contextualized standards, called indicators and their subsequent verifiers at the national level through its national bodies, to encourage sustainable forest management. It offers three types of standards: Forest Management, Chain of Custody (the integrity of supply chains), and Controlled Wood (responsible sourcing) standards (FSC, 2020b). The first set of unofficial P&Cs was approved at the Founding Assembly in 1993, but the newly established FSC Board of Directors approved the official first version of P&Cs in 1994. There were nine principles before the 1996 amendment in which the plantation-specific tenth principle was approved and established. The FSC subsequently made revision to the P&Cs in 2000 (document 1.2), 2005 (v4-0), and 2015 (v5-2) (FSC, 2021b).

In the beginning, FSC did not enjoy much support from the industry stakeholders and landowners because of the higher complexity of standards required to be implemented on the ground and the cost of certification itself (Cashore et al., 2004). They also did not think that their interests would be fairly represented in the institution's governance structure (Cashore et al., 2004). FSC has implemented strategic measures to attract industry stakeholders, many of which have been criticized for lowering the forest management standards (Humphreys, 2012). The proliferation of FSC certificates worldwide was driven in a major way by WWF's alliance of producers, forest landowners, and consumers called the Global Forest and Trade Network (GFTN), which NGOs use to promote FSC certifications across the global supply chains (Gulbrandsen and Humphreys, 2006). FSC has enjoyed strong support from NGOs since its inception, which partly has also led to its growth, although this support has faded in the last decade due to market competition and controversies. On the other hand, FSC has seen severe constraints imposed in its growth and development due to competition from other global forest certification programs, the largest of which is Programme for the Endorsement of Forest Certification (PEFC) (Gulbrandsen, 2005). Based within the fabric of the socio-political and economic contexts of the global forest products sectors and other national transnational processes, the trust and legitimacy of the market-driven governance as perceived by NGOs and civil stakeholder groups has seen an erosion of social capital (Moog et al., 2015). FSC, in the last decade, has seen NGO stakeholder groups leaving the certification program due to a 'race to the bottom' in terms of procedural and substantive norms (FERN, 2011; Lee, 2009). Nevertheless, after more than 25 years, it has created a formal and informal dialogue surrounding SFM between various stakeholders, including FMEs (Pappila, 2013). To date, FSC has certified over 222 million hectares of forest area globally (Fernholz et al., 2021).

2.2.5. SUSTAINABLE FORESTRY INITIATIVE (SFI)

It is important to note that PEFC does not have forest management standards of its own which get implemented on the ground as they are but is actually an umbrella certification program that endorses national and regional certification schemes based on standards for the scheme developers. For example, in North America, PEFC has endorsed the SFI, American Tree Farm System, and the Canadian Standards Association (PEFC, 2021a). In terms of area certified, with 152 million hectares area certified to forest management standards, the SFI is the world's second-largest single certification scheme after FSC; it is the largest in North America (Fernholz et al., 2021). Therefore, our study covers changes in the SFI standards instead of the PEFC standards for endorsement, not all of which are found in SFI forest management standards, e.g., P&Cs regarding trees outside forests.

The American Forest & Paper Association (AF&PA) founded the SFI in North America (the United States and Canada only) in 1994 in response to the FSC. The External Review Panel (ERP) was established by the AF&PA Board in 1995 to advise the SFI; ERP became independent in 1997, although the exact reasons are not clear (Stryjewski, 2007). The first version of standards was set by the industry association (second party), and their voluntary enforcement was first-party (self-assured). To improve its reputation and trust amongst stakeholders, in 1998, an option of third-party certification was included (Sasser et al., 2006). Furthermore, the Sustainable Forestry Board (SFB) was established by AF&PA to expand the stakeholder networks in 2000; 40% of the board was made of firms, and the rest from diverse stakeholder groups (Stryjewski, 2007). In 2001, SFI became an independent, not-for-profit organization. SFI executive and some staff were still employed through AF&PA at this time. In 2002, SFI followed suit with FSC's three-chambered model of stakeholder engagement. SFI achieved endorsement with the PEFC in 2005. Finally, at the beginning of 2007, the SFI became a fully independent, non-profit organization. SFI offers three certification standards like FSC: Chain of Custody, Forest Management, and Fiber Sourcing. SFI Forest Management standards are applicable to only North America, while coverage of FSC Forest Management standards is global.

2.3. ANALYSIS OF PC&I STANDARDIZATION

Forest governance, today, is considered to be a collection of processes through which the forests, their participatory management, and the general forestry resource utilization are governed

(Mohanty and Sahu, 2012). It covers planning, decision-making, implementation, and monitoring. Since the Agenda 21 of United Nations Conference on Environment and Development held in Rio in 1992 – where globalization of forestry stakeholders was heralded most prominently – designing and implementing 'principles, criteria, indicators, and verifiers' (PCI&V) of what constitute good forestry practices in multi-level systems (inter-/national/regional to local forest management unit/FMUs) has been deemed crucial for instituting SFM (Prabhu et al., 1998). This approach of PCI&Vs, PC&Is, C&Is, or even similar terminologies like objectives and performance measures (O&PM) in different systems represent Ockham's Razor approach to managing the complexities of global people-forestry linkages and interactions (Colfer et al., 1995). They form a hierarchy of assessment tools with an increasing level of specificity.

Prabhu et al. (1996) and FAO (2004) define a principle as a fundamental truth or law as the basis of reasoning or action to be formulated around core concepts dependent on ethics, values, as well as the scientific and traditional knowledge. It is the primary framework of SFM standardization and gives justification for the other three components of criteria, indicators, and verifiers. A criterion is defined as a standard that a thing is judged by and is conceptual enough to be a 'second order' principle because it adds a level of operationalization without being a direct measure of performance" (FAO, 2004). For example, for the principle of *ecosystem integrity is maintained*, one of the criteria could be *processes that maintain genetic variation are maintained* (FAO, 2004). An indicator is a further specification of criteria; it is *any variable or component of the forest ecosystem or the relevant management systems used to infer attributes of the sustainability of the resource and its utilization* (FAO, 2004). For the criterion - *processes that maintain genetic variation are maintained*, an appropriate indicator could be *directional change in allele or genotype frequencies*. In the example, the data that determines the acceptable standard of performance of *directional change in allele or genotype frequencies* can simply be *number of alleles* (FAO, 2004; Prabhu et al., 1996). This last level in the hierarchical specificities of SFM standardization is sometimes termed as a verifier. The revision of relevant PCI&V for protocols and certification schemes is driven through stakeholder consultation (Boström and Hallström, 2013).

The use of the terms – principles, criteria, indicators, and verifiers – differs slightly between the protocols and certification schemes. The different goals of the protocols and certification schemes also affect their overall framing, i.e., while the protocols are framed as "policies for health and safety," the corresponding certification schemes are always framed as "the organization *shall* have a policy on health and safety." This framing difference also stems from the goals of data collection and performance verification, respectively. Bueren and Blom (1997) argue that the hierarchical PC&I approach has its limitations, i.e., different standards can have a different interpretation of terms and different hierarchical placements within the standards, making them difficult to compare. Moreover, for developing the procedural and substantive criteria, indicators, and verifiers efficiently and effectively, it is critical to account for the diverse differences in geography, temperature and precipitation regimes, native wildlife, and historical human use among global forests as well the differences in socio-political and cultural affinities of human systems to natural resources. Such differences have meant that global forests are inherently managed differently, with unique protocols and certification schemes tailored to specific regions. This also insinuates that protocols and certification schemes are inherently dynamic in nature and respond to changes in environmental, cultural, political, and other relevant paradigms.

We are interested in comparing how the outcomes of stakeholder mobilization and coordination, viz. SFM standard development, come about. Indicators can be quantitative or qualitative, but as the FAO (2004) notes, "change in indicators cannot inherently be good or bad; it requires an assessment based on an acceptable standard of performance which is always geographically and culturally varied." Facilitation of responsible forestry discourse in protocols and certification systems takes place using keywords to identify important concepts discussed between the network members. As Sapir (1921) notes, "language is a symbolic guide to culture" (Sapir, 1921), henceforth, an understanding of cultural forces that shape SFM standard development for protocols and certification systems would need to come about through comparisons of keywords and concepts that have changed over time (Wierzbicka, 1997). Keywords can be added, removed, or exchanged within C&Is over time depending upon the support of stakeholder policy networks, which in turn is also dependent on ever-changing market, political, and social circumstances. Based on this argument, in the following section, we outline our methodology of assessing the trajectory of global forest governance by analyzing the changes in standards of the selected five SFM institutions.

2.4. METHODS

Arts and Buizer (2009) support a 'discursive-institutional' approach for understanding changes in global forest policy arrangements describing four possible discursive approaches - discourses as communication, texts, frames, and social practices. We agree with the authors that the combination of the latter two provides a more contextual and holistic picture of global policy changes as they relate how and to what extent ideas, concepts and narratives become institutionalized through particular framing of concepts and changes in the involved interest groups, respectively. Arts and Buizer (2009) use the policy arrangement analysis (PAA) approach of discursive institutionalization to outline trends in the global forest policy arena. We apply the same approach in this study. The protocols and certification schemes covered in this study cover the largest of global patchworks in the forest management regime complexes. In this section, we outline our methodology to track change and continuity in text and concept frames within standards of the selected five different global forest institutions, and finally, compare framing of the standards using generic categories.

We analyzed published standards for ITTO, MP, FE, FSC, and SFI from publicly available sources (FE, 2021b; FSC, 2021b; ITTO, 2021; MP, 2018; SFI, 2021a). A list of all the standards reviewed can be found in Annexure 1. We focused on primary forest management standards only. For example, in the case of ITTO, separate standards for mangroves and fire management were not included. The oldest certification standards, which were not available publicly, were obtained by contacting FSC and SFI directly. We selected only Forest Management Standard for certification schemes as well.

In the first part of our analysis, we went through the standards to extract the C&Is and qualitatively understand their trends over time since inception. The extracted C&Is for years in which major changes happened were identified, and the analysis of trends was divided into two periods – one from 1990 to 2005 and the second from 2005 to 2020. We then categorized the structural but substantive changes in the indicators for protocols and criteria for certification standards. Two types of changes were recorded: one regarding the restructuring of C&Is, i.e., whether one old indicator was separated into two or more in the following version and whether two or more older indicators were combined into a new indicator in the following version: those that did not undergo any restructuring changes were classified into an ‘unstructured’ group. The second type of change recorded was whether any terms were added, removed, and/or swapped from the older version to the following version and whether any whole new criteria and indicators were added or removed. Sankey diagrams have been known to be efficient in graphically depicting temporal flow changes (Cuba, 2015). Encoding the two types of changes, we created one Sankey diagram for each selected protocol and certification standard. We then compared the observed trends of changes in protocol indicators and certification criteria in each period to understand the C&I

convergence and dissonance between them. This methodology follows from the 'discourse as text' approach described by Arts and Buizer (2009), in which analysis of change in words in texts is undertaken.

In the second part of the analysis, we identified convergent and dissonant trends between the three protocols and the two certification schemes in a qualitative manner. To compare the level of convergences between the five standards, we used a framework of categories of C&Is extracted from the most common components of the five SFM standards, i.e., administrative, ecological, economic, institutional, legal, productive, and socio-cultural requirements (see Table 1 for definitions). Each of the indicators in all the versions of the five standards was categorized into seven categories. We measured the percentage of changed categories of indicators in each SFM process. This analysis follows from the 'discourse as frames' approach described by Arts and Buizer (2009) in which comparing changes in framing of concepts between the standards can provide more details about the underlying trends in the global forest governance.

Table 1. A framework of C&I categories extracted from the most common concepts found in three protocols and two certification standards.

Conceptual Frames	Definitions of Conceptual Frames
Administrative	Monitoring, Assessment, Management Plans, Availability of Guidelines, Strategies, and Tracking Systems related indicators
Ecological	Indicators related to Identification and Conservation of Natural Resources, Ecosystem Services, and Forest Products
Economic	Funding, Investment, and Taxation related indicators.
Institutional	Internal Structure, Staffing, Training, External Partnerships, Public Participation, Conflict Resolution, Programs & Services, R&D related indicators.
Legal	Legislation and International Agreements, including labor related indicators.
Productive	Indicators related to Maintenance of Productive Capacity and Sustained Yield.
Socio-cultural	Community Needs, Rights, Resource Distribution including Employment related indicators.

2.5. RESULTS

2.5.1. CHANGES IN ITTO STANDARDS

In the original ITTO version (1990-1992) for SFM standards for natural forests, there were 41 principles covering components of policy and legislation, forest management (planning, harvesting, protection, legal management, monitoring, and research), as well as socio-economic and financial aspects (relationship with the local population, incentives, taxation). These elaborated further into criteria and actions. This was simplified in 1993 for planted forests based on the inputs by the ITTO expert panel. It elaborated the standard into four components for planted forests, including policy and legislation, feasibility assessments, the establishment of planted forests, and post-establishment of planted forests, having a total of 66 principles.

In the 2004 version of its SFM standards, ITTO introduced the framework of seven criteria (a) enabling conditions for sustainable forest management, b) the extent and condition of forests, c) forest ecosystem health, d) forest production, e) biological diversity, f) soil and water protection, and g) economic, social, and cultural aspects) making the 1993 components more succinct and updated. This development followed in suit from the International Conference on the Contribution of Criteria and Indicators for Sustainable Forest Management that took place in 2003 in Guatemala (FAO, 2003). This revision brought the ITTO standard framework closer to MP and FE categorization of C&Is as noted below compared to ITTO's own initial versions of the SFM standards. The same framework of seven criteria was followed in the 2016 version of the ITTO standards, with only the third criterion expanded to 'forest ecosystem health and resilience'; the number of indicators for this criterion increased from two to five from 2004 to 2016 version of the standard. The number of indicators in the second criterion also increased from 10 to 12 in 2016. The criteria which had their indicators reduced in number were the fourth (forest production) and seventh (economic, social, and cultural aspects) – both had two indicators less. Apart from this change, very little restructuring took place to form the ITTO standard of 2016.

Figure 3 shows the detailed substantive structural changes that have taken place in the ITTO C&Is from 1992 to 2004 to 2016 versions. The 1992 version of C&I had separated the forest-level C&Is from the national level C&Is, but in subsequent iterations, they were combined. In the first iteration of the ITTO standards, we found that majority of C&Is were of productive (15) and ecological types (14) followed by legal (7) and institutional (6) types. Twenty-three new indicators were added in 2004, while four old ones were removed from 1992 during the first period. Sixty-three indicators were restructured while terms were added into 62, terms removed from 59, and terms were swapped in 54 indicators. Out of the new indicators – nine were socio-cultural, six were ecological, three were administrative, two belonged to economical and productive types each while one was of institutional type. Out of the indicators which got restructured from the 1992 standard – 20 were ecological, 14 were administrative, nine were institutional, eight belonged to productive type, five were economic, and three each belonged to legal and socio-cultural categories. Terms were added to 21 ecological, 14 administrative, 11 institutional, eight productive, five economic, and three socio-cultural indicators while terms were removed from 21 ecological, 16 administrative, eight productive, five economic, four institutional, three socio-cultural, and two legal types of indicators. Term swapped happened for 19 ecological, 11 administrative, nine institutional, eight productive, four economic, and three socio-cultural indicators.

In the second period, eight indicators were added new in 2016 (five of ecological and three each of administrative and institutional types) while 12 old ones were removed from 2004 (five institutional, three ecological, and two each of productive and socio-cultural types). Only 11 indicators were restructured (nine belonging to productive and two to ecological types). At the same time, terms were added into 34 (11 productive, 10 administrative, five ecological, four socio-cultural, three institutional, and one economic type of) indicators, terms removed from 57 (14 productive, 13 ecological, nine administrative, eight each of institutional and socio-cultural types, three legal, and two economic), and terms were swapped in 12 indicators (nine productive, two ecological and one of socio-cultural type).

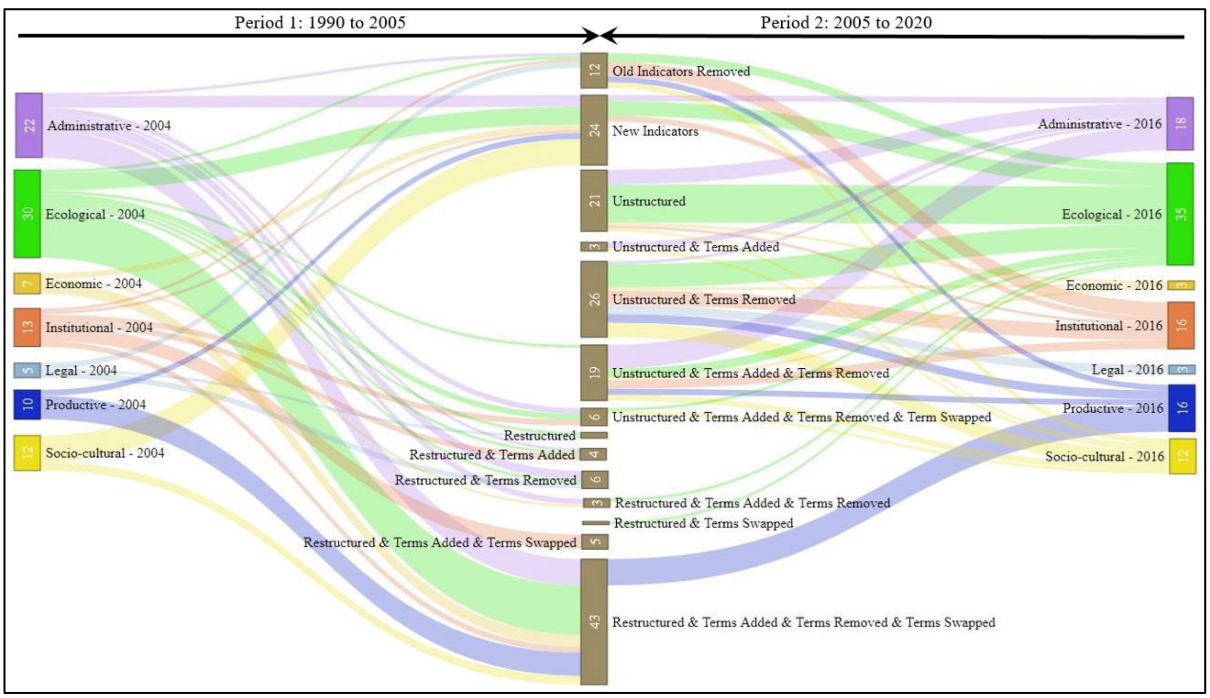

Figure 3. Changes in International Tropical Timber Organization protocol between 1992 and 2016 standard iterations. The numbers in the boxes and sizes of the connections between them indicate the number of indicators that changed (in terms of the words and their seven concept frames noted in Table 1). Color coding is done for each concept frame and center pillar enlists the types of changes.

2.5.2. CHANGES IN MP

In the context of the MP, the first version of the C&Is that was established in 1995 bear similarity with the ITTO's current seven-criteria framework, which has continued till the most recent (fifth) version of MP C&Is established in 2015, i.e., a) conservation of biological diversity, b) maintenance of productive capacity of forest ecosystems, c) maintenance of forest ecosystem health and vitality, d) conservation and maintenance of soil and water resources, e) maintenance of forest contribution to global carbon cycles, f) maintenance and enhancement of long-term multiple socio-economic benefits to meet the needs of societies, and g) legal, institutional and economic framework for forest conservation and sustainable management. In the first iteration of the MP standards, we found that majority of C&Is were of ecological (23), productive (14), and institutional (10) types. In 2007's second edition C&Is, Criterion 1 underwent an only restructuring of indicators, while in Criterion 4 - there was restructuring and a reduction in the number of indicators from eight to five. Most changes in the C&Is come in 2009 from criterion seven. There were 20 indicators for this criterion in 1995, which were reduced to 10 in 2009. Overall, from 1995 to 2015, the total number of indicators has reduced from 67 to 54.

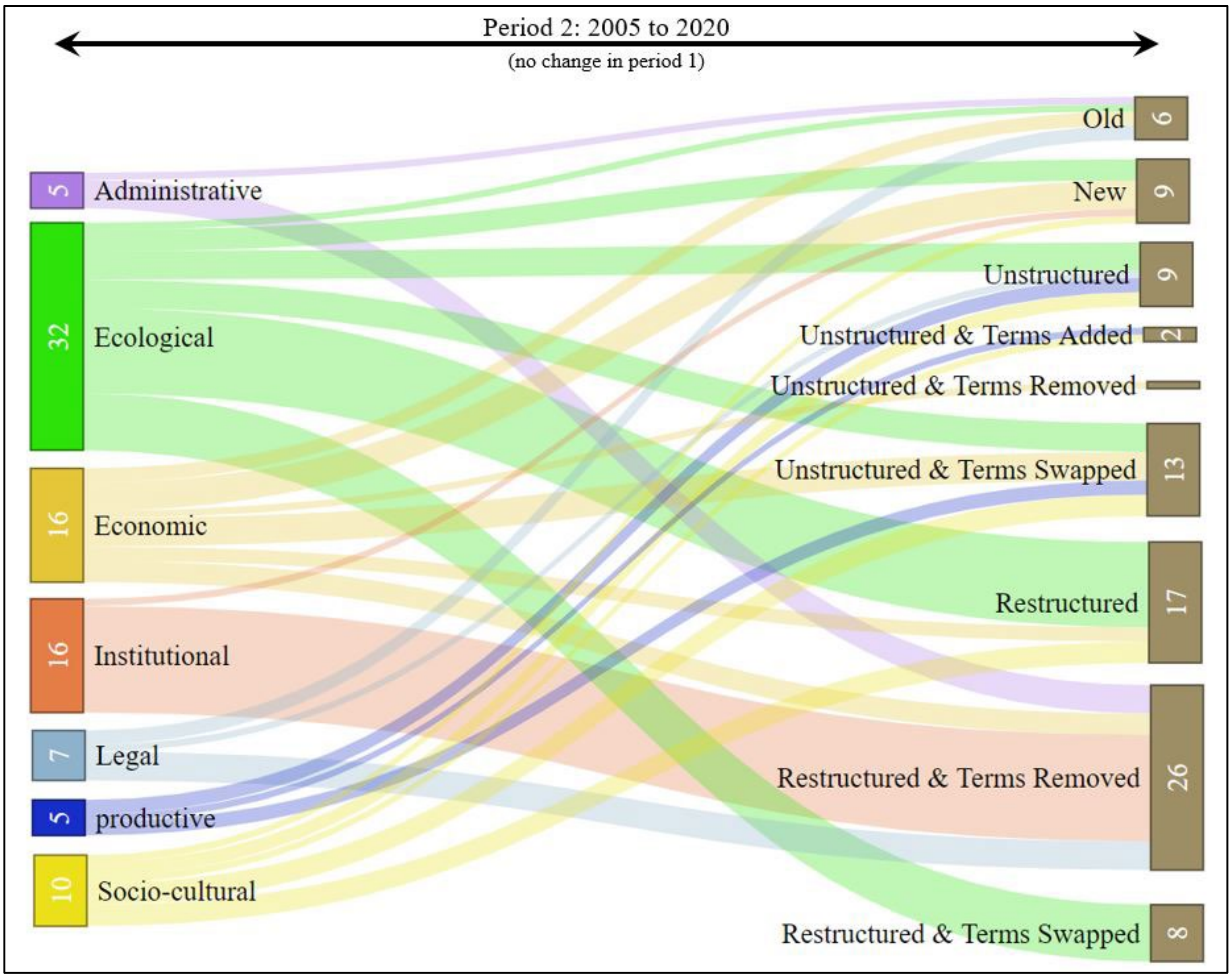

Figure 4. Changes in Montreal Protocol between 1995 and 2015 standard iterations. The numbers in the boxes and sizes of the connections between them indicate the number of indicators that changed (in terms of the words and their seven concept frames noted in Table 1). Color coding is done for each concept frame, and the right-side pillar enlists the types of changes.

In terms of the qualitative components of the standards themselves, the MP initially had more general and broader indicators before the 2007 and 2009 changes in its standard; for example, water quality indicator for MP in the first edition C&Is (4.c) was “percent of stream kilometers in forested catchments in which streamflow and timing have significantly deviated from the historic range of variation.” After the changes in the MP C&Is, the water-related indicators in Criterion 4’s first indicator was “proportion of forest management activities that meet best management practices or other relevant legislation to protect water-related resources.” This trend seems to give more agency and control to the forest managers. We also noticed these trends in the comparisons between standards components related to biodiversity, harvest levels, plantations, and chemical use.

Figure 4 shows the substantive structural changes that have taken place in the MP C&Is from 1995 to 2015 versions only as these two versions had the most salient changes. It is important to note that no changes happened in the MP standards before 2005, so Figure 4 only depicts changes that have taken place in the second period of our analysis.

Nine indicators were added (four economic, three ecological, one institutional, and one of socio-cultural type), while six old ones were removed from 1995. In total, 51 indicators were restructured (20 ecological, 15 institutional, five economic, four each of legal and administrative types as well as three indicators of socio-cultural type). While terms were added into just two indicators (one productive and one socio-cultural), terms were removed from 27 (15 institutional, and four each of administrative, legal, and economic), and terms were swapped in 21 indicators (12 ecological, four economic, three socio-cultural, and two productive types of indicators).

2.5.3. CHANGES IN FE

The six main criteria of FE found in the 1998 version (post-Lisbon resolution) cover a) general capacity (forest resources and carbon), land use and forest area, growing stocks, b) forest health and vitality, c) productive (wood and non-wood) functions, d) biological diversity, e) protective functions (general, soil and water); and finally, and f) socio-economic functions and conditions (forest sector, recreational services, employment, research, education, participation, and cultural values). In this initial iteration of the FE standard, indicators were differentiated between descriptive and quantitative; each of the six criteria had both types of indicators. In the subsequent two iterations of the C&Is of FE, from the Vienna (2002) declaration to the Madrid (2015) declaration, the number of quantitative indicators has stayed around the same (35 to 34), while the qualitative indicators have reduced from 19 to 11. More specifically, in the Vienna declaration, the qualitative indicators from 1998 version were consolidated into two separate categories at the end of the document requiring data on policies, institutions, and instruments belonging to ‘A’ (general SFM) and ‘B’ (by policy area/criteria). In the Madrid declaration, the latter (‘B’) was termed as ‘C’ category and assigned to each criterion, consolidating qualitative indicators further from 12 ‘B’s to 6 ‘C’s. Substantive changes like the inclusion of wood energy as well as occupational health and safety (among the qualitative indicators) come from the sectoral changes that the forestry industry has seen since the mid-1990s, as has been noted in the institutional histories of both MP and FE above as well as by Myers and Fosbroke (1995).

Figure 5 shows the substantive structural changes that have taken place in the FE C&Is from 1998 (post-Lisbon declaration) to 2002 to 2015 versions; these were the three versions in which C&I changes were most salient in terms of changes in the FE protocol standards. In the first iteration of the FE standards, we found that majority of C&Is were of ecological (23), productive (14), and institutional (10) types. Fourteen indicators were added new in 2002 (four each of ecological and economic types, two each of productive and socio-cultural types, and one each of administrative and institutional), while one qualitative indicator was removed from 1998 during the first period. Twenty-four indicators were restructured (15 institutional, seven ecological, and one each of legal and productive types). In comparison, terms were added into four indicators (two ecological and one each of institutional and socio-cultural types), terms removed from 32 indicators (16 institutional, 13 ecological, and one each of legal, productive, and socio-cultural), and terms were swapped in three indicators (two ecological and one productive). In the second period, only four new indicators (three ecological and one economic) were added in 2015, while eight old ones were removed from 2002. Five indicators were restructured (four institutional and one ecological). At the same time, terms were added into 10 (six institutional, three ecological, and one socio-cultural), terms removed from five (four institutional and one socio-cultural), and only one indicator of ecological type had terms swapped.

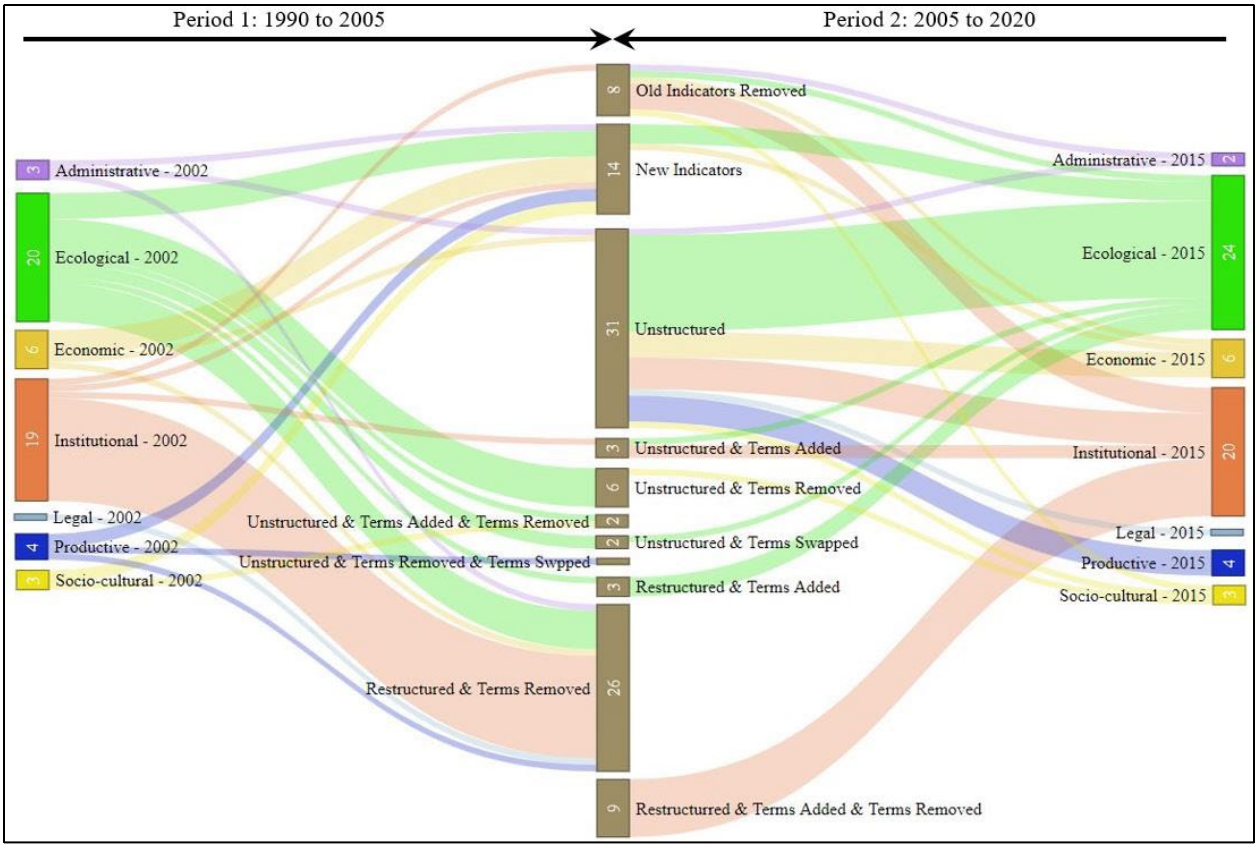

Figure 5. Changes in Forest Europe protocol between 1998 and 2015 standard iterations. The numbers in the boxes and sizes of the connections between them indicate the number of indicators that changed (in terms of the words and their seven concept frames noted in Table 1). Color coding is done for each concept frame, and the center pillar enlists the types of changes.

2.5.4. CHANGES IN FSC

FSC's Principles and Criteria Standard (FSC-STD-01-001) had about six iterations from 1994 when its board of directors approved the first version to 2015 when the current version – v5.2 – was adopted. Apart from this significant change, the first period saw minimal to no changes in the FSC criteria. In the second period, from 2005 to 2015, new indicators were introduced in the socio-cultural and legal (Principles 1, 3, 4), institutional (Principle 2), as well as ecological (Principle 6) aspects of the forest management standards. There was a significant restructuring of C&Is from the previous period into the new standard, while terms were added more often than removed or swapped in the unstructured C&Is.

Figure 6 shows the substantive structural changes that have taken place in the FSC P&Cs from 1994 to 2005 to 2015 versions. FSC had higher ecological (11), socio-cultural (11), and administrative (12) types of C&s in its first iteration of forest management standard. Seventeen criteria were added new by 2005 (13 ecological, three productive, and one administrative), while two old ones were removed from 1994 during the first period. There was neither restructuring of any indicators nor any changes to the criteria terms.

In the second period, 16 criteria were added new in 2015 (five socio-cultural, four institutional, three ecological, two each of administrative and legal types), while eight old ones were removed from 2002. Nineteen criteria were restructured (12 ecological, and two each of administrative, productive, socio-cultural, and one legal type) while terms were added into 48 criteria (19 ecological, eight each of administrative and socio-cultural, four institutional, three each of legal and productive, and two economic), terms removed from 32 (15 ecological, eight administrative, three each of institutional and productive, two socio-cultural, and one economic), and ten criteria had terms getting swapped (three each of ecological and productive, two legal, and one each of administrative and institutional types). We observed that the volume of changes was drastically high in the second period.

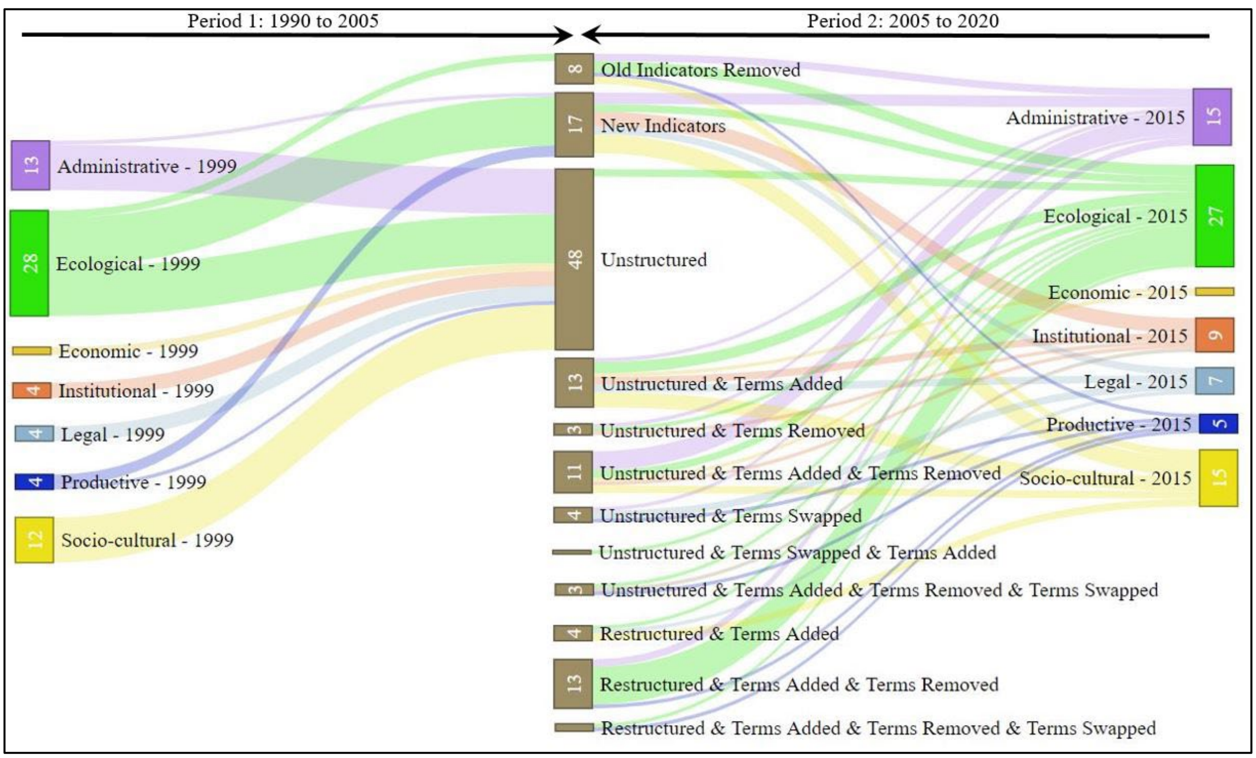

Figure 6. Changes in Forest Stewardship Council Forest Management standards between 1994 and 2015 standard iterations. The numbers in the boxes and sizes of the connections between them indicate the number of indicators that changed (in terms of the words and their seven concept frames noted in Table 1). Color coding is done for each concept frame, and the center pillar enlists the types of changes.

2.5.5. CHANGES IN SFI

The first forest management standard outlining a set of O&PMs driven by SFI as an independent organization was established in 2005. O&PMs were still present in the first version of the standard in 1995 when SFI was under the management of AF&PA, but a large volume of changes took place during the first period. The changes were procedural as well as substantive. For example, in the AF&PA version of the FM standard, a certificate holder was required to self-report conformances. In the subsequent iterations post-1999, third-party certification reports were required to demonstrate FM conformance. In the second period, procurement-related PMs were clearly being moved to the separate standard annex called Fiber Sourcing Certification Standard, but overall, fewer changes took place in SFI Forest Management Standards from 2005 to 2015 as compared to the first period. Overall, there were 12 objectives in the 1995 standard, which increased to 13 in the 2005 standard and 15 in 2015 standards.

Figure 7 shows the substantive structural changes that have taken place in SFI's O&PMs from 1995 to 2005 to 2015 versions. In the first iteration of the SFI standards, we found that majority of C&Is were of institutional (11), ecological (7), and socio-cultural (5) types. Eleven PMs were added new by 2005 (four institutional, three administrative, two ecological, and one each of legal and productive types), while twelve old ones were removed from 1995 during the first period. Five PMs were restructured (four institutional and one socio-cultural). At the same time, terms were added into 15 (six institutional, five ecological, two socio-cultural, and one each of economic and productive types), terms removed from 16 (seven institutional, five socio-cultural, three ecological, and one legal), and terms were swapped in three indicators (two ecological and one socio-cultural).

In the second period, nine PMs were added new in 2015 (four ecological, three socio-cultural, one administrative, and one institutional), while four procurement-related old ones were removed from the 2005 version. No instances of PM restructuring were observed during this second period. Terms were added into four PMs (one each of ecological, economic, institutional, and socio-cultural)), terms removed from three (all ecological type PMs), and one PM had terms getting swapped (productive).

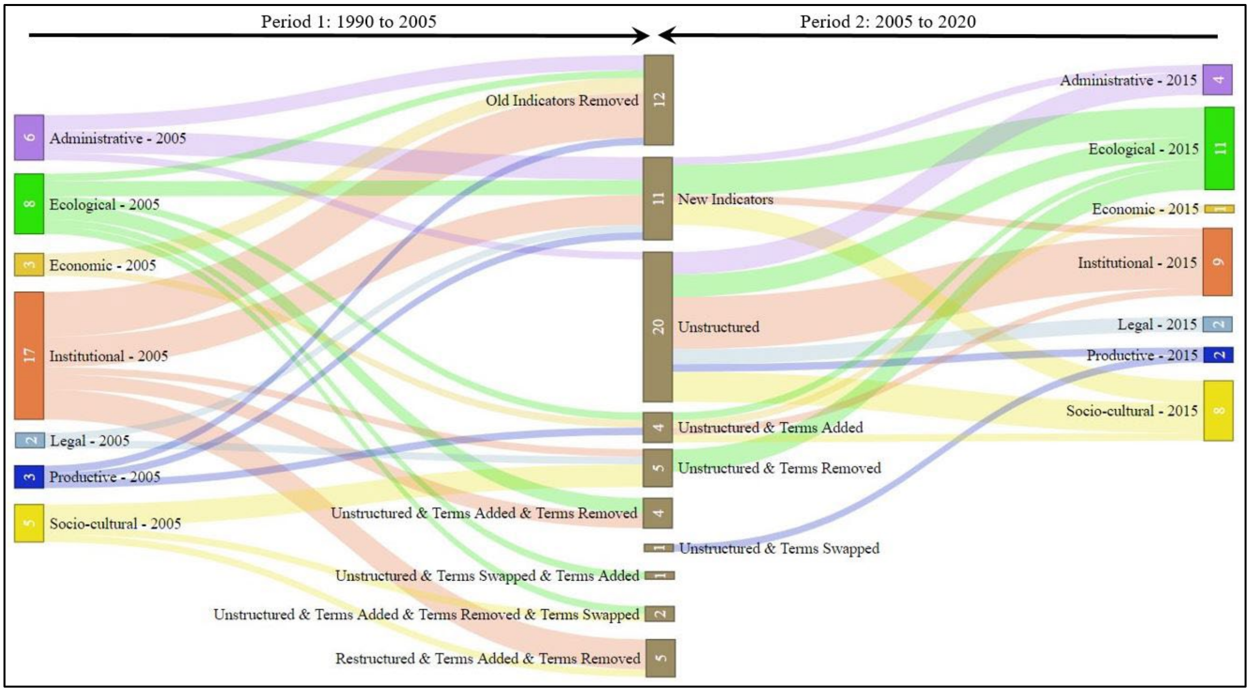

Figure 7. Changes in Sustainable Forestry Initiative Forest Management Standard between 1995 and 2015 standard iterations. The numbers in the boxes and sizes of the connections between them indicate the number of indicators that changed (in terms of the words and their seven concept frames noted in Table 1). Color coding is done for each concept frame, and the center pillar enlists the types of changes.

2.6. DISCUSSION

2.6.1. QUANTITATIVE COMPARISONS OF THE VOLUME OF C&I CATEGORY CHANGES OVER TIME

The results for the analysis of ITTO standard changes show that the first period had more structural and substantive changes as compared to the second period. Moreover, in the first period, ITTO introduced new indicators, added terms to, and swapped terms from six out of seven C&I categories, while restructuring and terms removal came from all seven categories. In the second period, on the other hand, new and restructured indicators came from only three and two categories, respectively, while addition and removal of terms came from six and seven types of C&Is, respectively. FE had more addition and restructuring on indicator levels in the first period but lower term removals. The number of C&I categories that were changed in this way also was higher (ranging from 2 to 6) in the first period even though changes in terms were equivalent to the second period (ranging from 2 to 4 categories of C&Is). Change trajectory in SFI's O&PMs was similar to that of ITTO and FE; most changes took place in the first period as compared to the second. Montreal protocol changes in the second period had a restructuring of indicators from six out of seven categories in the second period with no changes in the first period. The results for the analysis of FSC standard changes also show that the first period had minimal structural and substantive changes as compared to the second period; only the addition of criteria was almost equal. Comparing the certification standards, SFI had more changes in the first period (focused more towards institutional and administrative C&Is over others). In contrast, FSC changes seem to be more pronounced in the second period (leaning more towards ecological types of C&Is). The trends in the volume of changes themselves do not indicate any convergence without looking into the types of C&I categories that changed.

2.6.2. CONVERGENCE AND DISSONANCE BETWEEN TYPES OF C&I CATEGORY CHANGES

Figure 8 shows relative percentages of changed indicators for each of the five standards stacked on top of each other during the first period from 1990 to 2005. ITTO had a higher focus on changes in the framing of ecological, administrative, and institutional types of C&Is (in decreasing order). There was no change in the MP standards which maintained the initial higher percentage of ecological, productive, and institutional types of C&Is (in decreasing order). In contrast, FE had a higher focus on changes in the framing of institutional, ecological, and economical types of C&Is (in decreasing order). We can see that both ITTO and FE had changes in the institutional and ecological category of C&Is in the first period, which were also prominent in MP's first iteration of the standard. Considering the exact timeline of the standard development, the seven-criteria format used by MP in the first iteration (Santiago Declaration, 1995) was copied in the second period by ITTO (in 2004), and FE had parallel development to it (from 1998). It can be argued that both the types of C&I category changes focus on institutional and ecological categories amongst the three protocols and this timeline of standard development may indicate a key role of the common trade and socio-economic interests of stakeholder policy networks in this period for the three protocols. Further research to assess the validity of this argument is needed. We observed that FSC had higher ecological, socio-cultural, and administrative types of C&s in its first iteration of forest management standard, and the minimal changes in the first period for FSC were focused on ecological and productive types of C&Is. On the other hand, SFI Forest Management C&Is changed majorly in the institutional, administrative, ecological, and socio-cultural types of C&Is (in decreasing order). This may be likely due to SFI undergoing the observed changes while moving from management by AF&PA to being an independent organization which supports the argument by Ven and Cashore (2018) that industry-driven and NGO driven standards compete for legitimacy by expanding their governance networks (industry attracting civil society and NGOs while NGO-driven system attracts industry and landowners) although their argument was made in case of FSC and PEFC, not SFI.

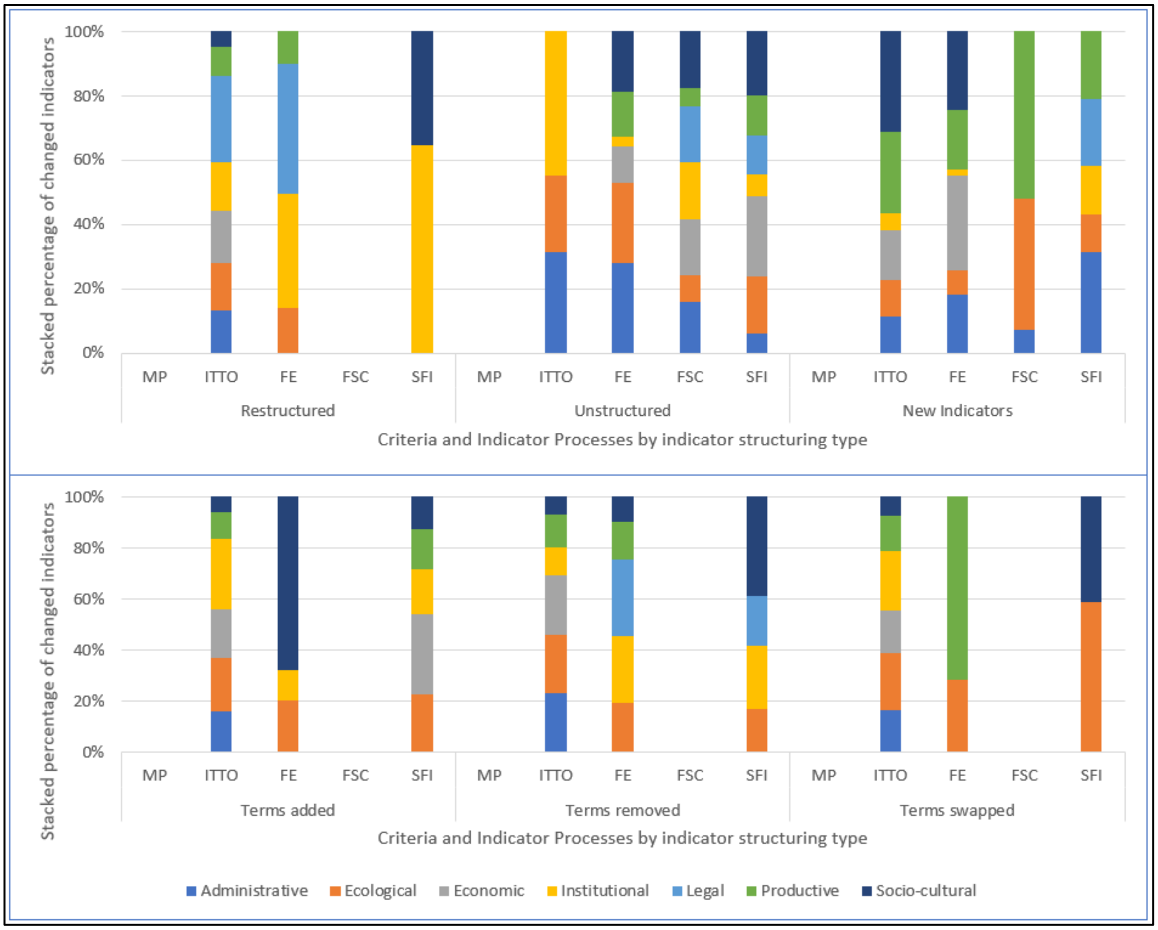

Figure 8. Comparing criteria and indicator changes between three protocols and two standards between 1990 and 2005. MP: Montreal Protocol. ITTO: International Tropical Timber Organization. FE: Forest Europe. FSC: Forest Steward Council. SFI: Sustainable Forestry Initiative.

Based on the institutional histories, MP and FE had a rapid C&I development process, partly in response to the rise of FSC. The convergence between MP and FSC on ecological types of C&Is can corroborate this institutional context, but this clearly did not translate to MP following FSC in terms of having a high socio-cultural type of C&Is in the first iterations of their respective standards. FSC may have been instrumental in MP having a higher ecological type of C&Is, but the dissonance with socio-cultural types of C&Is between the two could be a result of the differences in stakeholder policy networks with FSC having more powerful socio-cultural interests of stakeholder networks while MP has more economistic interests of stakeholder networks trying to ‘environmentalize’ their image as noted by Gale and Cadman (2014).

Figure 9 below shows the relative categorical changes in each SFM standard for the second period of 2005 to 2015. In this period of analysis, ITTO had a higher focus on changing ecological and productivity, as well as institutional and administrative types of C&Is (in decreasing order). FE showed a higher number of changes in the ecological and institutional types of C&Is in the second period. We observed that ecological and institutional types of C&Is were most changed in the Montreal Process standards as well during this time with smaller changes to economic and legal types of C&Is (all in decreasing order). SFI had a higher focus on changing the ecological type of C&I. ITTO, MP, FE, and SFI show convergence in terms of having specific convergence on ecological types of changes to their C&Is. This convergence could be a result of competing with stronger FSC standards in the area of ecological C&Is. It could also be a result of the international developments taking place during this period, e.g., publication of the Millennium Ecosystem Assessment (Millennium Ecosystem Assessment, 2005) after which ecosystem services started to gain more traction in global policy arenas.

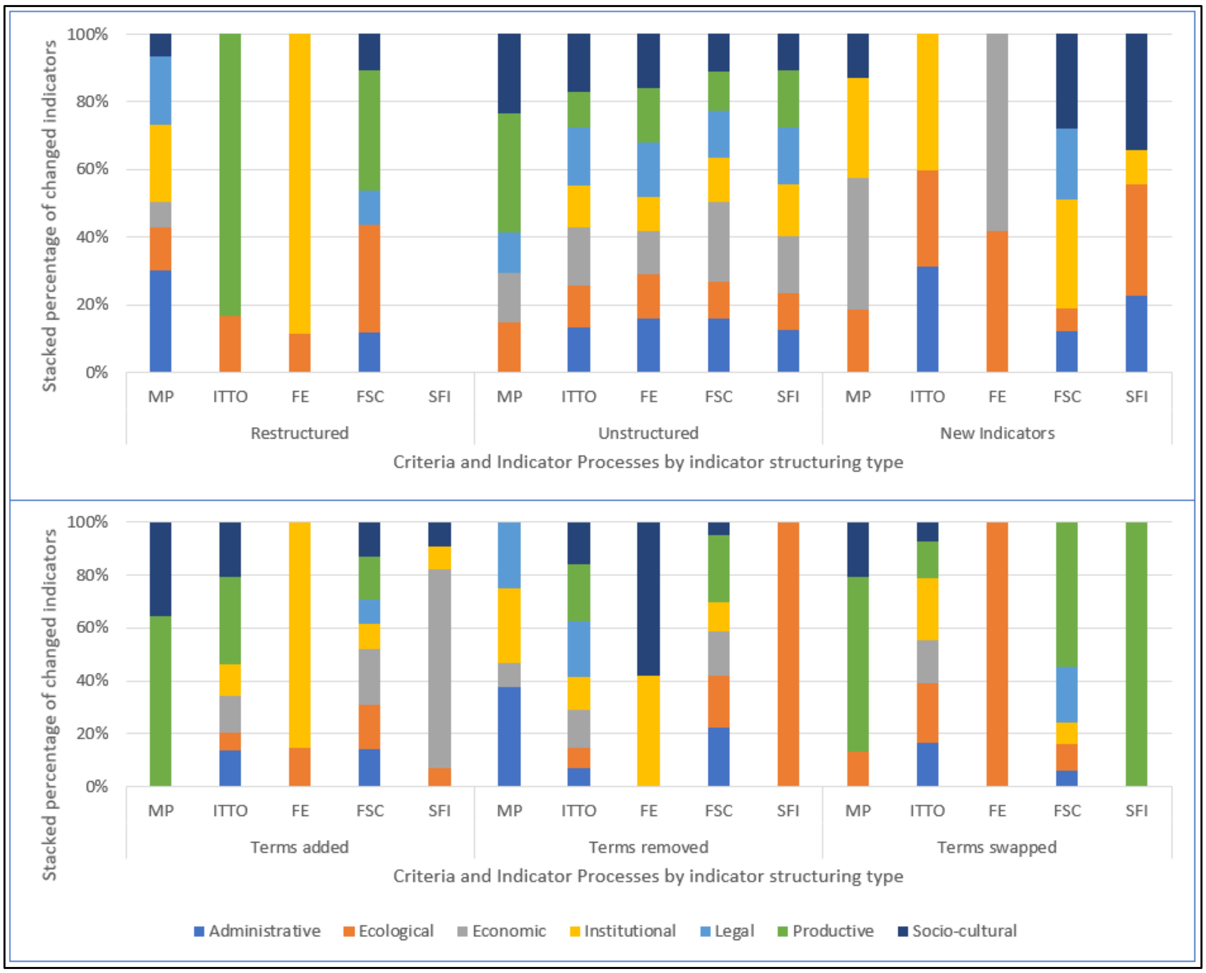

Figure 9. Comparing criteria and indicator changes between three protocols and two standards from 2005 to 2015; MP: Montreal Protocol. ITTO: International Tropical Timber Organization. FE: Forest Europe. FSC: Forest Steward Council. SFI: Sustainable Forestry Initiative.

2.6.3. TROPICAL STRANDS OF CONVERGENCE AND DISSONANCE

ITTO was the pioneer in the international collaborative C&I development process of SFM. Blockhus et al. (1992) reviewed the developments in standardizing SFM C&Is till 1992 in ITTO member countries. They noted that the first draft established in 1991 targeting natural forests was considered too prescriptive by different stakeholder groups for planted forests. Even though biodiversity conservation in tropical countries was one of the most widely raised issues on the international scale, on the national scale, only a few targeted measures were present in 1993. The development of regional C&Is of SFM did have an impact on the biodiversity conservation issue being raised more. In general, the environmental and forestry discourse in 1993 shows that logging impacts on biodiversity were believed to be more severe than impacts due to other sources (Johns, 1997). The review by Johns (1997) also showed that certain categories of biodiversity were threatened due to certain types of logging. These developments in discourse were critical to facilitating the emergence of the forestry industry as one of the key stakeholders, which aligns with standardization developments for ITTO in the 1990s.

Our results are significant in two ways: the timing of the standard changes and the actual type of the substantive changes. In terms of timing, it is essential to note that after setting the first standard in 1995, MP standards did not change at all till 2007. The seven-criteria framework, acting as the trend-setter, seems to have pulled ITTO and FE standards towards more alignment with it. This indicates how the historical context for the emergence of SFM standardization, initially driven by ITTO's focus on tropical deforestation, may have shifted to MP and FE forestry stakeholders majorly based in temperate and boreal countries. FSC's lack of changes in the first period can be explained by its higher legitimacy with the environmental and social NGO community in its beginning. ITTO and FSC have quite a few substantive parallels as observed in our review even though the timing of changes is different, with FSC changing the forest management standards more in the second period with respect to ecological and productive types of C&I (speculatively due to strategies to attract more industry and landowner stakeholder networks, in corroboration with Humphreys (2012) and Van and Cashore (2018)). Both SFM systems are arguably the only truly global systems analyzed in this study, with MP and FE overlapping with ITTO countries but not with themselves (Figure 2).

2.6.4. TEMPERATE AND BOREAL STRANDS OF CONVERGENCE AND DISSONANCE

Differences between North American and European forestry discourse (Cashore et al., 2003) may be responsible for differences in standard developments in MP and FE, respectively. More particularly, Cashore et al. (2003) note that higher representation of companies and landowners, less dependence on foreign markets, and structure of supply-side within a region (small vs large landowners) may be responsible for the North American dynamics of legitimacy. Within Europe, many countries import forest products from developing tropical countries, as seen by the overlapping of the FE member countries with the ITTO's consuming countries (Figure 2). This can explain why the standard developments in the MP countries were found to have a dissonance with the FE developments in terms of timing of C&I changes as FE would be expected to be more influenced by the developing discourse in tropical forestry than MP. The opposite timing of changes in the volume of C&Is between SFI and FSC also possibly shows a separation of focus between tropical and temperate and boreal forestry issues. The less uptake of FSC in North America, while SFI has a more certified area, can be argued to be driven by dynamics of North American stakeholders dominating in the standard development; such dynamics of legitimacy between North American stakeholders have been explored by Cashore et al. (2003) in greater details.

The observed differences of standard development between the world's two forest area certification programs, FSC and SFI, in terms of the former focusing on socio-cultural types of C&Is, while the latter focusing more on institutional types of C&Is may be present because SFI (as all PEFC standards) was developed by industry stakeholders as a response to FSC which are driven more by the civil society. Market competition between SFI and FSC has dominated the certification discourse in North America since the beginning of the 1990s (Sasser et al., 2006; Stryjewski, 2007). This indicates that stakeholders behind the standards shape them to the direction they want the standard to go. The convergence between all the standards in the context of ecological type C&Is can be a result of over-representation of large multinational NGOs like Amnesty International, Greenpeace, Worldwide Fund for Nature, etc. within the global multi-stakeholder networks as noted by Fransen and Kolk (2007), along with competition with FSC's 'eco-social' standard developments (Gale and Cadman, 2014).

2.6.5. TROPICAL VERSUS TEMPERATE AND BOREAL FOCI OF SFM STANDARDIZATION

Tropical deforestation and international supply chains were supposed to have driven all these developments, both in C&I processes and in certification standards, as evidenced by the discourse in the 1980s. But instead, the competition between FSC and the other four standards which we outlined in the institutional histories and international policy trends towards ecosystem services approaches, may be more important towards explaining the categories of changes that we observed in our analysis. Europe and North America driven international timber supply chains sourcing wood from tropical countries are increasingly becoming more formalized and monitored in national and regional legislations like the new European Union Timber Regulation (Giurca et al., 2013) and the United States Lacey Act amended in 2008 (Prestemon, 2015). Furthermore, the national legislative frameworks in the European and North American regions are stronger than those in developing tropical countries (Robinson et al., 2010). This may have given higher legitimacy for the increased recruitment of industry players into both the protocol and certification processes from the European and North American regions, which have a majority of temperate and boreal forests. This may have affected the observed developments in MP and FE standards. In terms of the timing of changes, we can argue that FSC, in the second period of this study, may be attempting more strategies to attract industry stakeholders because we observed a higher number of changes in productive types of C&Is in its standards as all standards continue to update ecologically framed C&Is while ITTO has been more reactive in changing the standards in general than MP and FE.

2.7. CONCLUSION

In this study, using the discursive-institutional approach and stakeholder theory, we argued that overlap of geographical networks and dynamics of global institutional histories could result in particular trends and levels of convergence and dissonance in SFM standardization. Comparing the trends in numbers and types of changes among the three international protocols of ITTO, MP, and FE with those among the forest certification schemes of FSC and SFI in two periods, from 1990 to 2005 and from 2005 to 2019, our results were situated within the historical dynamics between tropical and temperate as well as boreal institutions. In terms of the trends of global forest governance, a) prominence of changes in ecological types of C&Is may be associated with the overall movement from industry and government to the inclusion of civil society and NGOs in the policy arena from 1990 to 2015, and b) the importance of considering socio-economic institutional elements towards trends and developments in all the five standards is observed.

Our analysis is restricted to the seven concept frames of C&Is and does not refer to any further substantive or procedural convergence and dissonance in the five standards. Only detailed and comparative qualitative analyses in the future can help to assess that. Furthermore, our study is limited in the fact that direct connection with changes in specific stakeholder networks was out of the purview of this paper; nevertheless, we argue that changes in particular types of C&I framing may represent the influence of a particular type of stakeholder policy networks. Future research can also find such interconnections in a more explicit and quantitative way through social network analyses (Paletto et al., 2015). The issue of geographical scale is also at the heart of C&I convergences. Future research should attempt to empirically disentangle the effects of geography-driven variables, including socio-economic characteristics and ecological priorities of participating stakeholders, to understand the dynamics of standardization that have taken place in these SFM systems.

We recognize that the observed convergences and dissonance in SFM standardization might not indicate any practices that might be good or bad, only the raw structural changes in the C&Is. Conducting analyses of on the ground impact evaluation is outside the scope of this paper, but future research connecting on the ground impacts with standard convergence and dissonance can show whether the fragmented international forest regime is having a positive or negative impact and where the impact is taking place. Furthermore, it will be informative to categorize and track the convergence and dissonance by concept frames more detailed than the ones used in this study. Categorizing in such a generic way will help future researchers smoothen out the default goal-driven differences between protocols and certification standards, consequently allowing higher focus on actual substantive changes. Furthermore, our future research can build on this study by empirically identifying interconnections between changing legitimacy dynamics as used by Cashore et al. (2003) and standard developments that take place in global SFM institutions.

CHAPTER 3

A SPATIAL DEPENDENCE APPROACH TO ASSESSING THE IMPACTS OF SUSTAINABLE FIBER INITIATIVE'S FIBER SOURCING CERTIFICATION ON THE FORESTRY BEST MANAGEMENT PRACTICES IN GEORGIA, UNITED STATES[1]

[1] Parag Kadam, Puneet Dwivedi, Nicholas Magnan, To be submitted to [Forest Policy and Economics].

Abstract

Using nested spatial regression methodology, this study analyzes the impacts of Sustainable Forestry Initiative Fiber Sourcing Standard (SFI-FSS) on forestry Best Management Practices (BMP) implementation rate in Georgia, United States, between 2002 and 2019. The results of our Tobit models show that increasing non-certified sourcing area overlaps has a negative effect on BMPs, while increasing certified sourcing overlaps has a positive effect. The Spatial Durbin Model (SDM), which is found to be the most appropriate, corroborated this effect on the landscape level. It gives marginal direct and indirect (or neighborhood) effects at the local level. Particularly, average certified overlaps, mean elevation, and interaction of associated mill size and harvested area in neighboring mills' sourcing areas seem to influence BMP rates at a sourcing mill. Neighbor's certified overlaps seem to have a negative effect on average BMP rates associated with a sourcing mill. This may be because of supply chain inefficiency brought on by concurrent contracting behavior between small mills and their larger certified neighbors. The results show that spatial dependence might be an important mechanism towards actualizing the effectiveness of the SFI-FS program. Based on our results, we provide recommendations for strategizing a constructive growth of its system, which may be beneficial to SFI and its stakeholder groups.

Keywords

Best Management Practices, Responsible Sourcing, Sustainable Forestry Initiative, Spatial dynamics

3.1. INTRODUCTION

Forest certification is a market-driven mechanism for ensuring responsible forest management through compliance of the relevant certificate holder to a set of stakeholder-developed standards which is verified by independent third-party auditors(van der Ven and Cashore, 2018). It started in the mid-1990s as a compromise between the industry and NGO sectors, led by the discussions before and at the Earth Summit of Rio (Kadam et al., 2021b). In the last 25 years, there have been several certification organizations that have designed different types of standards. Led by NGOs, social groups, and the forestry industry, the two organizations leading in this respect have been: Forest Stewardship Council (FSC) and the Programme for the Endorsement of Forest Certification (PEFC), an endorsement umbrella system. The Sustainable Forestry Initiative (SFI) and the Canadian Standards Association (CSA) have been endorsed by the PEFC in North America (PEFC, 2021b).

The SFI has certified over 147 million hectares together in the United States and in Canada (120 million hectares in Canada and over 27 million hectares in the United States) through its forest management standard (SFI, 2021b). Overall, it offers three certification standards. The Chain of Custody (CoC) standard ensures that certified forest products don't mix with non-certified ones throughout the supply chain, while the Forest Management (FM) Standard covers an area-based certification. The complexity of standards and the cost of implementing them are two of the primary hurdles among certificate holders to implementing an area-based forest management standard (Cashore, 2002). Attempting to mitigate these challenges, the Fiber Sourcing Standard (SFI-FS) is a responsible sourcing standard covering requirements for the certified mills to implement procurement practices and responsibly mitigate risk, if applicable (Kadam et al., 2021a). As some of the requirements of the standard, while allowing sourcing from non SFI-FM certified forestlands, the certified mills are required to use only loggers who have been trained and certified by an SFI-recognized logger education program for implementation of forestry Best Management Practices (BMPs). The BMPs are monitored regularly from independent evaluations at active harvesting sites in different states.

Much of earlier research in understating the impacts of forest certification has been focused on processes instead of outcomes, and the researchers have used data received after third-party audits (Johansson and Lidestav, 2011). One of the reasons for this is that long-term, on-the-ground data of environmental changes as well as the performance of certified and non-certified management entities have been difficult to obtain. Blackman et al. (2017) suggest that the best impacts analysis strategy would be to compare the outcomes of certified and non-certified entities having similar characteristics. They accept that finding comparable data for such cases is indeed difficult.

A major lacking in the existing impact studies for forest certification is the spatial dependence of a variety of factors. Tobler's first law of geography states that "everything is related with everything else, but near things are more related than distanced things" (Tobler, 1970). There is enough history of assessing spatial dependence in landowners' characteristics and motivations in the United States (Poudyal et al., 2019) to warrant considering any possible spatial dependence (or, in other words, auto-correlation). In the United States, forest landowners have different motivations and management objectives both on local levels (Erickson et al., 2002; Salmon et al., 2006) and nationwide (Butler et al., 2016; Butler and Leatherberry, 2004). Moreover, the motivations and subsequent behaviors of the landowners are constantly evolving (Sorice et al., 2014).

Poudyal et al. (2019) found that landowner motivations regarding monetary and tangible benefits were spatially auto-correlated but not the intangible and non-monetary benefits. This indicates that market-driven professional networks in mechanisms such as forest certification would also be spatially correlated. Indeed, Poudyal et al. (2019) also found that the spatial variation in landowners' land-based 'green certification' adoption was statistically significant. They identified hotspots of clusters of landowners that were certified with a forest management certification, viz. in "smaller pockets of southcentral Carolina, the Tall Timber region of southern Georgia and northern Florida, south-central Alabama, southwestern Arkansas and west-central Louisiana." There are few other studies that have assessed the spatial dimensions of forest management and found them significant. For example, Chambers et al. (2017) recorded that landowners in particular areas had the same conservation attitudes. Through studying spatial patterns of forest management behaviors of landowners, Aguilar et al. (2017) found that the forest landowners near each other showed similar behaviors towards land use choices.

Likely, underlying differences and similarities in social, economic, as well as bio-physical factors may lead to a similarity in behaviors amongst landowners as well as amongst loggers. There are two ways that their relationship may actualize in practice: through proximal social interactions and peer-networking (Kueper et al., 2013; Mouw, 2006) as well as through similarities of resources, like investment in logging companies and availability of trained loggers (Kadam et al., 2021a). A study by Galik and Grala (2017) argues that particular patterns of interrelationships between landowners and their assisting institutions are indeed salient. We argue that landowners and loggers with similar socio-economic contexts may behave in line with the economic theories that dictate supply chain business strategies of value proposition and capture (Teece, 2010). Landowners with diverse motivations may lean more on getting the right value proposition, but business models of logging companies value enticing more mill-owner and landowner customers to pay for the value of the services they provide. Implementing forestry BMPs has become costlier (Conrad et al., 2018) and the loggers who plan harvesting would likely differentiate their financial and technical resource allocation strategies between SFI-FS certified and non-certified mill sourcing because of extra BMPs that they have to follow with certified sourcing.

Poudyal et al. (2019) specifically note that the abundance of sawmills could be one of the factors which may affect landowner choices likely because of available timber selling opportunities, which in turn, may affect logger behavior. In a similar way, we would expect the availability of trained loggers for a mill might affect mill-owner choices. It is the loggers that implement BMPs and, in an area with a dense concentration of mills, this may likely create a strain on the effectiveness of BMP implementation. This relationship would likely be spatial. Moreover, the financial capacities of landowners who have a contractual relationship with logging companies and who partly or wholly bear the cost of BMP implementation also matter. Corporate landowners with higher capital availability may likely find BMP implementation less of a burden, just as higher investment in logging businesses is associated with higher BMP implementation rates (Kadam et al., 2021a). We are not aware of any impact studies that incorporate spatial auto-correlation effects in forest certification systems for a responsible sourcing system like the SFI-FS, either local, regional, or global. To understand the regional dynamics of environmental outcomes of programs like SFI-FS, it is essential to consider spatial patterns of ownership and management (Nielsen-Pincus et al., 2015). This can be useful towards organizational and landscape-level planning through the mapping of logger and mill preferences (Bontrager et al., 2016).

There are no long-term studies that have statistically analyzed the spatial autocorrelation/dependence effects of SFI-FS or similar responsible sourcing systems. The forestry BMP implementation rate in Georgia was 65% in 1991 at the advent of forest certification, but it rose to around 90% since mid-2000 (Georgia Forestry Commission - GFC, 2018). This coincides with the growth of SFI-FS. In the North American context, Dwivedi et al. (2018)

conducted a study on the impacts of SFI-FS standard on average BMP implementation by assessing the BMP implementation rates of harvest sites within sourcing radius of SFI-certified mills and found them to be 2% higher than those outside their sourcing radius. Using the long-term data collected by GFC on the forestry BMP, the overall goal of this study is to explore the spatial dependence dynamics in the impact of increasing SFI-FS certified fiber sourcing on the BMP rates in relation to the non-certified fiber sourcing. The principal policy requirement for the SFI-FS program is an understanding of whether it is effective and, if so, in which contexts. This will be crucial not only for SFI to strategize development constructively but also for stakeholders to recognize and critique the forest certification system. The specific objective of this study is to explore how and where the change in rates of BMPs at harvested sites is affected by an increase in overlaps of wood sourcing areas of certified and non-certified mills in Georgia.

3.2. METHODS

3.2.1. STUDY AREA

There were several reasons for choosing Georgia as our study area. Georgia was able to supply around 4% of national roundwood harvests, which was one of the highest in 2017 (Oswalt et al. 2019). Its vibrant wood products industry generated an economic impact of around $36 billion between 2017 and 2018 (GFC, 2019). Moreover, Butler (2008) found that about 91% of the total forest land in Georgia is privately owned; 63% of that belong to family forest landowners. Non-industrial private forest (NIPF) landowners own and manage about 65 million hectares of forest land in the US south (Butler et al., 2016; Southern Group of State Foresters, 2021). This makes the voluntary SFI-FS system an important policy variable towards ensuring forest resource sustainability because a high percentage of land under NIPF is not certified (Southern Group of State Foresters, 2021). As Georgia shares a similar climate, social, cultural, economic, political, land ownership, and policy landscapes with other southern states, the results of the study may be relevant for them as well. In regard to the BMPs, in Georgia, regular independent evaluations are under the mandate of the GFC, a state-level agency responsible for the development, education, implementation, and monitoring of forestry BMPs. Even though they are voluntary (non-regulatory) in Georgia, BMPs have been known to play an essential role in facilitating "quality management feedback in SFI-FS standard by facilitating a requirement for the certified mills to use trained loggers and regularly monitor their BMP compliance rates" (Kadam et al., 2021a).

3.2.2. DATA COLLECTION AND CLEANING

GFC collects data on forestry sites and their implementation rates of forestry BMPs every two to three years (GFC, 2021). We received the BMP survey site GFC data for the years 1998, 2002, 2004, 2007, 2009, 2011, 2013, 2015, 2017, and 2019. BMP assessments for non-harvested sites (e.g., chemical preparation, road management, etc.) were not included in our dataset. There were several observations for which clarification and corrections had to be asked from GFC, especially for the early years till 2009. BMP data collected for the year 1998 had a completely different metric of BMP assessments and could not believe that reliably compared and combined with other years in our dataset. Thus, BMP survey data from 2002 to 2019 were used. The discrepancies between the mean BMP rates reported by GFC, by Dwivedi et al. (2018), and our study can be explained by these changes in the datasets. Furthermore, we also collected data regarding the lists of all primary wood-consuming mills in these same years from GFC. Timber Mart South (TMS) publishes quarterly reports on the state of the mills in the US South, including the changes in production, ownership restructuring, closures, and shutdowns. The data regarding ownership changes, closures, and shutdowns were corroborated with the GFC lists of primary wood-consuming mills, and an exhaustive comparison showed that corrections regarding mill names and locations were required from GFC – most prominently for the year 2007. The resultant dataset contained arguably the most reliable compilation of all primary wood-consuming mills to have been ever created for the state of Georgia. Data on the ownership type, harvested area, and perennial stream length at each of the survey sites were present in the GFC dataset.

The data regarding the annual status of SFI-FS certification was also collected from multiple sources. Firstly, we collected observations from SFI's online directory and compared them to the study conducted by Dwivedi et al. (2018). Using our complete dataset of all primary wood-consuming mills, SFI helped to clarify and correct the certification status of several mills. For the remaining mills, we contacted their respective CBs to inquire about the same. Subsequently, for the mills whose status was still not clear, we contacted the mills directly. In total, data were combined to identify a) all existing primary mills, 2) mills that were certified with SFI-FS certification, and 3) mills that were not certified.

3.2.3. DATA EXTRACTION: GIS ANALYSIS

The coordinates of each survey site and primary mill were imported into ArcMap for spatial analysis using Geographic Coordinate System GCS_WGS_1984 and Projected Coordinate Systems WGS_1984_UTM_17N. TIGER line shapefiles were utilized to delineate the state boundaries (US Census Bureau, 2021). Once mill locations were imported to ArcMap, we created buffers around them. Coastal mills were differentiated from inland ones as their procurement distances vary. Using the results from the USDA Forest Service's Timber Product Output Surveys (USDA Forest Service, 2021) and incorporating information from Conrad et al. (2018), we estimated buffers for coastal and inland wood consuming mills for our spatial analyses. Coastal wood-consuming mills received buffers with a radius of 65 miles (104.6 km), and inland wood-consuming mills received buffers of 45 miles (72.4 km). These are called 'wood baskets' in our study.

The primary mill on which level the BMP rates were aggregated as means in a given year were the units of analyses. Taking all certified and non-certified mills together, we conducted spatial analysis ('*zonal statistics*) to determine the average BMP rates, average elevation (using Georgia's Digital Elevation Model from United States Geological Survey, 2022) within each wood basket in each year. A wood basket overlap is defined as the instance when a BMP harvesting site falls within the sourcing area of two or more mills, either certified or non-certified. Multiple overlaps were found at each BMP site, and numbers of certified as well as non-certified overlaps were noted against each survey site observation. Average certified and noncertified overlaps were aggregated for certified mill baskets and non-certified mill baskets separately. The size of the sourcing mill has been shown to be a factor in sourcing radii and stumpage volumes (Anderson and Germain, 2007). Information on the size of each mill was collected from the GFC reports. The total number of loggers who were trained by the Georgia Mass Timber Harvester – GAMTH training program in a given year were received from one of the SFI coordinators (Cook, 2022). Drought conditions in Georgia have been argued to possibly cause a drop in BMP rates (Dwivedi et al., 2018), so a dummy variable for drought conditions was included, with 1 indicating drought condition. The data was collected from the National Integrated Drought Information System (NIDIS)'s online dataset (NIDIS, 2021). Along with aggregating mean BMPs on the primary mill level, we also extracted the percentage of corporate, NIPF, and public-owned BMP sites along with the total harvested area (in hectares) and the total length of perennial streams within each wood basket. Harvest intensity (the number of loggers harvesting for a sourcing mill) can likely influence the implementation of BMP rates, but this data is not available. An interaction term of the total harvested area and mill size is included in the statistical modeling as an independent variable as a proxy for the harvesting intensity in the mill wood basket in a given year. These variables were used to run the following analyses.

3.2.4. STATISTICAL ANALYSES

Straightforward Tobit regressions, where ordinary least square (OLS) architecture is applied to uncensored latent variables to improve the reliability and consistency of the analyzed effects, may still yield biased and/or inconsistent estimates when spatial correlation exists either in the form of a) spatial dependence (lag) in dependent and/or independent variables, or b) spatial dependence in the errors (Bini et al., 2009; Lennon, 2000). None of the Tobit models include measures to correct for spatial dependence effects like lag or error (Anselin, 2009). One of the basic assumptions of the OLS model is that $E(e_i|X) = 0$ for all *i*s, i.e., the distribution of mean errors is zero. This assumption fails to be satisfied in the case of spatial data. Specifically, if there is spatial autocorrelation in the dependent or independent variables (lag), if the OLS model is applied, the size and signs of estimates will be biased and inconsistent, and standard errors are underestimated while in the case of spatial correlation of errors, the effect estimates are unbiased but inconsistent (estimate sizes and signs are asymptotically right but standard errors are still underestimated). Moreover, the OLS model heightens the conventional omitted variable bias when an omitted variable is correlated with an independent variable (Pace and LeSage, 2010).

We compared the results of the Tobit modeling with spatial regression models. The full model equation for the Tobit regression was as follows:

$$BMP_{wood\ basket\ mean} = \beta_0 + \beta_1 * Mean\ noncertified\ overlaps + \beta_2 * Mean\ certified\ overlaps + \beta_3 * Percent\ sites\ with\ corporate\ ownership\ type + \beta_4 * Percent\ sites\ with\ NIPF\ ownership\ type + \beta_5 * Percent\ sites\ with\ public\ ownership\ type + \beta_6 * Length\ of\ perenial\ streams + \beta_7 * (Total\ Harvest\ Area * Mill\ Size) + \beta_8 * Mean\ elevation + \beta_8 * Total\ Harvest\ Area + \beta_9 * Mill\ Size + \varepsilon$$

Two-way fixed effects were included in the above equation, and the resulting models were compared to the random-effects model. The residual and normality plots were compared to determine the best fit model in terms of the consistency of the estimates. Different combinations of the independent variables were tested to see which explained the most variance in the BMP rates and which fit the model better. Only heteroskedastic and cluster corrected standard errors were used (clustering on mill ID). The same process was undertaken for the spatial regression models.

The most widely used test for spatial autocorrelation has been the Moran's I test (Anselin, 2009). To be able to use this test, we created a weight matrix – W – that can be used to assign row standardized weights to the mean BMP outcomes and its corresponding independent variables at the wood basket level based on inverse-distance between the mills. We used 45 miles as the distance to define neighboring mills. Before running the spatial regression models, spatial patterns in the dependent variable were explored using GeoDa software and the weight matrix W for each year. There is no single consistent measure for the space-time matrix in GeoDa, so Moran's I was calculated for each of the years separately. To check the pattern of spatial clustering in terms of the dependent variable, cluster maps of high-high to low-low clusters of mean BMP rates (statistically significant associations between local neighbors) were created using GeoDa. These cluster maps use Local Indicators of Spatial Associations (LISAs) to identify cores of clusters and neighbors (Anselin, 1995).

To incorporate and correct for the influence of spatial autocorrelation, there is a whole family of regression models called the 'Manski model' (Elhorst, 2010), a type of general nesting spatial model. Elhorst (2010) depicts the hierarchy of these models succinctly, which is shown in Figure 10.

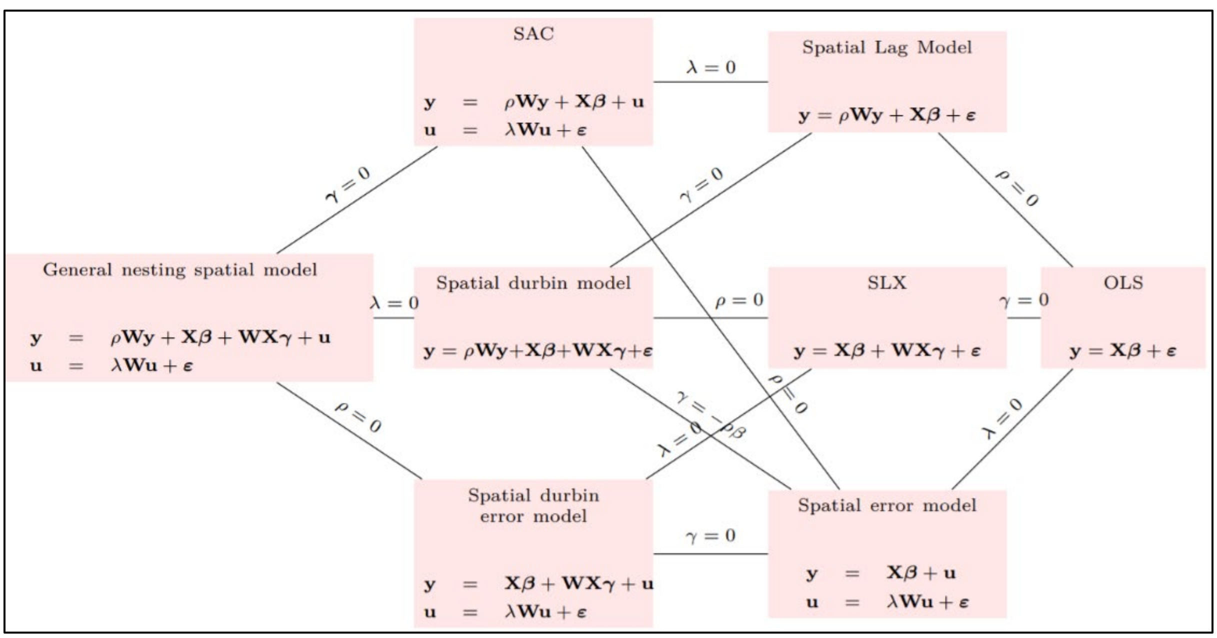

Figure 10. Hierarchy of spatial regression models; from Elhorst (2010)

LeSage (2014) note that a global spatial autocorrelation is defined as the case when observations at a site affect its neighbor's observations which in turn affects its neighbor's observations and so on, feeding back on the original site ('a ripple effect'). On the other hand, a local spatial autocorrelation is defined as the case when observations of a neighbor only affect the nearest neighbor, not all other sites in the dataset – there is no feedback propagation on the ‘global’ level. The main Manski model has all the possible spatial influences, including lagged dependent variable (in case the dependent variable at a site is affected by its neighbor), lagged independent variables, and dependence in error terms. The Kelejian-Prucha model (KP or SAC) and the Spatial Durbin Model (SDM) models are more global models with lagged dependent and independent variables, while the Spatial Durbin Error model (SDEM) nested models are local. We explored the significance of each of the models and their parameters, starting from the most inclusive of spatial dependences. We compared the results with the Tobit models (Tobin, 1958), as the data on BMP implementation rates were found to be censored at 100% with several observations at that at this upper limiting value. All the statistical analyses were run in Stata 17.

There are very few statistical tools that can create and incorporate a spatio-temporal weight matrix (using chronocker product matrix methodology) (Anselin et al., 2008) – which was the case with our data – and none of them can deal with an unbalanced panel data, as far as we know. In Stata, the tool xsmle allows for the estimation of effects within balanced panel data. The algorithm for estimation of the spatial models using xsmle as given in Figure 10 has been given by Belotti et al. (2016). Using the robust stata tool of multiple imputations – also recommended by Belotti et al. (2016), we created the required dataset using the available variables using 20 imputations for each variable with missing data. The multiple imputation methodology, which draws the parameters of an imputation model from a Bayesian posterior distribution, is given by Eddings and Marchenko (2012). The missing data in our dataset were due to the absence of certain mills in certain years, which was at random. The final panel data was used in the Tobit and the spatial dependence models. Post-estimation analyses included a selection of the best (unbiased, consistent, and efficient) of the models when different combinations of independent variables were considered, including for defining different lagged independent variables in SDM. As suggested by Belotti et al. (2016), SDM can be extended to SAR and SEM when $(\gamma = 0)$ and when $(\gamma = -\rho\beta)$, respectively. We tested whether either of the two conditions was statistically true. Comparisons between SDM and SAC models was done on the basis of both the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) which measures predictive accuracy and goodness of fit respectively, with the latter penalizing free parameters more strongly (Shmueli, 2010).

As part of the post-estimation analyses, the predicted values of BMP rates and the residuals were recorded for all the Tobit and spatial models, irrespective of efficiency. Moran's I was calculated again in GeoDa for the residuals of these models using the same weight matrix W.

3.3. RESULTS

Our dataset included a total of 2515 BMP survey site observations over the period of the study since 2002; only 10 survey site observation data were not included because of location uncertainties. The distribution of ownership covered four major types – NIPF, corporate, public, and timberland investment management organizations (TIMOs) – and is given in Figure 11. In terms of the number of primary wood-consuming mills over different years, the dataset yielded the number of mills which are also shown in Figure 11. Table 2 shows the distribution of mean BMP implementation rates for each year aggregated overlapping SFI-FS wood baskets. The general trend seen in this raw dataset is a slight decrease in the mean BMP rates as the overlaps increase, especially in the later years.

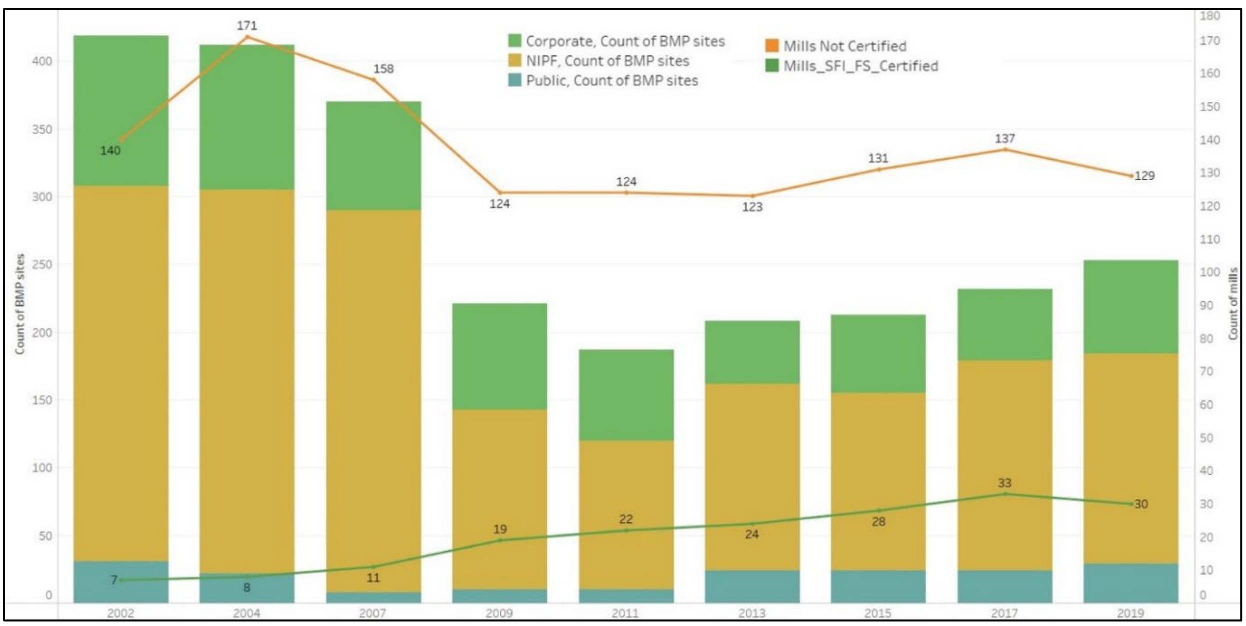

Figure 11. Distribution of BMP survey site ownership types and certification status (Y-axes) of mills over the years (depicted on X-axis). NIPF: Non-Industrial private forest owners, SFI-FS: Sustainable Forestry Initiative's Fiber Sourcing certification, BMP sites: Harvesting sites assessed by Georgia Forestry Commission with respect to forestry Best Management Practices.

Table 2. Best management practice (BMP) implementation rates by number of overlaps of sourcing areas that are certified by the Sustainable Forestry Initiative's Fiber Sourcing (By Year).

Year	0 certified overlaps	1 certified overlap	2 certified overlaps	3+ certified overlaps
2002	87.07	87.06	91.73	88.50
2004	89.89	91.89	90.31	90.70
2007	94.10	93.79	92.21	89.91
2009	93.36	94.92	94.33	93.78
2011	95.68	96.59	95.72	95.99
2013	95.87	89.87	91.11	91.73
2015	91.83	91.86	92.84	92.67
2017	99.09	97.98	93.33	91.83
2019	97.59	95.80	95.05	93.69

From the perspectives of the mean BMP implementation rates within the wood basket of all primary mills in Georgia, LISA cluster maps generated by Geoda help understand the statistically significant spatial cluster cores of the dependent variable. Figure 12 shows that the pattern of high-high association (hotspots where the variable shows a spatial association between neighbors leading to high values of both) for mean BMP rates are localized to the coastal and southern parts of Georgia with low-low clustering in the north and south in the earlier years while the clusters shift post-2011 (when a significant drought happened). Low-low clusters are coldspots where the variable shows a spatial association between neighbors leading to low values ('sinks'). The pattern of BMP rate clustering with low-low associations was initially found in the northern mountainous areas but shifted to the southern parts post-2011.

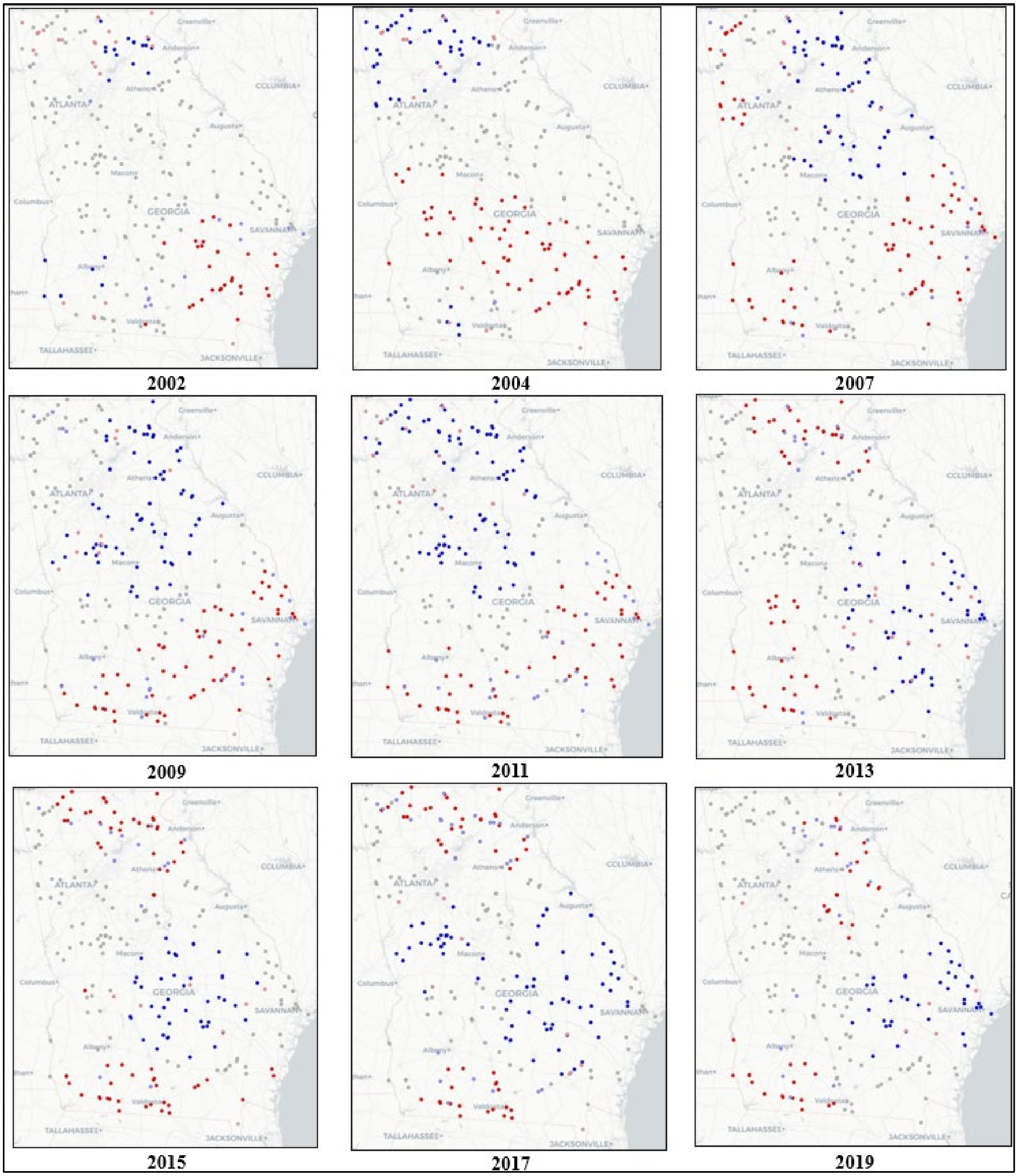

Figure 12. LISA cluster maps of primary mills for mean Best Management Practice (BMP) implementation rates within their sourcing wood baskets for each year of Georgia Forestry Commission (GFC)'s assessments in Georgia, United States, since 2000.

After the spatial join analyses in ArcMap, we found that the number of overlapping non-certified mill baskets at a BMP survey site ranged from 2 to 33 (mean = 15.3, SE = 0.11) while the overlapping certified mill baskets ranged from 0 to 8 (mean = 1.83, SE = 0.03). Table 3 gives the regression estimates for the best of the Tobit models (based based on their AIC and BIC).

Table 3. Results of the best non-spatial tobit regression model. Estimates are noted and the brackets contain heteroscedasticity and autocorrelation corrected robust standard errors. Dependent variable: Mean BMP implementation rate within ood, (p values = *:0.1, **:0.05, ***:0.01, ****:0.001).

Independent Variable\Model	**OLS**
Mean certified basket overlaps within wood baskets	0.23
	(0.08)***
Mean non-certified basket overlaps within wood basket	-0.34
	(0.04)****
Percent sites with Non Industrial Private Forest (NIPF) ownership within wood basket	-0.074
	(0.012)****
Percent sites with corporate ownership within wood basket	0.027
	(0.013)**
Total length of perennial streams within wood basket (km)	0.04
	(0.02)**
Mean elevation within wood basket	-0.01
	(0.003)****
Total Harvest Area within wood basket (km^2) * Sourcing Mill size	0.028
	(0.009)***
R^2	0.3457
R^2 Adjusted	0.2616
Log-likelihood	-5564.018
Degrees of freedom	257
Akaike Information Criterion (AIC)	11642.04
Bayesian Information Criterion (BIC)	13111.74

The tests to compare the SDM models with SAR and SEM were significant, meaning there were no combinations of lagged and main independent variables for which $(\gamma = 0)$ and/or $(\gamma = -\rho\beta)$. This showed that SDM models were more appropriate over SAR and SEM models in all cases. The comparisons between the AIC and BIC values for the SAC and different combinations of lagged independent variables in SDM models are shown in Table 4.

Table 4. Model selection between the Spatial Durbin model (SDM) models with different lagged variables and best of the Kelejian-Prucha model (KP or SAC) models based on the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC). The reported best SAC model and SDM models (non-lagged) are based on the independent variables: Average Certified overlaps, Average non-Certified overlaps, Percent sites with Non-Industrial Private Forest (NIPF) and corporate ownership within wood basket, length of Perennial streams, (Harvest Area*Mill Size), and Elevation.

Different combinations of lagged independent variables in SDM		SDM model		SAC Model	
		AIC	BIC	AIC	BIC
1.	Average Certified overlaps, Average non-Certified overlaps	9790.28	9864.04		
2.	Average Certified overlaps, Average non-Certified overlaps, Harvest Area, Elevation	9740	9831.13		
3.	Average Certified overlaps, Average non-Certified overlaps, (Harvest Area*Mill Size), Elevation	9744.07	9828.91	9760.15	9830.7
4.	Average Certified overlaps, (Harvest Area*Mill Size), Elevation	9740.03	9808.6		
5.	Average Certified overlaps, (Harvest Area*Mill Size)	9749.72	9823.09		
6.	(Harvest Area*Mill Size), Elevation	9751.83	9825.14		

This shows that the SDM was the most appropriate model for our dataset when the lagged variables of “Average Certified overlaps, (Harvest Area*Mill Size), Elevation” are included along with the main variables. This model had an AIC of 9740.03 and a BIC of 9808.6. These are lower than the best SAC model values, as shown in Table 4. The effect estimates and the parameters of the best SDM model are given in Table 5.

Table 5. Results of the Spatial Durbin Model (SDM) with direct and lagged independent variables in estimates and robust standard errors. Dependent variable: Mean BMP implementation rate within the wood basket. Estimates are noted and the brackets contain heteroscedasticity and autocorrelation corrected robust standard errors. (p values = *:0.1, **:0.05, ***:0.01, ****:0.001).

Independent Variable	Direct effect	Indirect (spatially lagged) effect
Mean certified basket overlaps within wood basket	0.39	-0.37
	(0.08)****	(0.13)****
Mean non-certified basket overlaps within wood basket	-0.25	NA
	(0.03)****	
Percent sites with Non-Industrial Private Forest (NIPF) ownership within wood basket	-0.064	NA
	(0.008)****	
Percent sites with corporate ownership within a wood basket	0.0027	NA
	(0.009)	
Total length of perennial streams within a wood basket (km)	0.023**	NA
	(0.01)	
Mean elevation within a wood basket	-0.014	0.011
	(0.005)****	(0.003)**
Total Harvest Area within a wood basket (km^2) * Sourcing Mill size	-0.044	0.061
	(0.006)****	(0.009)****
Spatial parameter Rho (ρ)	0.63	
	(0.03)****	
R^2 Within	0.1948	
R^2 Between	0.1079	
R^2 Overall	0.1541	
Log-pseudolikelihood	- 4858.013	
Degrees of freedom	12	
Akaike Information Criterion (AIC)	9740.03	
Bayesian Information Criterion (BIC)	9808.6	

The direct effects summarize the impact of changing independent variables at a survey site on BMP implementation rate at that survey site, while the indirect effects (coming from the estimates of the lagged independent variables) summarize the impacts of changing the neighbors' weighted independent variables on the BMP at the site. The estimate sizes and some of the signs in the direct effects of the SDM model (table 5) are different from the estimate sizes and their signs in the Tobit as seen in Table 3. The direct effects are statistically significant for average certified overlaps within the wood basket and are positive, but the indirect effect of the mean certified basket overlaps is negative. This presents a very interesting set of results in which the increasing certified mill overlap in a wood basket positively affects the BMP rates in it by 0.39 while increasing the same certified overlap by the neighboring wood basket decreases it by 0.37. The overall effect of certified overlaps on the landscape as a whole is positive. When the average non-certified overlaps increase in a wood basket, the average BMP rates decrease by 0.25 percent. An increasing percentage of corporate harvesting sites and decreasing NIPF sites seems to have the effect of increasing the mean BMP rates. As the number of perennial streams increases in a wood basket, the BMP rates also seem to increase, indicating the implementation of good forestry practices in the context of streams. The variable of elevation has a direct negative effect on BMP rates and a positive indirect/lagged effect; the overall effect of elevation on BMP rates on the landscape as a whole seems to be negative. Harvest intensity interaction term has direct negative and indirect/lagged positive effect on BMP rates. The overall effect of harvest intensity on the landscape as a whole seems to be positive, indicating a concurrency of harvest area increase and associated mills being larger has a positive neighbor effect but a negative direct effect on BMP rates. Finally, Figures 13 and 14 show the Moran scatter plots for each of the years based on the OLS models and the SDM models, respectively.

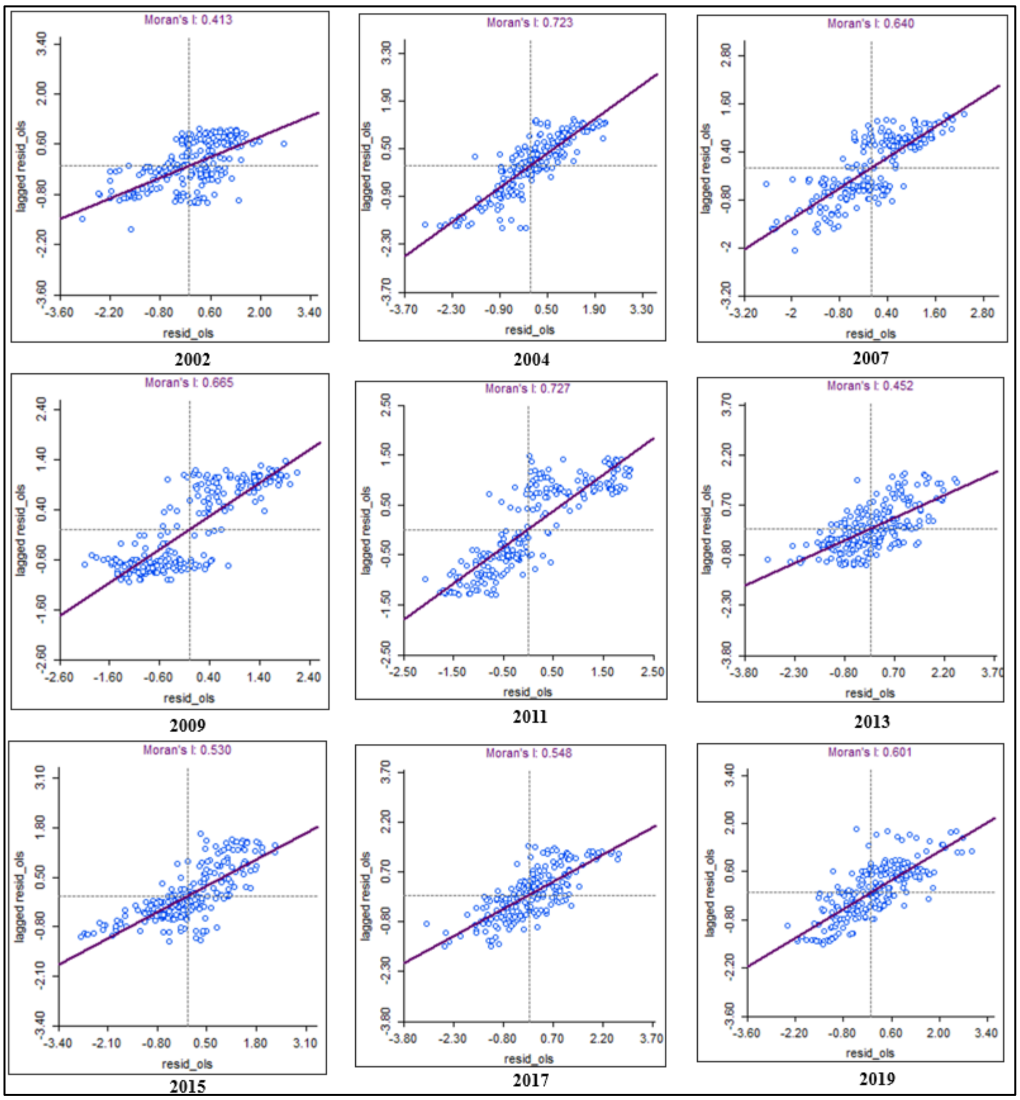

Figure 13. Results of Moran's I tests under randomization for residuals of the best ordinary least square (OLS) model.

The difference between the years in terms of spatial dependence observed in the residuals is clear. OLS shows spatial dependence in the residuals for all years while the SDM residuals don't.

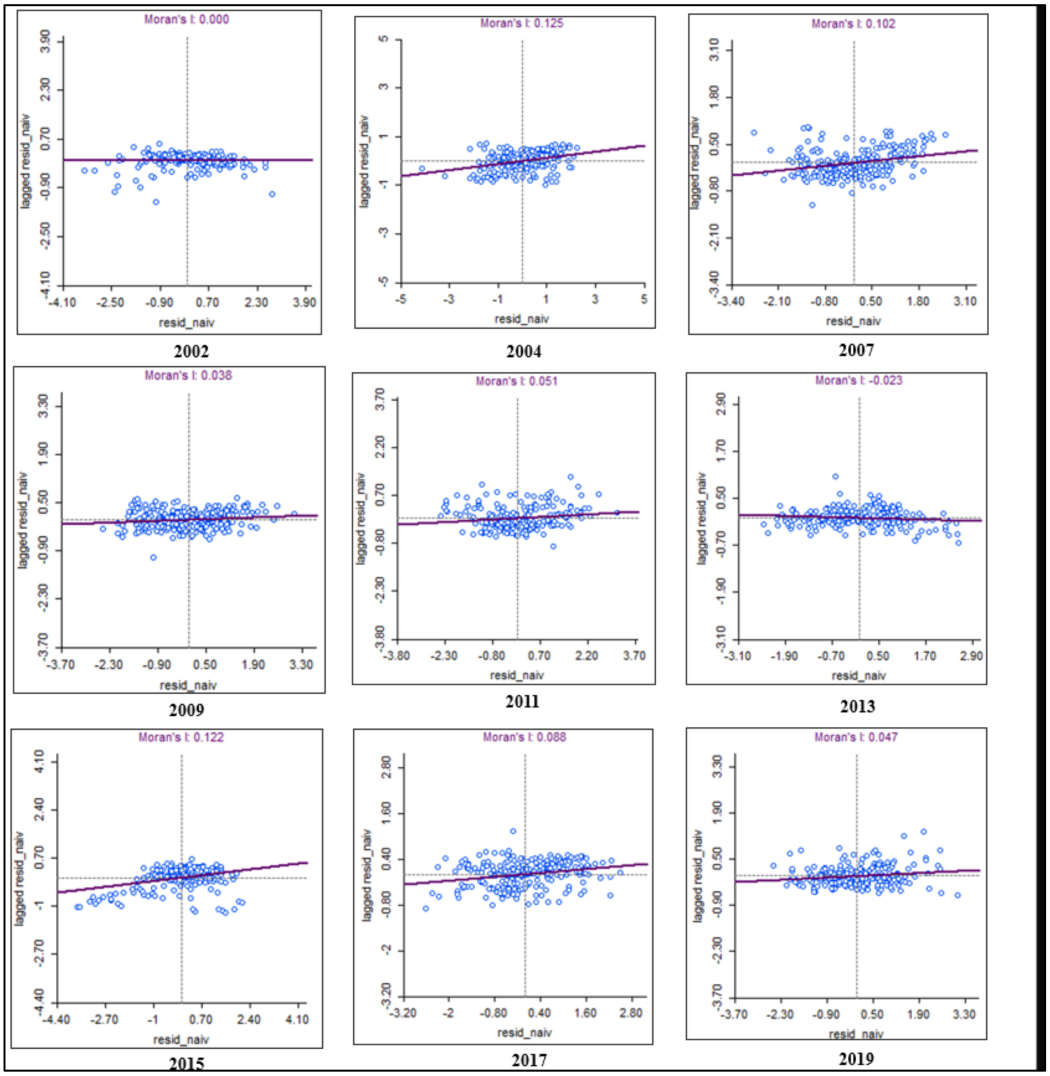

Figure 14. Results of Moran's I tests under randomization for residuals of the best Spatial Durbin Model (SDM).

3.4. DISCUSSION AND CONCLUSION

Our study has updated the Tobit analyses of Dwivedi et al. (2018) by a) making the data collection more robust through holistic corroboration, b) including non-certified mills in the data analyses along with the ownership, time, and ecoregion dummies, and c) incorporating the effects of spatial dependence. Comparing the Tobit and spatial models, we show that the estimates of Tobit, being a global model, do not explain the spatial patterns of dependence between the variables considered, which may bias the estimates. Moreover, the AIC and BIC of the OLS indicate that the corresponding spatial models are a better fit for this type of data than simple Tobit regression. We find that the SDM model is the most appropriate for our data and shows that the certified overlaps, mean elevation, and harvest intensity (represented by interaction of total harvested area and associated mill size) within neighboring mill wood sourcing baskets likely have an influence on the mean BMP rates within a mill's basket.

The results of our Tobit modeling show that increasing non-certified basket overlaps has a negative effect on BMPs (which is consistent with its total impact in the SDM as well as other spatial models) while the effect of changing certified basket overlaps is found to be positive and statistically significant. The total effect of certified overlaps on the BMP rates at the landscape level, viz. the addition of direct and indirect/lagged effects, is still positive but much smaller than that reported by Dwivedi et al. (2018). This is because the indirect/lagged or neighbor's certified overlaps show a negative relationship with the BMP rates.

The Tobit result shows that the large mills harvesting more has a positive impact on the BMP rates which is also seen in SDM model at the landscape level. On the other hand, the SDM model shows that the direct impact of harvesting intensity is negative on the BMP rates indicating that the stronger positive impact comes from the neighbors' characteristics. If the neighboring mill is larger and there is more harvested area in its sourcing wood basket, the BMP rates of the associated mill basket increase. This is in congruence with the argument that small-sized operations likely depend on larger neighbors when contracting and monitoring logging companies' performance to conserve their operational and financial capacities. All the certified mills in Georgia are classified as 'large' by the GFC. For certified sourcing, the mills have to contract loggers who have been trained by the GAMTH training program. When multiple mills are interested in contracting loggers, generally, a common broker guides the process. This lengthens the supply chain around the trained loggers and likely decreases the efficiency of BMP implementation. This can explain the indirect negative impact of neighbors' certified overlaps observed in our results.

Our results are in sync with Ruben (2017), who argues that certification systems have heterogeneous impacts at local and global levels due to variability in "resource endowments, risk attitudes, and adjustment capacities" of the management entity and that reporting only the average treatment effect is not adequate. Ruben (2017) also argues that initial impacts of certification vanish later on due to neighbors copying each other's practices. In the case of SFI-FS certification, the supply chain dynamics between logger contracting large and small mills, as noted above, is likely involved in a similar copying behavior. Reducing non-certified basket overlaps (by certifying the corresponding mills) can increase the effectiveness of the BMP requirements in the SFI-FS system. It can also be argued that the locations where we find high-high associations of non-certified basket overlaps and low-low associations of certified basket overlaps are good locations to incentivize operating mills and loggers to get certified and/or GAMTH trained. The locations for low-low associations / 'sinks' of BMP implementation rates (as seen in Figure 12) can be identified and investigated in more detail to understand the local dynamics that may be present. Moreover, from the point of view of the mills, optimizing the certification supply chains involving landowners and loggers may help in potentially further increasing the BMP implementation rates on a local level.

The Tobit results also indicate that, within a mill basket, BMP rates decrease with increasing elevation, which is what would be expected because it is generally more difficult to implement BMPs in mountain areas. The SDM model indicates that with increasing elevation, the BMP rates decrease at the landscape level but also identifies that when a neighboring wood basket has higher mean elevation, the BMP rates within the relevant wood basket increase. The incorporation of spatial dependence has helped our analyses to tease out the marginal direct and indirect effects, which the Tobit analyses do not.

Romero et al. (2013) argue that understanding what factors drive the probability of mills getting certified and recruiting GAMTH trained loggers to source certified wood will be critical to the future of such neighborhood spatial research. These factors would include the characteristics of this self-selection process, particularly issues related to "costs, expertise, and knowledge vs. external such as consumer confusion and supply-chain structure." In the SFI-FS system, future studies can start assessing decision-making by mills and logging companies which may reveal important factors like informational awareness and technological access. One limitation of this study may be that motivations and opinions have been known to predict management decisions more than spatial property characteristics (Jacobson, 2002). In spite of that, the theory of cognitive hierarchy (Vaske and Donnelly, 2010) suggests that motivations are formed based on personal and prestige-based values (see the theory of planned behavior by Ajzen, 1991). Future spatial studies of SFI-FS or similar responsible sourcing systems can incorporate these motivational factors in their analyses of spatial impacts.

Using robust corroborations of multiple spatial data sources, this study spatially analyzed the impacts of certified as well as non-certified basket overlaps on BMP implementation. The two broad policy recommendations from our study that can help improve the BMP implementation rate are to optimize certification supply chains and assess appropriate locations to grow certification. Comparing multiple approaches to assess these impacts, from simple Tobit to improving the models by incorporating spatial dependence, our robust results are unique because spatial patterns in the responsible certification system have never been studied to date. SFI-FS certification indeed has positive impacts on BMP rates in Georgia, as found by Dwivedi et al. (2018), but the effect on the landscape level might not be as strong as they report. The discrepancy between the direct and indirect effects of SFI-FS certification can help SFI and its stakeholders design strategies in the future to grow and improve the impacts of SFI-FS both systematically and structurally.

CHAPTER 4

A GLOBAL ASSESSMENT OF LINKAGES BETWEEN THE FOREST STEWARDSHIP COUNCIL'S FOREST MANAGEMENT CERTIFICATION AND BIODIVERSITY USING GENERALIZED RANDOM FOREST[1]

[1] Parag Kadam, Puneet Dwivedi, Submitted to [Scientific Reports], [03/31/2022].

Abstract

This study explores the linkages of country-level socioeconomic and ecological characteristics associated with Forest Stewardship Council's Forest Management (FSC-FM) certifications with biodiversity loss in 91 countries between 2008 and 2019. Each percent increase in FSC-FM area out of total forest area is associated with a decrease in the percent threatened species by a factor of about 0.1 to 0.15. The trends in associations found by our robust ordinary least square regressions with fixed effects reveal linkages through the random forest estimates. FSC-FM certification is positively associated with biodiversity when population densities and tree cover loss are high. FSC-FM is also good for biodiversity in the context of the enabling conditions of higher perception of corruption control and lower extraction of non-forestry natural resources. The associated heterogeneous linkages can help the FSC decision-makers to strategize the expansion of the FM certification in countries where these factors are present.

Keywords

Forest Stewardship Council, Random Forest, Biodiversity, Global

4.1. INTRODUCTION

Voluntary forest certification is a non-state and market-driven governance mechanism for conservation (van der Ven and Cashore, 2018). Forest Stewardship Council (FSC)'s voluntary forest certification began in 1993 as a moderate response to frequently contentious direct-action strategies of environmental NGOs, including disruptive environmental boycotts (Bartley, 2007). The FSC theory of change involves enhancing conservation benefits through forest management entities (FMEs) adopting responsible forest management practices based on conformance to FSC's forest management (FM) standards, assurance of which is provided by a third-party independent certification body (CB) audits (FSC, 2015). In this governance mechanism, costs involved in assurance are ideally to be balanced by market benefits from selling high-in-demand certified products (Cashore et al., 2007). The efficacy of this market-based instrument depends on identifying and resolving institutional, social, and ecological externalities that may cause market failures by distancing decision-making from actual on-the-ground impacts (Taherzadeh and Howley, 2017). Particularly, as noted by the authors, factors of access to nature and distributive justice can be associated with the relationship between market-based mechanisms and biodiversity.

Globally, the FSC has certified 228.4 million hectares in over 130 countries (FSC, 2021), each under a nationally unique set of verifiers but with globally common principles and criteria. Figure 15 shows the distribution of the FSC certified area as a percentage of total forest area in 2020. After almost 30 years, it has created a formal and informal dialogue surrounding sustainable forest management between various stakeholders, including FMEs (Pappila, 2013) but global impact on biodiversity and other on-the-ground natural values remain to be assessed. This is especially relevant as 64.4% of the total known species were found in forests in 2020, out of which 64.9% were found in countries that had FSC-certified forestlands, amounting to 41.8% of total species in the world (from International Union for Conservation of Nature (IUCN, 2021a)). It is necessary to incorporate economic and ecological knowledge for efficiently developing strategies for biodiversity management (Wätzold et al., 2006). Business as usual approaches will be detrimental to this issue in the light of projections showing a decrease in biodiversity (Ehrlich and Pringle, 2008). The goal of this study is to assess the association of FSC certification presence with biodiversity outcomes from a global perspective given the heterogeneity in country-level complex politico-ecological and economic systems.

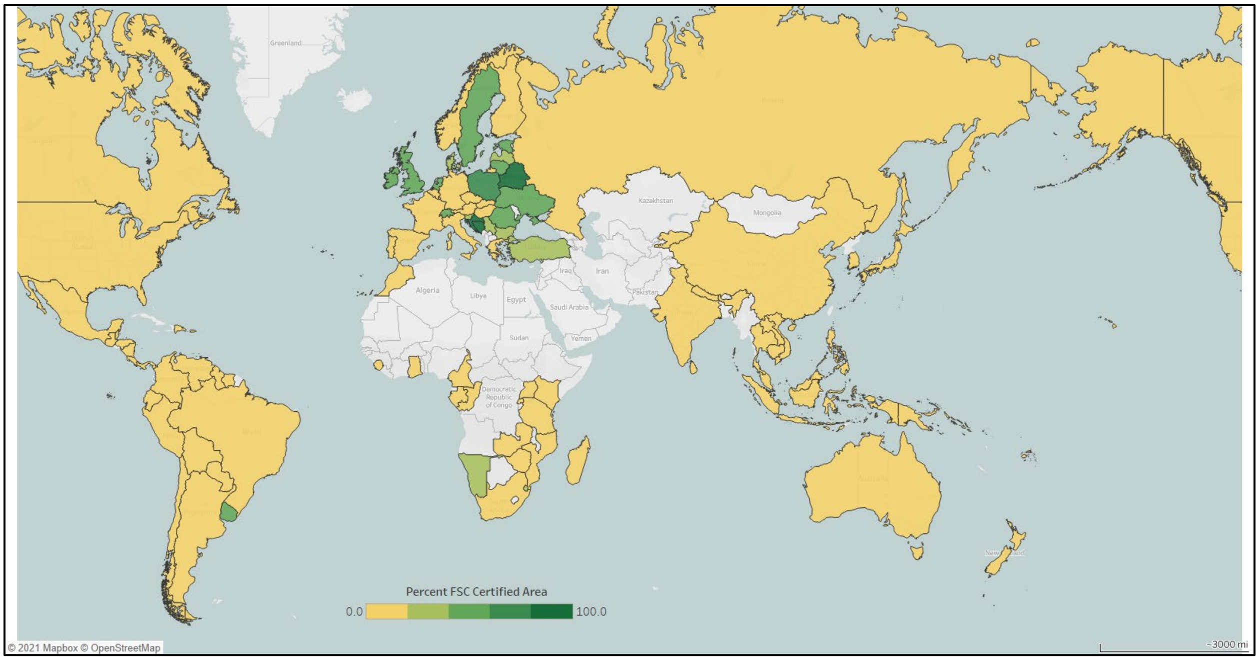

Figure 15. Global distribution of FSC certified areas as a percent of total forest area in a country in 2020. Source: FSC (2021).

Direct analyses of possible associations between biodiversity and certified area are few and either on a smaller geographical or temporal scale. Some note that the FSC system is not related to an adequate motivation for the forest landowners to maintain or enhance forest cover (Gullison, 2003) while others find positive associations. Particularly, Miteva et al. (2015) find positive social and environmental impacts of FSC certification using spatially-explicit village-level data from Kalimantan, Indonesia. Damette and Delacote (2011) find a negative impact of certification on deforestation on a global level, but the extent of timber extraction increases deforestation; moreover, they argue that certification may mediate (or rather soften) that relationship when the quality of governance, including corruption, is considered. Agreement exists that forest certification mechanism is strengthened by parallel forest governance from governments or people (Cerutti et al., 2011). For example, Maryudi (2015) shows that tenure security is a major hurdle to forest certification as conflicting governance frameworks “impinge on areas currently managed by forest concessions” (page 1). According to Romero et al. (2013), to effectively assess the role of forest certification, knowledge about the political economy of the forest sector and land use change is crucial, along with temporal dynamics of certification. Nevertheless, such multivariate and multi-directional associations on a global scale restrict analyses of causality because of the presence of endogenous variables. In a complex system, especially on a global level, different factors may frequently act as both cause and effect, but as has been noted by Mauro (1997) – policy conclusions do not entirely depend on definitively establishing the direction of causality. This study explores the linkages of country-level economic, social, and ecological characteristics with the association of FSC certification and biodiversity but cannot attribute direct causality of effects.

Several specific variables, which may be associated with the linkage between forest certification and its impact on biodiversity and other forest-based ecosystem services, have been included in the theoretical frameworks at the global level (Halkos, 2011). Possible sources and mediating pathways of heterogeneity in the role of forest certification, in general, and FSC, in particular, could be socio-ecological factors including tree cover loss (Chust et al., 2003), population density (Luck, 2007; McKee et al., 2004), and agricultural growth (Jusys, 2016) as well as politico-economic ones like gross domestic product (GDP) (Chang et al., 2019; Jusys, 2016), corruption(Mauro, 1997, 1995) and natural resource rents (Okada and Samreth, 2017; Shittu et al., 2021). Tree cover loss and agricultural growth can be argued to affect the uptake of FSC certification as well as biodiversity, and FSC certification can, in turn, bring about a change in them because the implementation of FSC standards requires forest management decision making to balance ecological, economic, and social concerns of all the relevant stakeholders. This may involve restricting tree cover loss or restricting the clearing of a forest for agricultural purposes. Population density, corruption, and GDP per capita indicate socio-economic dimensions of countries that can represent access to the resource, political stability, and distributive justice, respectively. Taherzadeh et al. (2017) support including these variables because they specifically represent the respective dimensions. They also note that these variables have been known to be associated with the efficacy of market-based mechanisms like certification. Natural resource rent is defined as the revenue generated above the cost of extraction (due to limited availability), and its increase indicates the depletion of a country’s capital stock. Extraction of natural resources (oil, natural gas, and forestry together) has been known to affect ecological footprint in a negative way (Shittu et al., 2021) and is relevant to the association of FSC with biodiversity.

These specific variables, which may be associated with the linkage between FSC-FM and biodiversity, have been included in the theoretical frameworks for modeling biodiversity on the global level. Decision-makers are known to bring about changes in SFM practices only when required to do so for getting certified (van der Ven and Cashore, 2018). This further increases difficulty in analyzing certification impacts on biodiversity as separate from impacts of activities towards compliance with governmental regulations or corporate social responsibility (CSR) activities or other governance systems affecting biodiversity. Data availability, identifying corresponding scales of analyses, and other study design difficulties are argued to be some of the major factors that hinder undertaking impact assessments for forest certification (van der Ven and Cashore, 2018). Much of earlier research has been focused on processes instead of outcomes, and the researchers have used data received after third-party certification audits (Johansson and Lidestav, 2011). The objective of this study is to explore the linkages of country-level characteristics in the association of FSC-FM certification area uptake rates globally with independently made biodiversity outcome estimates from the International Union for Conservation of Nature (IUCN). This is done through exploring estimates of the association of FSC-FM certification's presence on percent threatened species from 2008 to 2019 across 91 countries using a machine learning tool of causal forests, a generalized random forest method, detailed algorithm for which can be found in Athey and Wager (2019). We firstly ran simple heteroskedasticity and cluster corrected regressions with just year and with both year and country as fixed effects in order to verify whether the estimates of chosen independent variables show more cross-country or more within-country variation. The second part of the analyses involved training random forests, an ensemble learning methodology, in which random subsets of observations are used to test which independent variables can partition the samples most effectively (Amit and Geman, 1997) using both full and country-level modeling as suggested by Athey and Wager (2019). The detailed methodology can be found in the 'methods' section at the end of this paper. We find that FSC-FM certification has a positive association with biodiversity, but there may be several country-level limiting contexts on its association with biodiversity, including the state of the economy, extraction, corruption, and socio-ecological characteristics.

4.2. METHODS

4.2.1. DATA ASSEMBLY

The observations on FSC certification and IUCN's percent threatened species were acquired from publicly available sources, viz. FSC (2021) and IUCN (2021a), respectively. FSC data on the presence and absence of forest management certification as well as area was available from 1993 to 2021 with the required information on 94 countries. The IUCN's data on threatened species for the same countries was found to be complete only after 2008. FSC FM certified areas were used as a percent of total forest area (source: Food and Agriculture Organization, FAO (2020)) in a country in a given year instead of raw hectares. Percent threatened species were calculated from numbers of species assessments (terrestrial forest-based: plants and animals) following IUCN (2021b) formulated by:

$$Percent\ Threatened\ Species = \left(\frac{Critically\ Endangered + Endangered + Vulnerable}{Total\ assessed - Extinct - Data\ Deficient}\right) * 100 \qquad (1)$$

Tree cover loss (Global Forest Watch, 2021) was calculated as a percentage of the total forest available in each country in a given year, while agricultural land was used as a percentage of total land (source: FAO (2020)). Data on economic and social dimensions relevant to the study were collected from the World Bank. Specifically, observations on the perception of the Control of Corruption index from the World Governance Indicators (World Bank, 2021a), percent annual growth of GDP per capita (World Bank, 2021b), population density (number of people per square km) (World Bank, 2021c), and natural resource rents (as a percent of GDP) (World Bank, 2021d) were collected for each country for required years. Natural resource rents data included rents from oil, natural gas, coal, and forestry; so two different variables – non-forestry rent (NFR, containing oil, natural gas, and coal rents) and forestry rent – were used in the models to compare patterns within the total natural rents (World Bank, 2021e). Observations for Taiwan, Eswatini, and Liechtenstein could not be used for statistical modeling as several covariates, including GDP, tree cover loss, rents, and certification, were missing. Moreover, agricultural and rent observations for the year 2020 were not published yet, so the analyses were kept restricted to 2008 to 2019 across 91 countries.

4.2.2. STATISTICAL METHODS

Simple ordinary least square regression (OLS) model was built, once with both year and country fixed effects and again with only year effects, to assess the patterns of variable estimates and significance. This was done to verify whether the estimates of chosen independent variables show more cross-country or more within-country variation. Only heteroskedasticity and autocorrelation corrected robust standard errors were used in all the regression and other models in this study. The full regression equation for the two-way fixed effects model was:

$$Percent\ Threatened\ Species_{i,j} = dCountry_i + dYear_j + Percent\ tree\ cover\ loss_{i,j} +$$
$$Percent\ agricultral\ land_{i,j} + GDP\ per\ capita\ percent\ growth_{i,j} +$$
$$Population\ density_{i,j} + Corruption\ control_{i,j} + Non\ forestry\ rent_{i,j} +$$
$$+Forestry\ rent_{i,j} + Interaction\ of\ Corruption\ control\ and\ non\ forestry\ rent_{i,j} +$$

$$Interaction\ of\ Corruption\ control\ and\ forestry\ rent_{i,j} + Percent\ FSC\ certified\ area_{i,j} + dFSCcertification_{i,j} \quad (2)$$

where *i* denotes the country and *j* denotes the year.

The perception of corruption control variable (originally continuous) was changed into a binary variable (all positive values get a 'yes' or 1, and all others get a 'no' or -1) and then used in the interaction term with non-forestry and forestry rents.

Amit and Geman (1997) introduced the core idea of the 'random forest', an ensemble learning methodology, in which a random subset of observational data is used to test which of the independent variables can partition the samples in the most effective way creating a decision-tree of effects. Per Breiman (2001), estimates of effects are determined by averaging all the estimates in individual trees. The 'causal forest' methodology of the Generalized Random Forest (GRF) builds individual trees using greedy recursive partitioning and is randomized using bootstrap (or subsample) aggregation like classical random forests but is different in that, instead of the kernel weighting function, an adaptive weighting function is used to identify partitions and capture heterogeneity in the estimated average treatment effects using covariate-based CATE (Athey et al., 2016). We used the models from equation (2) to train our data using the grf package in R (a detailed algorithm is given by Athey and Wager (2019)).

We trained a 'pilot' raw random forest with all covariates first and a second causal forest on only those covariates which showed a higher number of splits in the pilot forest trees. As suggested by Athey et al. (2016), we trained both forests with the goal of reducing the out-of-bag error (of subsamples not used to train main forests) using i) 2000, 4000, 6000, 8000, 10000, and 12000 trees, ii) using 'mtry' parameter (how many covariates are used to construct splits) as $min(sqrt(p) + 20, p)$, where p is number of variables, and iii) honesty fractions (fraction of samples used in selecting tree split) from 0.5 to 0.8 . We recorded importance of each covariate in the first raw forest as denoted by percent share of number of splits, and then trained a second forest on only those features that saw a reasonable number of splits in the first step. Plotting the distributions of CATEs to explore directions of heterogeneity in the FSC-FM association with biodiversity, we also tested whether the difference between high and low estimates as conditioned on each covariate were statistically significant. Finally, we trained a third forest using averaged out country level data to assess whether an analysis that only focuses only on country-level associations can capture heterogeneity signals better than the full forest. We tested heterogeneity in the data captured by the three forests using the 'best linear predictor' methodology of Chernozhukov et al. (2017), which fits CATE as a linear association of the out-of-bag causal forest estimates (Athey and Wager, 2019). It provides information on whether the predictions are correct (if the coefficient of 'mean.forest.prediction' is 1 and significant) and whether the forest could capture the underlying heterogeneity signals in the data (if the coefficient of 'differential.forest.predictions' is 1 and statistically significant).

4.3. RESULTS

Per regression modeling, many covariates became statistically significant when country-level fixed effects were not included in the model (Table 6). However, the same covariates were not significant when country-level fixed effects were included. This shows that cross-country variation of impacts of FSC-FM on percent threatened species are important to be considered, and attributing causality of relationship would not be appropriate. Estimates in Table 6 indicate the importance of using only non-forestry rent, which was statistically significant in the two-way fixed effects model despite country fixed effect; it was positively associated with percent threatened species. The interaction of resource rents with control of corruption was only significant for non-forestry rents and had a positive estimate. Increasing GDP per capita, population density, and percent tree cover loss were also positively associated with the percent of threatened species. Controlling for other variables, percent FSC certified area and perception of control of corruption were found to be negatively associated.

Table 6. Results of ordinary least square regression of equation (2) model. Dependent variable: Percent threatened species. Estimates and heteroskedasticity and cluster corrected robust standard errors (in the brackets) are noted for each independent variable.

Independent variables	Model eq (2) with total Natural Resource Rents	
	Two-way fixed effects	Only Year fixed effects
FSC certification presence (0,1)	-1.68 (2.12)	-0.52 (1.58)
FSC Certified Area (% of Forest)	0.05 (0.03)	-0.11**** (0.02)
GDP per capita percent growth	0.13 (0.09)	0.27** (0.11)
Non-forestry Rents (% of GDP)	0.36** (0.12)	0.12** (0.03)
Forestry Rents (% of GDP)	-0.07 (0.01)	-0.16 (0.12)
Control of Corruption	-0.21 (3.21)	-0.49**** (0.23)
Interaction of Corruption Control and Non-forestry Rents	0.36 (0.15)	0.38*** (0.11)
Interaction of Corruption Control and Forestry Rents	-0.01 (0.34)	0.03 (0.21)
Population Density	0.02 (0.05)	0.007* (0.004)
Percent Agricultural Land	0.10 (0.25)	-0.001 (0.02)
Tree Cover Loss (% of Forest Area)	0.75 (0.73)	2.13*** (0.78)
R-squared	0.3542	0.1927
Residual standard error	9.85	11.52
Number of observations	1087	1087

Table 7 contains the results of the 'best linear predictor' methodology of Chernozhukov et al. (2017) to assess whether the trained forest was well-calibrated. The predictor indicates that the conditional average treatment effects (CATEs) could be fitted as a linear association of the out-of-bag causal forest estimates using our model (the coefficient of mean.forest.prediction was 1 and statistically significant) and that the country level forest could identify heterogeneous linkage signals in the data (the coefficient of differential.forest.predictions was also very close to 1 and significant for both country-level forests) (Table 7). The results below indicate that the country-level forests could sufficiently capture the heterogeneity in the association of FSC certification with percent threatened species, but the full models could not.

Table 7. Forest calibrations for model equation (2). Estimates and heteroskedasticity and cluster corrected robust standard errors (in the brackets) are noted for each independent variable. (p values = *:0.1, **:0.05, ***:0.01, ****:0.001).

	Selected variables' forest	Country-level forest
Mean.forest.prediction	0.65	1.004****
	(1.21)	(0.08)
Differential.forest.prediction	-5.4	1.23****
	(1.96)	(0.12)

In the full forest with selected variables and the country-level forests, non-forestry rent was the most split variable indicating its importance in the recursive partitioning algorithm. It amounted to around 53% of the total splits in the country-level forest. Percent tree cover was consistently the second most important variable in the model (29.4%), and the percent FSC certified area was also found important (9.6%). Other important variables were the interaction of resource rent with control of corruption (8.1%) and population density (7.4%).

Figure 16 shows the distribution of high to low CATEs along independently taken covariates, which were statistically significant (p<0.05). Association of FSC certification with biodiversity may be more positive (meaning a less percentage of threatened species) in countries with a higher loss of tree cover, higher population density, lower extraction of non-forestry resources, higher perception of control of corruption, and higher percent FSC certified area. The association of FSC certification with biodiversity along this interaction term of natural resource rent and corruption control may have a U shape, with it being more negative in countries with not so well-governed high extraction and slightly less negative for those with extremely well-governed high extraction countries with an inflection at zero.

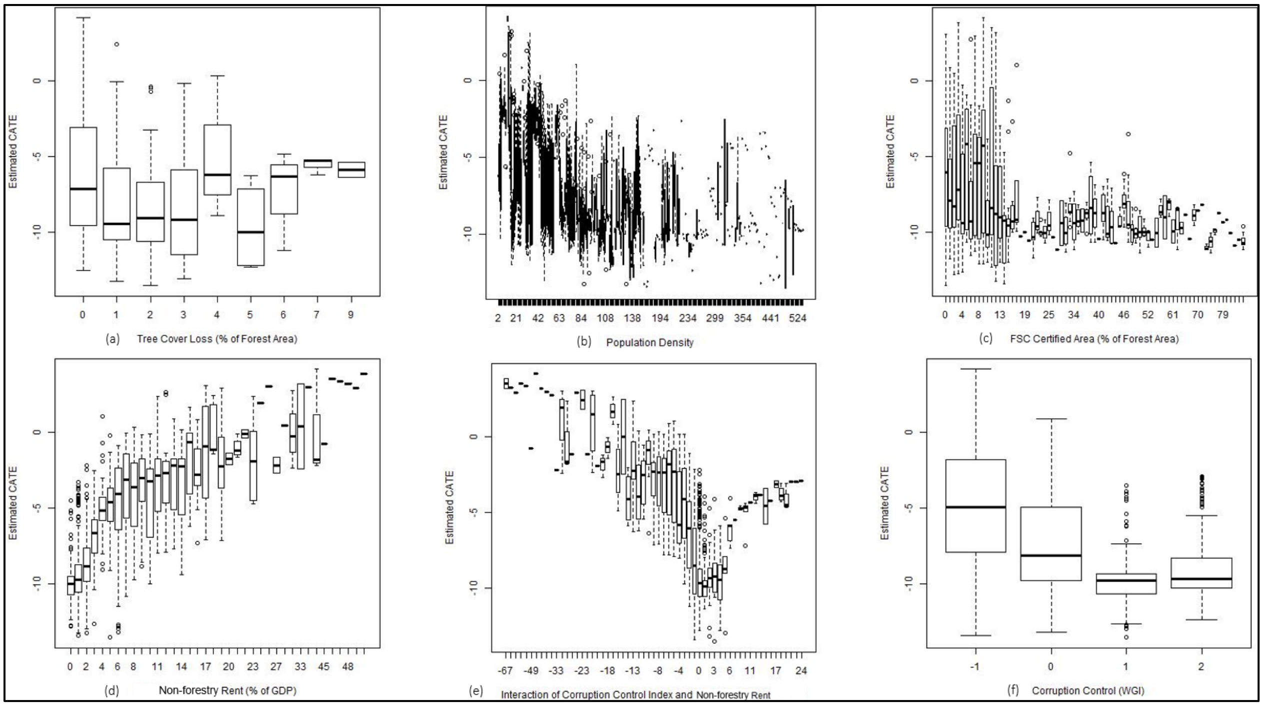

Figure 16. Statistically significant distributions of conditional average treatment effects (CATEs) along with covariates from model equation (2): with respect to a) tree cover loss, b) population density, c) FSC area, d) natural resource rents, f) control of corruption, and e) the interaction of the two. Dependent variable: Percent threatened species. Treatment variable: FSC certification (presence/absence).

Table 8 contains the results of country-level forests showing the estimates and robust standard errors for modification in the association of FSC certification presence with biodiversity. Figure 16 shows the distribution of CATEs when covariates are independently taken, while table 8 results show a modification in the association when other covariates are controlled for. The association of FSC certification with biodiversity is positive in the contexts of higher percent FSC area and higher tree cover loss but negative when natural resource rent and its interaction with a perception of corruption control increases.

Table 8. Results of modifications in association between FSC certification and biodiversity as identified by the country-level forest. Dependent variable: Percent threatened species. Treatment variable: FSC certification (presence/absence). Estimates and heteroskedasticity and cluster corrected robust standard errors (in the brackets) are noted for each independent variable. Dependent variable: Percent threatened species. (p values = *:0.1, **:0.05, ***:0.01, ****:0.001).

Independent variables	Effect modification for Model eq (2) with total Natural Resource Rents
FSC Certified Area (% of forest area)	-0.15**** (0.04)
GDP per capita percent growth	0.82 (0.21)
Non-forestry Rents (% of GDP)	0.96**** (0.29)
Forestry Rents (% of GDP)	-0.03 (0.36)
Control of Corruption	-0.51 (1.02)
Interaction of Corruption Control and Non-forestry Rents	0.64** (0.42)
Interaction of Corruption Control and Forestry Rents	-0.25 (0.36)
Population Density	-0.007 (0.006)
Percent Agricultural Land	0.03 (0.04)
Tree Cover Loss (% of Forest Area)	-4.82*** (1.56)
R-squared	0.318
Residual standard error	6.68
Number of observations	91

4.4. DISCUSSION

Using a novel machine-learning algorithm of the generalized random forests, this study analyzed the linkages in the association of FSC-FM certifications with biodiversity loss from a global perspective and successfully identified country-level factors which moderate the estimated association. Trends found by our robust ordinary least square regressions with fixed effects reveal linkages associated with the estimates through the random forest analyses.

It is relevant to note that the non-forestry rent globally was the only variable statistically significant in the two-way fixed effects model and was also the most important variable on a national level with respect to a direct association with biodiversity as well as a moderating factor for the association of forest certification with biodiversity loss. Moreover, this association does not seem to exist for just forest rents as none of the estimates are found to be significant. This indicates that forest extractions per se might not be important to the association of FSC-FM with biodiversity, but other natural resources do. Total and forestry natural resource rents have been known to have different moderating influences due to their respective contexts and roles in globalization and trade (Sinha and Sengupta, 2019). This means that the international supply chains and trade-networks for natural resource rent for oil and gas are higher in volume compared to forest products indicating possible stronger linkages with biodiversity. This might be one of the reasons why, in our models, forest rent was not significant, but natural resource rent was. Future research must include relevant variables from dimensions of globalization and international trade to make the modeling more robust, as biodiversity outcomes are known to be exported from high-income to low-income countries (Bjelle et al., 2021). Furthermore, including the forest-related dimension of economic inequality along with corruption is also important as they have been known to increase threatened species (Holland et al., 2009), likely through an increase in rent-seeking activities. The linkage found in our study is similar to that of Okada and Samreth (2017), who found that forest rents are not associated with corruption, unlike with total natural resource rents, which include oil, natural gas, coal along forestry.

These results support the arguments that a) FSC-FM certification has a positive association with biodiversity where they are much needed (possibly in developing countries where population densities and tree cover loss is high, see Winkler et al. (2021) and Bjelle et al. (2021)), and b) enabling conditions of higher perception of corruption control and lower extraction of non-forestry resources are needed for that positive association of FSC-FM. The results of this study only incorporate observations between 2008 and 2019 and are limited by that timeframe. It is also possible that observed trends in the global slowdown in land-use changes after the economic crisis of 2007-2009 (Winkler et al., 2021) may be relevant to our results. Our results can be useful for FSC to strategically plan expansion around the world where there are better enabling conditions but also where there is a need for sustainable and responsible forest management. The heterogeneous linkages observed in our analyses can help policy and decision-makers to improve the association of FSC-FM with biodiversity worldwide.

CHAPTER 5

CONCLUSION

The overarching goal of this dissertation is to explore the changes in the standards of FSC and SFI Forest Management standards and the environmental impacts of these two most widely used forest certification systems in the world. The principal questions were a) where FSC and SFI FM standards have changes convergent with the international SFM protocols, b) whether SFI-FS has spatial impacts on forestry BMP implementation rate, and c) whether FSC-FM has impacts on biodiversity at the global level. The scale of the study area in the latter two, local and global respectively, is dependent on the availability of comparable long-term on-the-ground data of not only the environmental outcomes (i.e., BMPs and threatened species) but also certification locations and areas. By using a mix of qualitative and quantitative methods as well as incorporating the political ecology and socio-economy variables into the analyses, the results of this dissertation show that FSC and SFI have clear convergences with the international SFM protocols in ecological and socio-economic spheres of standards. Moreover, both FSC and SFI have positive impacts on the environmental outcomes, albeit with some constraints and contexts.

Chapter 2 results show that FSC has been instrumental in driving the changes in ecological types of C&Is within the major SFM standard systems. Moreover, the trends of socio-economic types of C&Is are concurrent with the histories of particular SFM institutions. In the last 15 years or so, FSC has been pushing to attract more landowners and industry stakeholders, while SFI (and PEFC, in general) have been strategizing to attract more NGO and civil society stakeholders. The results of this study show that the stakeholders who are involved in standard development processes have to be cognizant of the power relations and historical growth of a particular institution. Moreover, it may be contingent on the governing bodies of the SFM institutions to offer the same to its stakeholder networks as part of a responsible implementation of their FPIC. Future studies should look into the relationship of the actual stakeholder networks and power relations among them with the kind of standards being developed.

Results of chapter 3 indicate that increase in overlaps of SFI-FS certified sourcing areas do indeed lead to better BMP implementation rates on the landscape level, but the effect is likely smaller than that identified by Dwivedi et al. (2018) because, on a local level, there is a negative spatial dependence between neighbors' certified overlaps on a focus site's BMP rates. This negative neighbor's effect may likely exist because of supply chain inefficiencies brought on by concurrent contracting by small mills and their larger harvesting intensity counterparts. We also find that an increase in non-certified sourcing overlaps decreases BMP rates, as does an increase in elevation. None of the studies that I know of have studied the spatial dimensions of forest certification implementation, and I believe the results will be instrumental in driving a new avenue of research in the future, viz., considering the inter-relationships between landowners and possibly, between loggers and certificate holding mills as well. The same dynamic can be studied for FSC Controlled wood as well and will yield a more overarching understanding of the forest certification impacts. Studying the impact on the local level allowed me to assess the spatial dimensions, but the data on the long-term spatial data on a global level is not always available. To counteract that and the myriad biophysical and socio-economic differences among the countries, my objective of chapter 4 was to assess the different heterogeneous linkages in the impact of FSC FM certification presence with different socio-ecological and economic factors.

I was able to show that the FSC-FM system requires enabling political and resource extraction conditions to succeed in reducing the percentage of threatened species. The picture about the positive impact on biodiversity where there are high tree cover loss and high population densities tells the story that FSC may be instrumental in developing countries. This result is comparable with Chapter 2, where FSC has driven the changes in ecological types of C&Is among major international SFM systems since its inception. Future studies should analyze the associations between the standards and the on-the-ground impacts for a more robust understanding of where improvements can be made in the FSC system.

BIBLIOGRAPHY

Aguilar, F.X., Cai, Z., Butler, B., 2017. Proximal Association of Land Management Preferences: Evidence from Family Forest Owners. PLoS One 12, e0169667. https://doi.org/10.1371/journal.pone.0169667

Ajzen, I., 1991. The theory of planned behavior. Organ. Behav. Hum. Decis. Process. 50, 179–211. https://doi.org/10.1016/0749-5978(91)90020-T

Amit, Y., Geman, D., 1997. Shape Quantization and Recognition with Randomized Trees. Neural Comput. 9, 1545–1588. https://doi.org/10.1162/NECO.1997.9.7.1545

Anderson, N., Germain, R., 2007. Variation and trends in sawmill wood procurement in the Northeastern United States. For. Prod. J. 57, 36–44.

Anselin, L., 2009. Spatial Regression, in: Fotheringham, A.S., Rogerson, P.A. (Eds.), The SAGE Handbook of Spatial Analysis. United Kingdom: SAGE Publications, pp. 255–275.

Anselin, L., 1995. Local Indicators of Spatial Association—LISA. Geogr. Anal. 27, 93–115. https://doi.org/10.1111/J.1538-4632.1995.TB00338.X

Anselin, L., Gallo, J. Le, Jayet, H., 2008. Spatial Panel Econometrics. Adv. Stud. Theor. Appl. Econom. 46, 625–660. https://doi.org/10.1007/978-3-540-75892-1_19

Arts, B., Buizer, M., 2009. Forests, discourses, institutions. A discursive-institutional analysis of global forest governance. For. Policy Econ. 11, 340–347. https://doi.org/10.1016/j.forpol.2008.10.004

ATFS, 2020. The History of the American Tree Farm System [WWW Document]. URL https://www.treefarmsystem.org/the-history-of-the-american-tree-farm-system (accessed 2.27.20).

Athey, S., Tibshirani, J., Wager, S., 2016. Generalized Random Forests. Ann. Stat. 47, 1179–1203. https://doi.org/10.1214/18-AOS1709

Athey, S., Wager, S., 2019. Estimating Treatment Effects with Causal Forests: An Application. Obs. Stud. 5, 37–51. https://doi.org/10.1353/obs.2019.0001

Bartley, T., 2007. How Foundations Shape Social Movements: The Construction of an Organizational Field and the Rise of Forest Certification. Soc. Probl. 54, 1533–8533. https://doi.org/10.1525/sp.2007.54.3.229

Belotti, F., Hughes, G., Mortari, A.P., 2017. Spatial panel data models using Stata. Stata J. 17, 1–37.

Berny, N., Rootes, C., 2018. Environmental NGOs at a crossroads? Env. Polit. 27, 947–972. https://doi.org/10.1080/09644016.2018.1536293

Biermann, F., Pattberg, P., van Asselt, H., Zelli, F., 2009. The fragmentation of global governance architectures: A framework for analysis. Glob. Environ. Polit. 9, 14–40. https://doi.org/10.1162/glep.2009.9.4.14

Bini, L.M., Diniz-Filho, J.A.F., Rangel, T.F.L.V.B., Akre, T.S.B., Albaladejo, R.G., Albuquerque, F.S., Aparicio, A., Araújo, M.B., Baselga, A., Beck, J., Bellocq, M.I., Böhning-Gaese, K., Borges, P.A.V., Castro-Parga, I., Chey, V.K., Chown, S.L., De Marco, P., Dobkin, D.S., Ferrer-Castán, D., Field, R., Filloy, J., Fleishman, E., Gómez, J.F., Hortal, J., Iverson, J.B., Kerr, J.T., Kissling, W.D., Kitching, I.J., León-Cortés, J.L., Lobo, J.M., Montoya, D., Morales-Castilla, I., Moreno, J.C., Oberdorff, T., Olalla-Tárraga, M.Á., Pausas, J.G., Qian, H., Rahbek, C., Rodríguez, M.Á., Rueda, M., Ruggiero, A., Sackmann, P., Sanders, N.J., Terribile, L.C., Vetaas, O.R., Hawkins, B.A., 2009. Coefficient shifts in geographical ecology: An empirical evaluation of spatial and non-spatial regression. Ecography (Cop.). 32, 193–204. https://doi.org/10.1111/j.1600-0587.2009.05717.x

Bjelle, E.L., Kuipers, K., Verones, F., Wood, R., 2021. Trends in national biodiversity footprints of land use. Ecol. Econ. 185, 107059. https://doi.org/10.1016/J.ECOLECON.2021.107059

Blackman, A., Raimondi, A., Cubbage, F., 2017. Does Forest Certification in Developing Countries Have Environmental Benefits? Insights from Mexican Corrective Action Requests. Int. For. Rev. 19, 247–264. https://doi.org/10.1505/146554817821865072

Blockhus, J., Dillenbeck, M., Sayer, J., Wegge, P., 1992. Conserving Biodiversity in Managed Tropical Forests., IUCN. Gland, Switzerland.

Bontrager, A., Kretser, H., Leong, K., Connelly, N., 2016. Conservation Opportunity and Risk Mapping for Carnivores Using Landowner Survey Data from the Greater Yellowstone Ecosystem. http://dx.doi.org/10.1080/00330124.2016.1208101 69, 225–238. https://doi.org/10.1080/00330124.2016.1208101

Boström, M., Hallström, K.T., 2013. Global multi-stakeholder standard setters: how fragile are they? J. Glob. Ethics 9, 93–110. https://doi.org/10.1080/17449626.2013.773180

Breiman, L., 2001. Random forests. Mach. Learn. 45, 5–32. https://doi.org/10.1023/A:1010933404324

Bueren, E.L. van, Blom, E., 1997. Hierarchical Framework for the Formulation of Sustainable Forest Management Standards. Pathfind. 2–94.

Butler, B.J., 2008. Family Forest Owners of the United States, 2006, Gen. Tech. Rep. NRS-27. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 72 p. https://doi.org/10.2737/NRS-GTR-27

Butler, B.J., Hewes, J.H., Dickinson, B.J., Andrejczyk, K., Butler, S.M., Markowski-Lindsay, M., 2016. Family Forest Ownerships of the United States, 2013: Findings from the USDA Forest Service's National Woodland Owner Survey. J. For. 114, 638–647. https://doi.org/10.5849/jof.15-099

Butler, B.J., Leatherberry, E.C., 2004. America's family forest owners. J. For. 102, 4–14. https://doi.org/10.1093/jof/102.7.4

Cadman, T., 2011. Quality and Legitimacy of Global Governance, Quality and Legitimacy of Global Governance. https://doi.org/10.1057/9780230306462

Cashore, B., 2002. Legitimacy and the Privatization of Environmental Governance: How Non-State Market-Driven (NSMD) Governance Systems Gain Rule-Making Authority. Governance 15, 503–529. https://doi.org/10.1111/1468-0491.00199

Cashore, B., 1997. Flights of the Phoenix: Explaining the Durability of the Canada-U.S. Softwood Lumber Dispute. Can. Am. Public Policy 32, 1–58.

Cashore, B., Auld, G., Newsom, D., 2004. Governing through markets: Forest certification and the emergence of non-state authority, Governing Through Markets: Forest Certification and the Emergence of Non-State Authority.

Cashore, B., Auld, G., Newsom, D., 2003. Forest certification (eco-labeling) programs and their policy-making authority: Explaining divergence among North American and European case studies. For. Policy Econ. 5, 225–247. https://doi.org/10.1016/S1389-9341(02)00060-6

Cashore, B., Egan, E., Auld, G., Newsom, D., 2007. Revising theories of nonstate market-driven (NSMD) governance: Lessons from the finnish forest certification experience. Glob. Environ. Polit. https://doi.org/10.1162/glep.2007.7.1.1

Cerutti, P.O., Tacconi, L., Nasi, R., Lescuyer, G., 2011. Legal vs. certified timber: Preliminary impacts of forest certification in Cameroon. For. Policy Econ. 13, 184–190. https://doi.org/10.1016/j.forpol.2010.11.005

Chambers, S.N., Baldwin, R.F., Baldwin, E.D., Bridges, W.C., Fouch, N., 2017. Social and spatial relationships driving landowner attitudes towards aquatic conservation in a Piedmont-Blue Ridge landscape. Heliyon 3, e00288. https://doi.org/10.1016/J.HELIYON.2017.E00288

Chang, C.-P., Dong, M., Liu, J., 2019. Environmental Governance and Environmental Performance, ADBI Working Paper 936. Tokyo.

Chernozhukov, V., Demirer, M., Duflo, E., Fernandez-Val, I., 2017. Generic machine learning inference on heterogenous treatment effects in randomized experiments. Centre for Microdata Methods and Practice (cemmap), London. https://doi.org/10.1920/wp.cem.2017.6117

Colfer, C.J.P., Prabhu, R., Wollenberg, E., 1995. Principles, criteria and indicators: applying Ockham's Razor to the people-forestry link. Bogor, Indonesia. https://doi.org/10.17528/cifor/000068

Conrad, J., Greene, D., Hiesl, P., 2018. A Review of Changes in US Logging Businesses 1980s-Present. J. For. https://doi.org/10.1093/jofore/fvx014

Cook, C., 2022. Personal Communication.

CSA, 2021. CSA Forest Certification - | Canadian Sustainable Forest Management [WWW Document]. URL https://www.csasfmforests.ca/ (accessed 5.10.21).

Cuba, N., 2015. Research note: Sankey diagrams for visualizing land cover dynamics. Landsc. Urban Plan. 139, 163–167. https://doi.org/10.1016/j.landurbplan.2015.03.010

Damette, O., Delacote, P., 2011. Unsustainable timber harvesting, deforestation and the role of certification. Ecol. Econ. 70, 1211–1219. https://doi.org/10.1016/j.ecolecon.2011.01.025

Delmas, M., Young, O., 2009. Governance for the Environment: New Perspectives. Cambridge Univ. Press.

Dimitrov, R.S., 2003. Knowledge, power, and interests in environmental regime formation. Int. Stud. Q. 47, 123–150. https://doi.org/10.1111/1468-2478.4701006

Dwivedi, P., Tumpach, C., Cook, C., Izlar, B., 2018. Effects of the sustainable forestry initiative fiber sourcing standard on the average implementation rate of forestry best management practices in Georgia, United States. For. Policy Econ. 97, 51–58. https://doi.org/10.1016/j.forpol.2018.08.016

Eddings, W., Marchenko, Y., 2012. Diagnostics for multiple imputation in Stata. Stata J. 12, 353–367.

Ehrlich, P.R., Pringle, R.M., 2008. Where does biodiversity go from here? A grim business-as-usual forecast and a hopeful portfolio of partial solutions. Proc. Natl. Acad. Sci. 105, 11579–11586. https://doi.org/10.1073/PNAS.0801911105

Elhorst, J.P., 2010. Applied Spatial Econometrics: Raising the Bar. https://doi.org/10.1080/17421770903541772 5, 9–28. https://doi.org/10.1080/17421770903541772

Erickson, D.L., Ryan, R.L., De Young, R., 2002. Woodlots in the rural landscape: landowner motivations and management attitudes in a Michigan (USA) case study. Landsc. Urban Plan. 58, 101–112. https://doi.org/10.1016/S0169-2046(01)00213-4

European Commission, 2021. Pan-European Ministerial Conference on the Protection of Forests in Europe [WWW Document]. URL https://ec.europa.eu/environment/forests/mcpfe.htm (accessed 6.11.21).

FAO, 2020. FAOSTAT [WWW Document]. URL https://www.fao.org/faostat/en/#data (accessed 12.6.21).

FAO, 2004. FAO/ITTO Expert Consultation on Criteria and Indicators for Sustainable Forest Management. Cebu City, Philippines.

FAO, 2003. International Conference on the Contribution of Criteria and Indicators for Sustainable Forest Management: The Way Forward (CICI-2003). Guatemala City, Guatemala.

FAO, UNEP, 2020. The State of the World's Forests 2020. Forests, biodiversity and people. Rome. https://doi.org/https://doi.org/10.4060/ca8642en

FE, 2021a. Ministerial Conferences [WWW Document]. URL https://foresteurope.org/ministerial-conferencies/ (accessed 6.11.21).

FE, 2021b. SFM Criteria & Indicators [WWW Document]. URL https://foresteurope.org/sfm-criteria-indicators/ (accessed 6.17.21).

FE, 2016. SFM Guidelines - Forest Europe [WWW Document]. URL foresteurope.org/sfm-guidelines/

FERN, 2011. FERN statement to the Forest Stewardship Council on withdrawing FERNs membership [WWW Document]. URL www.fern.org (accessed 12.10.20).

Fernández-Blanco, C.R., Burns, S.L., Giessen, L., 2019. Mapping the fragmentation of the international forest regime complex: institutional elements, conflicts and synergies. Int. Environ. Agreements Polit. Law Econ. 19, 187–205. https://doi.org/10.1007/s10784-019-09434-x

Fernholz, K., Bowyer, J., Erickson, G., Groot, H., Jacobs, M., Mcfarland, A., Pepke, E., 2021. Forest Certification Update 2021: The Pace of Change.

Fransen, L.W., Kolk, A., 2007. Global Rule-Setting for Business: A Critical Analysis of Multi-Stakeholder Standards. Organization 14, 667–684. https://doi.org/10.1177/1350508407080305

FSC, 2021a. Facts & Figures | Forest Stewardship Council [WWW Document].

FSC, 2021b. Document Centre - FSC-STD-01-001 FSC Principles and Criteria for Forest Stewardship - Standard (STD) v(5-2) [WWW Document]. URL https://fsc.org/en/document-centre/documents/resource/392 (accessed 6.17.21).

FSC, 2020a. Governance - Members lead FSC [WWW Document]. URL https://us.fsc.org/en-us/who-we-are/governance (accessed 6.11.21).

FSC, 2020b. Certification [WWW Document]. URL https://us.fsc.org/en-us/certification

FSC, 2015. Demonstrating Impact [WWW Document]. URL https://fsc.org/en/details-page/roadmap-change#theory-of-change (accessed 10.31.19).

FSC, 2014. 20 Years Forest Stewardship Council.

Gale, F., Cadman, T., 2014. Whose Norms Prevail? Policy Networks, International Organizations and "Sustainable Forest Management." Soc. Nat. Resour. 27, 170–184. https://doi.org/10.1080/08941920.2013.840875

Galik, C.S., Grala, R.K., 2017. Conservation program delivery in the southern U.S.: Preferences and interactions. J. Environ. Manage. 198, 75–83. https://doi.org/10.1016/J.JENVMAN.2017.04.043

GFC, 2021. Resources | Georgia Forestry Commission [WWW Document]. URL https://gatrees.org/resources/ (accessed 8.23.21).

GFC, 2019. Economic Benefits of the Forest Industry in Georgia: 2018.

GFC, 2018. Data from GFC's BMP assessments.

Giessen, L., Burns, S., Sahide, M.A.K., Wibowo, A., 2016. From governance to government: The strengthened role of state bureaucracies in forest and agricultural certification. Policy Soc. 35, 71–89. https://doi.org/10.1016/j.polsoc.2016.02.001

Giurca, A., Jonsson, R., Rinaldi, F., Priyadi, H., 2013. Ambiguity in Timber Trade Regarding Efforts to Combat Illegal Logging: Potential Impacts on Trade between South-East Asia and Europe. Forests 4, 730–750. https://doi.org/10.3390/f4040730

Global Forest Watch, 2021. Global Deforestation Rates & Statistics by Country [WWW Document]. URL https://www.globalforestwatch.org (accessed 12.6.21).

Gulbrandsen, L.H., 2005. Sustainable Forestry in Sweden: The Effect of Competition Among Private Certification Schemes. J. Environ. Dev. 14, 338–355. https://doi.org/10.1177/1070496505280061

Gulbrandsen, L.H., Humphreys, D., 2006. International Initiatives to Address Tropical Timber Logging and Trade: A Report for the Norwegian Ministry of the Environment, FNI Report 4/2006.

Gullison, R.E., 2003. Does forest certification conserve biodiversity? ORYX 37, 153–165. https://doi.org/10.1017/S0030605303000346

Halkos, G., 2011. Modelling biodiversity. J. Policy Model. 33, 618–635.

Holland, T.G., Peterson, G.D., Gonzalez, A., 2009. A Cross-National Analysis of How Economic Inequality Predicts Biodiversity Loss. Conserv. Biol. 23, 1304–1313. https://doi.org/10.1111/J.1523-1739.2009.01207.X

Humphreys, D., 2014. Forest politics: The evolution of international cooperation. Routledge, London. https://doi.org/10.4324/9781315870120

Humphreys, D., 2012. Logjam: Deforestation and the crisis of global governance, Logjam: Deforestation and the Crisis of Global Governance. https://doi.org/10.4324/9781849771863

ITTO, 2021. Policy Series - Resources [WWW Document]. URL https://www.itto.int/policy_papers/ (accessed 6.17.21).

IUCN, 2021a. IUCN Red List of Threatened Species [WWW Document]. Version 2021-2. URL https://www.iucnredlist.org (accessed 12.7.21).

IUCN, 2021b. Summary Statistics [WWW Document]. URL https://www.iucnredlist.org/resources (accessed 12.7.21).

Jacobson, M.G., 2002. Factors affecting private forest landowner interest in ecosystem management: linking spatial and survey data. Environ. Manage. 30, 577–583. https://doi.org/10.1007/S00267-002-2605-Y

Jeon, S., Sarker, P.K., Giessen, L., 2019. The forest policies of ASEAN and Montréal process: Comparing highly and weakly formalized regional regimes. Forests 10, 1–23. https://doi.org/10.3390/f10100929

Johansson, J., Lidestav, G., 2011. Can voluntary standards regulate forestry? - Assessing the environmental impacts of forest certification in Sweden. For. Policy Econ. 13, 191–198. https://doi.org/10.1016/j.forpol.2010.11.004

Johns, A.G., 1997. Timber production and biodiversity conservation in tropical rain forests. Timber Prod. Biodivers. Conserv. Trop. rain For.

Jusys, T., 2016. Fundamental causes and spatial heterogeneity of deforestation in Legal Amazon. Appl. Geogr. 75, 188–199. https://doi.org/10.1016/J.APGEOG.2016.08.015

Kadam, P., Dwivedi, P., Cook, C., Tumpach, C., Izlar, R., Carroll, T., 2021a. The role of a fiber sourcing standard in the sustainable management of forests in Georgia, United States. Trees, For. People 5, 100110. https://doi.org/10.1016/j.tfp.2021.100110

Kadam, P., Dwivedi, P., Karnatz, C., 2021b. Mapping convergence of sustainable forest management systems: Comparing three protocols and two certification schemes for ascertaining the trends in global forest governance. For. Policy Econ. 133, 102614. https://doi.org/10.1016/J.FORPOL.2021.102614

Krasner, S.D., 1982. Structural Causes and Regime Consequences: Regimes as intervening variables. Int. Organ. 36, 185–205. https://doi.org/10.1017/S0020818300018920

Kueper, A.M., Sagor, E.S., Becker, D.R., 2013. Learning from Landowners: Examining the Role of Peer Exchange in Private Landowner Outreach through Landowner Networks. http://dx.doi.org/10.1080/08941920.2012.722748 26, 912–930. https://doi.org/10.1080/08941920.2012.722748

Lee, M., 2009. Can we trust the FSC? [WWW Document]. Ecologist. URL theecologist.org (accessed 12.10.20).

Lemos, M.C., Agrawal, A., 2006. Environmental Governance. Annu. Rev. Environ. Resour. 31, 297–325. https://doi.org/10.1146/annurev.energy.31.042605.135621

Lennon, J.J., 2000. Red-shifts and red herrings in geographical ecology. Ecography (Cop.). 23, 101–113. https://doi.org/10.1111/j.1600-0587.2000.tb00265.x

LeSage, J.P., 2014. What Regional Scientists Need to Know about Spatial Econometrics. Rev. Reg. Stud. 44, 13–32. https://doi.org/10.52324/001C.8081

Luck, G.W., 2007. A review of the relationships between human population density and biodiversity. Biol. Rev. 82, 607–645. https://doi.org/10.1111/J.1469-185X.2007.00028.X

Maryudi, A., 2015. The political economy of forest land-use, the timber sector, and forest certification, The context of natural forest management and FSC certification in Indonesia. CIFOR, Bogor, Indonesia. https://doi.org/10.17528/cifor/005653

Maser, C., 1990. The redesigned forest. Stoddart Publishing Co. Limited.

Mauro, P., 1997. Why Worry About Corruption? Washington, DC.

Mauro, P., 1995. Corruption and Growth. Q. J. Econ. 110, 681–712. https://doi.org/10.2307/2946696

Mayer, F., Gereffi, G., 2010. Regulation and economic globalization: Prospects and limits of private governance, in: Business and Politics. https://doi.org/10.2202/1469-3569.1325

McKee, J.K., Sciulli, P.W., David Fooce, C., Waite, T.A., 2004. Forecasting global biodiversity threats associated with human population growth. Biol. Conserv. 115, 161–164. https://doi.org/10.1016/S0006-3207(03)00099-5

Millennium Ecosystem Assessment, 2005. Ecosystems and human well-being, Ecosystems. Island Press, Washington, DC. https://doi.org/10.1196/annals.1439.003

Miteva, D.A., Loucks, C.J., Pattanayak, S.K., 2015. Social and environmental impacts of forest management certification in Indonesia. PLoS One 10, 1–18. https://doi.org/10.1371/journal.pone.0129675

Mohanty, B., Sahu, G., 2012. An Empirical Study on Elements of Forest Governance: A Study of JFM Implementation Models in Odisha. Procedia - Soc. Behav. Sci. 37, 314–323. https://doi.org/10.1016/j.sbspro.2012.03.297

Moog, S., Spicer, A., Böhm, S., 2015. The Politics of Multi-Stakeholder Initiatives: The Crisis of the Forest Stewardship Council. J. Bus. Ethics 128, 469–493. https://doi.org/10.1007/s10551-013-2033-3

Mouw, T., 2006. Estimating the Causal Effect of Social Capital: A Review of Recent Research. https://doi.org/10.1146/annurev.soc.32.061604.123150 32, 79–102. https://doi.org/10.1146/ANNUREV.SOC.32.061604.123150

MP, 2018. The Montréal Process Criteria and Indicators [WWW Document]. URL https://www.montrealprocess.org/The_Montreal_Process/Criteria_and_Indicators/index.shtml (accessed 6.17.21).

MP, 2017. Yanji Declaration.

MP, 2009. Country Forest Report (2009).

MP, 2003a. Montreal Process First Country Forest Report (2003 Report).

MP, 2003b. Québec City Declaration.

MP, 1999. The Montréal Process "Forests for the Future" [WWW Document].

MP, 1995. Santiago Declaration.

Myers, J.R., Fosbroke, D.E., 1995. The occupational safety and health administration logging standard: what it means for forest managers. J. For. 93, 34–37.

Naka, K., Hammett, A.L., Stuart, W.B., 2000. Forest certification: Stakeholders, constraints and effects. Local Environ. https://doi.org/10.1080/713684891

NIDIS, 2021. Georgia | Drought.gov [WWW Document]. URL https://www.drought.gov/states/georgia#historical-conditions (accessed 2.12.22).

Nielsen-Pincus, M., Ribe, R.G., Johnson, B.R., 2015. Spatially and socially segmenting private landowner motivations, properties, and management: A typology for the wildland urban interface. undefined 137, 1–12. https://doi.org/10.1016/J.LANDURBPLAN.2014.11.020

Okada, K., Samreth, S., 2017. Corruption and natural resource rents: evidence from quantile regression. http://dx.doi.org/10.1080/13504851.2017.1287849 24, 1490–1493. https://doi.org/10.1080/13504851.2017.1287849

Oswalt, S.N., Smith, W.B., Miles, P.D., Pugh, S.A., 2019. Forest Resources of the United States, 2017, General Technical Report WO-97. Washington, DC. https://doi.org/10.2737/WO-GTR-97

Pace, R.K., LeSage, J.P., 2010. Omitted variable biases of OLS and spatial lag models. Adv. Spat. Sci. 63, 17–28. https://doi.org/10.1007/978-3-642-03326-1_2

Paletto, A., Hamunen, K., De Meo, I., 2015. Social Network Analysis to Support Stakeholder Analysis in Participatory Forest Planning. Soc. Nat. Resour. 28, 1108–1125. https://doi.org/10.1080/08941920.2015.1014592

Pappila, M., 2013. Forest certification and trust - Different roles in different environments. For. Policy Econ. 31, 37–43. https://doi.org/10.1016/j.forpol.2012.10.005

PEFC, 2021a. PEFC Canada [WWW Document]. URL https://www.pefc.org/discover-pefc/our-pefc-members/national-members/pefc-canada (accessed 6.11.21).

PEFC, 2021b. PEFC Annual review 2020.

Poudyal, N.C., Butler, B.J., Hodges, D.G., 2019. Spatial analysis of family forest landownership in the southern United States. Landsc. Urban Plan. 188, 163–170. https://doi.org/10.1016/j.landurbplan.2018.10.018

Prabhu, R., Colfer, C.J.P., Shepherd, G., 1998. Criteria and indicators for sustainable forest management: new findings from CIFOR's forest management unit level research. Rural Dev. For. Netw. 20.

Prabhu, R., Colfer, C.J.P., Venkateswarlu, P., Tan, L.C., Soekmadi, R., Wollenberg, E., 1996. Testing criteria and indicators for the sustainable management of forests: phase 1. Final Report. Center for International Forestry Research (CIFOR), Bogor, Indonesia. https://doi.org/10.17528/cifor/000393

Prestemon, J.P., 2015. The impacts of the Lacey Act Amendment of 2008 on U.S. hardwood lumber and hardwood plywood imports. For. Policy Econ. 50, 31–44. https://doi.org/10.1016/j.forpol.2014.10.002

Rayner, J., Buck, A., Katila, P., 2010. Embracing Complexity: Meeting the Challenges of International Forest Governance. A Global Assessment Report. IUFRO World Series Vol 28, Vienna, Austria.

Robinson, E.J.Z., Kumar, A.M., Albers, H.J., 2010. Protecting Developing Countries' Forests: Enforcement in Theory and Practice. J. Nat. Resour. Policy Res. 2, 25–38. https://doi.org/10.1080/19390450903350820

Romero, C., Putz, F.E., 2018. Theory-of-change development for the evaluation of forest stewardship council certification of sustained timber yields from natural forests in Indonesia. Forests 9. https://doi.org/10.3390/f9090547

Romero, C., Putz, F.E., Guariguata, M.R., Sills, E.O., Cerutti, P.O., Lescuyer, G., 2013. An overview of current knowledge about the impacts of forest management certification: a proposed framework for its evaluation (No. 91), CIFOR, Occasional Paper. Bogor, Indonesia. https://doi.org/10.17528/cifor/004188

Rosa, I.M.D., Smith, M.J., Wearn, O.R., Purves, D., Ewers, R.M., 2016. The Environmental Legacy of Modern Tropical Deforestation. Curr. Biol. 26, 2161–2166. https://doi.org/10.1016/j.cub.2016.06.013

Ruben, R., 2017. Impact assessment of commodity standards: Towards inclusive value chains. Enterp. Dev. Microfinance 28, 82–97. https://doi.org/10.3362/1755-1986.16-00020

Salmon, O., Brunson, M., Kuhns, M., 2006. Benefit-Based Audience Segmentation: A Tool for Identifying Non-Industrial Private Forest (NIPF) Owner Education Needs. Environ. Soc. Fac. Publ. 104.

Sapir, E., 1921. Language: An Introduction to the Study of Speech. Harcourt Brace & Company, San Diego, CA.

Sasser, E.N., Prakash, A., Cashore, B., Auld, G., 2006. Direct targeting as an NGO political strategy: Examining private authority regimes in the forestry sector. Bus. Polit. 8. https://doi.org/10.2202/1469-3569.1163

SFI, 2021a. SFI Standards [WWW Document]. URL https://www.forests.org/sfistandards/ (accessed 6.17.21).

SFI, 2021b. Growing solutions for 25 years [WWW Document]. URL https://www.forests.org/wp-content/uploads/SFI-ProgressReport-2020_web.pdf (accessed 8.7.21).

SFI, 2019. About Us | SFI Program [WWW Document]. URL https://www.sfiprogram.org/aboutus/ (accessed 2.3.20).

Shittu, W., Adedoyin, F.F., Shah, M.I., Musibau, H.O., 2021. An investigation of the nexus between natural resources, environmental performance, energy security and environmental degradation: Evidence from Asia. Resour. Policy 73, 102227. https://doi.org/10.1016/J.RESOURPOL.2021.102227

Shmueli, G., 2010. To Explain or to Predict? https://doi.org/10.1214/10-STS330 25, 289–310. https://doi.org/10.1214/10-STS330

Sinha, A., Sengupta, T., 2019. Impact of natural resource rents on human development: What is the role of globalization in Asia Pacific countries? Resour. Policy 63, 101413. https://doi.org/10.1016/J.RESOURPOL.2019.101413

Sorice, M.G., Kreuter, U.P., Wilcox, B.P., Fox, W.E., 2014. Changing landowners, changing ecosystem? Land-ownership motivations as drivers of land management practices. J. Environ. Manage. 133, 144–152. https://doi.org/10.1016/j.jenvman.2013.11.029

Southern Group of State Foresters, 2021. Call for Evidence on the Role of Biomass in Achieving Net Zero. https://doi.org/10.2737/SRS-GTR-258

Stiglitz, J., 2003. Chapter 2: Globalization and Development, in: Held, D., Koenig-Archibugi, M. (Eds.), Taming Globalisation. Polity Press, Cambridge, pp. 47–67.

Stryjewski, E., 2007. The Sustainable Forestry Initiative vs. The Forest Stewardship Council: Evaluating the Credibility of Competing Forest Certification Schemes.

Taherzadeh, O., Howley, P., 2017. No net loss of what, for whom?: stakeholder perspectives to Biodiversity Offsetting in England. Environ. Dev. Sustain. 1–24. https://doi.org/10.1007/s10668-017-9967-z

Teece, D.J., 2010. Business Models, Business Strategy and Innovation. Long Range Plann. 43, 172–194. https://doi.org/10.1016/J.LRP.2009.07.003

Tobin, J., 1958. Estimation of Relationships for Limited Dependent Variables. Econometrica 26, 24. https://doi.org/10.2307/1907382

Tobler, W.R., 1970. A Computer Movie Simulating Urban Growth in the Detroit Region. Econ. Geogr. 46, 234. https://doi.org/10.2307/143141

U.S. Endowment for Forestry and Communities, 2017. Certified forests [WWW Document].

United Nations, 1987. Our Common Future ('The Brundtland Report'):, World Commission on Environment and Development. https://doi.org/10.9774/gleaf.978-1-907643-44-6_12

United States Geological Survey, 2022. GIS Data Download | U.S. Geological Survey [WWW Document]. URL https://www.usgs.gov/the-national-map-data-delivery/gis-data-download (accessed 2.15.22).

US Census Bureau, 2021. TIGER/Line Shapefiles [WWW Document].

USDA Forest Service, 2021. Forest Inventory and Analysis National Program - Timber Products Output [WWW Document]. URL https://www.fia.fs.fed.us/program-features/tpo/ (accessed 9.8.21).

van der Ven, H., Cashore, B., 2018. Forest certification: the challenge of measuring impacts. Curr. Opin. Environ. Sustain. 32, 104–111. https://doi.org/10.1016/j.cosust.2018.06.001

Vaske, J.J., Donnelly, M.P., 2010. A Value-Attitude-Behavior Model Predicting Wildland Preservation Voting Intentions. http://dx.doi.org/10.1080/089419299279425 12, 523–537. https://doi.org/10.1080/089419299279425

Washburn, M.P., Block, N.E., 2001. Comparing Forest Management Certification Systems and the Montreal Process Criteria and Indicators. Environ. Stud.

Wätzold, F., Drechsler, M., Armstrong, C.W., Baumgärtner, S., Grimm, V., Huth, A., Perrings, C., Possingham, H.P., Shogren, J.F., Skonhoft, A., Verboom-Vasiljev, J., Wissel, C., 2006. Ecological-Economic Modeling for Biodiversity Management: Potential, Pitfalls, and Prospects. Conserv. Biol. 20, 1034–1041. https://doi.org/10.1111/J.1523-1739.2006.00353.X

Westoby, J., Simmons, I.G., 1989. Introduction to World Forestry. Geogr. J. 156, 98. https://doi.org/10.2307/635472

Wierzbicka, A., 1997. Understanding Cultures Through Their Key Words. Oxford University Press: United Kingdom.

Winkler, K., Fuchs, R., Rounsevell, M., Herold, M., 2021. Global land use changes are four times greater than previously estimated. Nat. Commun. 2021 121 12, 1–10. https://doi.org/10.1038/s41467-021-22702-2

World Bank, 2021a. Worldwide Governance Indicators - Control of Corruption [WWW Document]. URL https://databank.worldbank.org/source/worldwide-governance-indicators (accessed 12.6.21).

World Bank, 2021b. GDP per capita growth (annual %) [WWW Document]. URL https://data.worldbank.org/indicator/NY.GDP.PCAP.KD.ZG (accessed 12.6.21).

World Bank, 2021c. Population density (people per sq. km of land area) [WWW Document]. URL https://data.worldbank.org/indicator/EN.POP.DNST (accessed 12.6.21).

World Bank, 2021d. Total natural resources rents (% of GDP) [WWW Document]. URL https://data.worldbank.org/indicator/NY.GDP.TOTL.RT.ZS (accessed 12.6.21).

World Bank, 2021e. Forest rents (% of GDP) [WWW Document]. URL https://data.worldbank.org/indicator/NY.GDP.FRST.RT.ZS (accessed 12.6.21).