Tackling the “wicked” conservation problem of tropical deforestation in global commodity supply chains using mixes of mechanisms

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Abstract

Tropical deforestation in global agricultural commodity supply chains is a “wicked” problem. Attempted solutions to wicked conservation problems like tropical deforestation often involve idealised, technical mechanisms. For example, company commitments to “zero deforestation” have become a mainstay of global forest conservation efforts. To be resolved, however, wicked conservation problems require strategically-developed, context-specific mixes of mechanisms. Drawing on interdisciplinary literature from the policy sciences, energy and land-use policy, and conservation, we examine why the contextual complexity of wicked conservation problems demands mixes of mechanisms. We present an operational model of conservation that incorporates the mechanism mix concept. We then explore how the dynamism and uncertainty of wicked problems means mixes of mechanisms must be

continually reconfigured. Drawing the concepts of contextual complexity, dynamism and uncertainty together, we propose a conceptual model – the “M³ Model” – which aids understanding of how mechanism mixes can be reconfigured to sustain progress towards a desired outcome. The M³ model has four practical implications, which we discuss with reference to supply chain initiatives to reduce deforestation. First, it makes the need to address multiple interacting variables explicit, countering the tendency to seek panaceas. Second, it emphasises the importance of analysing mechanisms’ contributions to problem amelioration, instead of their shortcomings as idealised solutions. Third, it highlights the possibility of failure, reorienting conservation practice towards learning. Fourth, it emphasises polycentric governance, reinforcing the need for distributed mechanism deployment across stakeholder groups. Our synthesis provides tools to support a more holistic, systemic approach to tackling wicked conservation problems.

Introduction

Global demand for agricultural commodities including beef, soy and palm oil has driven tropical deforestation throughout the 21st century (Curtis et al. 2018). Tropical deforestation threatens biodiversity (Gibson et al. 2011) and ecosystem services, such as freshwater provision (Boers et al. 2017), while contributing significantly to greenhouse gas emissions (Pendrill et al. 2019). Multi-stakeholder targets to achieve “zero net deforestation” globally by 2020 have been missed (Lyons-White et al. 2020). Primary forest loss hit record highs in 2016 and 2017, with 3.8 Mha lost in 2019 (Weisse & Goldman 2020). Failure to secure forest conservation targets suggests strategies for reducing deforestation require review.

Conservation problems such as tropical deforestation are often “wicked”, meaning they are complex, dynamic, contextually unique and engage diverse stakeholder values (Head 2008; Rittel & Webber 1973). Because they present high levels of uncertainty and lack clear solutions, wicked problems require real-time, flexible, ongoing responses (Peters 2017). As systems that generate wicked problems are path-dependent, interventions are often

irreversible and may trigger unanticipated feedbacks (Pirard et al. 2016) or perverse outcomes (Lim et al. 2017). Wicked problems become “super wicked” when they involve time running out, no centralised control, irrational discounting of the future, and when the same stakeholders contribute to both the problem and solution (Levin et al. 2007). Tropical deforestation meets most of these criteria.

Ironically, considering the time, resource and political challenges that characterise wicked problems (and conservation professionals’ awareness of this complexity), conservation often involves technical solutions suited to simpler, tractable problems (DeFries & Nagendra 2017; Game et al. 2014). For example, campaigners have demanded that companies commit to “zero deforestation” (Greenpeace 2007). This assumes companies can manage the operational and technical dimensions of supply chains to eliminate deforestation from agricultural commodity production or sourcing (Garrett et al. 2019). “Sustainable supply chain initiatives” including zero-deforestation commitments have become a cornerstone of global forest conservation (Lambin et al. 2018). However, zero deforestation is a slippery concept and supply-chain management depends on other mechanisms, such as state regulation, to reduce deforestation (Lyons-White & Knight 2018). Context-specific mixes of complementary state and non-state mechanisms – such as zero-deforestation commitments alongside payments for ecosystem services, extension support and regulatory enforcement – are more likely to reduce deforestation effectively (Azevedo et al. 2017; Börner et al. 2014).

“Policy mixes” have been studied extensively in the policy sciences (Kern et al. 2019), but less commonly in conservation (e.g., Barton et al. 2013; Ring & Schröter-Schlaack 2011; Young et al. 1996). Increasingly, policy mix research has addressed tropical deforestation, including several studies of interactions between mechanisms in the Brazilian Amazon (e.g., Börner et al. 2015; Gebara et al. 2019). Growing calls have also been made by international bodies to use policy mixes in conservation. In 2019, the Intergovernmental Science-Policy

Platform on Biodiversity and Ecosystem Services (IPBES) Global Assessment called for “smart” policy mixes (Chan et al. 2019). In 2020, the Tropical Forest Alliance (TFA) called on the European Union to adopt a “smart mix of measures” to reduce deforestation in agricultural commodity supply chains, including partnerships with producer countries, legislation, and finance for sustainable production (TFA 2020). Here, we use the term “mechanisms”, rather than “policies” or “measures”, as “policies” is used differently across different disciplines (Rogge & Reichardt 2016), whereas “mechanisms” captures institutions, games or procedures, including policy instruments and incentives, designed to achieve a desired outcome (Maskin 2008).

Despite the existing literature on mechanism mixes, operational models of conservation practice (e.g., CMP 2020; Knight et al. 2006) typically omit interactions between mechanisms, even when designed with wicked problems in mind (DeFries & Nagendra 2017). Operational models provide representations of how processes function in practice and can be contrasted with conceptual frameworks, which organise classes of variables (Knight et al. 2006). Both conceptual frameworks and operational models are important for effective praxis (theory-informed practice) in conservation (Knight et al. 2019; Knight et al. 2006). In consideration of increasing calls for mechanism mixes to address global conservation challenges and the growing literature, an operational model that draws together existing knowledge on using mechanism mixes to address wicked conservation problems could prove useful. As wicked problems are dynamic, it is also important to consider how mechanism mixes can be adapted over time to sustain progress towards a goal.

Here, we draw on interdisciplinary literature from the policy sciences, land-use and energy policy, and conservation to explore why dynamic mechanism mixes are needed to address wicked conservation problems, and we present a new operational model for conserving tropical forests. Specifically, mechanism mixes can address fundamental characteristics of wicked problems that single mechanisms typically cannot: contextual complexity, dynamism

and uncertainty (Head 2008). We begin by reviewing why mixes of complementary mechanisms are required to tackle contextual complexity, and introduce the operational model. We then argue that dynamism and uncertainty demand continually reconfiguring mechanism mixes through time. We present a conceptual model, the Multiple Mechanism Mix (M^3) Model, which illustrates how mechanism mixes can be perpetually reconfigured to sustain progress towards a desired outcome. We conclude by discussing the practical implications of the M^3 Model for addressing wicked conservation problems, focusing on sustainable supply chain initiatives to reduce deforestation.

Tackling contextual complexity by designing mixes of mechanisms

Wicked conservation problems arise in complex social-ecological systems in which ascribing causality is challenging (Ostrom 2009). In Brazil, for example, social and economic variables including the size of the Amazonian cattle herd and variations in the domestic economy have been correlated with deforestation rates, but causality cannot be systematically attributed to any one variable in isolation (Ewers et al. 2008). Addressing wicked conservation problems requires considering numerous variables and engaging diverse stakeholders. Achieving an overarching conservation outcome, such as halting deforestation, requires several narrower policy targets addressing specific variables' impacts (Maron et al. 2018; Tinbergen 1952).

The Tinbergen Rule is an economic theory which holds that effective policymaking requires at least one mechanism for each policy target needed to attain an overarching outcome (Tinbergen 1952). This is because target-specific mechanisms can often address individual targets more fairly and efficiently than general mechanisms; and because conflict between targets can be mitigated by using mechanisms in different combinations. This necessitates multiple mechanism options for each target. Using multiple mechanisms also ensures the strengths and weaknesses of different mechanisms can be balanced (Young et al. 1996). For addressing deforestation, mechanisms include: outreach (e.g., education, extension support); finance (e.g., payments for ecosystem services); framework policies (e.g., strategic

planning); regulation (e.g., protected areas); research; tradeable permits and certificates (e.g., eco-certification); and voluntary instruments and agreements (e.g., moratoria) (Lambin et al. 2014; Schaffrin et al. 2014).

Mixing mechanisms raises a major combinatorics problem, and guidance is needed on how to assess what mixes might be “optimal” (Young et al. 1996). In theory, optimal mixes maximise desired outcomes (Tinbergen 1952). In practice, wicked problems have no ideal solutions and evolve in response to interventions, so an “optimal” mix addresses market, governance and behavioural failures more effectively than feasible alternatives (Bouma et al. 2019). Multiple configurations of mechanisms with comparable effectiveness (“fitness”) may be possible (Freeman 2000).

Interactions between mechanisms can be complementary (mutually reinforcing), conditioning (mechanisms directly or indirectly enable others), substitutive, or antagonistic (conflicting) (Lambin et al. 2014; Milhorange et al. 2020). Consequently, combining mechanisms in different ways may produce nonlinear differences in outcomes. Interactions operate across multiple spatial scales and governance levels over varying time periods, and individual mechanisms’ impacts may covary with biogeographic factors such as location and ecosystem characteristics (Barton et al. 2013; Pfaff & Robalino 2012), and underlying institutional and policy contexts (Wong et al. 2017). For example, payments for ecosystem services can enhance rural incomes in Brazil and increase the equity of forest conservation, but they also produce varying effects on the cost-effectiveness of enforcing Brazil’s Forest Code; these effects are modulated by other factors including monitoring capacity and support from different groups of landholders (Börner et al. 2015). Because mechanisms interact, thereby modifying their individual effects (Nauwelaers et al. 2009), individual mechanisms’ impacts must be assessed contextually (Schmidt & Sewerin 2019). Correspondingly, mechanisms’ “additionality” – net contributions to desired outcomes (Garrett et al. 2016) – may differ substantially across contexts.

Conceptual frameworks for analysing mixes of mechanisms in conservation have previously focused on assessment criteria like effectiveness, equity and feasibility (Schröter-Schlaack & Ring 2011). In the policy sciences, important characteristics of mechanism mixes have also been defined, including *consistency* (mechanisms align to support targets' attainment); *coherence* (policymaking and implementation processes are synergistic); *credibility* (a mechanism mix will reliably achieve targeted outcomes); and *comprehensiveness* (a mechanism mix addresses relevant market, system and institutional failures) (Kern et al. 2019; Rogge & Reichardt 2016). An extended conceptual framework for analysing mechanism mixes additionally incorporated strategy, policy processes and dimensions (defined as governance level, policy field and time) alongside mix characteristics (Rogge & Reichardt 2016). We build on these conceptual frameworks by presenting an operational model for using mechanism mixes to address wicked conservation problems like tropical deforestation (**Figure 1**).

Figure 1. Operational model to guide the design and implementation of mixes of mechanisms to address wicked conservation problems like tropical deforestation. The model integrates concepts from both wicked problems and frameworks for analysing mechanism mixes (Rittel & Webber 1973; Rogge & Reichardt 2016; Schröter-Schlaack & Ring 2011; Tinbergen 1952), and stages from existing operational models of conservation (Knight et al. 2006). The model charts a sequence of actions through the policy process, including policymaking (assessment and planning), implementation and review.

The operational model in **Figure 1** charts a sequence of actions through a policy process, from assessment through planning to implementation and review (Knight et al. 2006). In addition to being consistent, coherent, credible and comprehensive, mechanism mixes should include a diversity of mechanism types, with some redundancy to ensure robustness (Capano & Woo 2018). Consideration should be given to a mix's *balance* (dispersion of mechanisms across mechanism types) and individual mechanisms' *design features* (e.g., *intensity*, comprising objectives, scope, budgets, implementation and monitoring) (Schmidt & Sewerin 2019). Attending to these characteristics encourages consideration of how mixes function as systemic wholes. This does not mean mechanism mixes necessarily need to be implemented as whole "packages"; "layering" new mechanisms on existing mixes can also be effective (ibid). Carefully sequencing individual mechanisms (e.g., deploying benefit-based mechanisms before cost-based ones) can also be essential to mitigate economic and political constraints, and promote effectiveness (Meckling et al. 2017).

Our operational model provides two advances on previous operational models in conservation. First, it emphasises interactions between mechanisms. Second, it recognises that wicked problems are transformed by interventions, necessitating monitoring, evaluation and continual reappraisal of problems, mechanism mixes and their impacts. "Horizontal" interactions between mechanisms at a single governance level (e.g., within a particular

jurisdiction) are demonstrated. Implementing the model also requires situating it in the context of vertical interactions between governance levels and across jurisdictional boundaries, as well as social networks and power relations, all of which can influence mechanism mixes' effectiveness (Howlett et al. 2017; Milhorange et al. 2020).

The utility of mechanism mixes has been demonstrated in the Brazilian Amazon. Here, more than 10 complementary mechanisms including the Soy Moratorium and enforcement of Brazil's Forest Code, deployed in varying combinations, purportedly contributed to a 70% reduction in deforestation between 2005–2013 (Nepstad et al. 2014). Notably, mechanisms deployed in the Amazon targeted and reduced large forest clearing events, but did not deter small clearings, which increased in prominence and accounted for 73% of deforestation by 2009 (Rosa et al. 2012). Further reductions in deforestation required alterations to the mechanism mix to address insufficiently targeted activities, like smallholder expansion (Azevedo et al. 2017; Godar et al. 2014). For example, formal land titling programmes can encourage mid-sized smallholders to comply with forest protection mechanisms when registering with Brazil's Rural Environmental Registry, substantially reducing deforestation on smaller properties (L'Roe et al. 2016).

Managing dynamism and uncertainty by reconfiguring mechanism mixes

Wicked problems are characterised by non-linear dynamics, producing uncertainty with respect to risks, patterns of change and consequences of actions (Head 2008). Uncertainty can arise endogenously within a conservation action due to feedback processes (Béland & Schlager 2019) or failures (see Catalano et al. 2018), or exogenously due to changes in a problem context (Anderies et al. 2007) or mechanism interactions (Béland et al. 2020). Endogenous and exogenous dynamics ensure the fitness of any mechanism, and any mechanism mix, will change. For example, the mix that reduced deforestation in the Brazilian Amazon was vulnerable to destabilisation by dynamic political and social processes, including shifting political alliances and changing patterns of foreign investment

(Hecht 2011). Large-scale clearing increased after 2012 as impetus to avoid deforestation waned (Schielein & Börner 2018), and when Jair Bolsonaro was elected Brazil's President in 2018, the national deforestation rate increased substantially (Escobar 2019). Conservation professionals must be conceptually and operationally equipped to manage dynamism and uncertainty if progress towards goals is to be sustained. This entails making perpetual improvements to individual mechanisms to attain durable objectives (Auld et al. 2020), and perpetual reconfigurations of mechanism mixes.

In conservation, an often-promoted approach to managing uncertainty is using adaptive management to inform incremental improvements to individual mechanisms (e.g., CMP 2020; DeFries & Nagendra 2017). Although well-suited to systems with high levels of uncertainty, adaptive management requires considerable resource control to test mechanisms iteratively (Allen & Gunderson 2011). Consequently, adaptive management is unsuitable for dealing with change in complex social-ecological systems that cover large spatial and temporal scales, where levels of control are low and experimental testing is impractical (Allen et al. 2011). These systems may be subject to paradigmatic (fast) as well as incremental (slow) change (Cashore & Howlett 2007), and phases of adaptive cycles such as "release", where the prevailing system collapses (Gunderson & Holling 2002). In such systems with high uncertainty and low controllability, scenario planning (Peterson et al. 2003), horizon scanning (Schultz 2006), and prototyping (Jobst & Meinel 2014) may be more suitable than adaptive management. Consequently, a suite of tools in addition to adaptive management is required to plan, design and implement new mechanism mixes, and reconfigure existing mechanism mixes through time.

If a new mechanism mix is deployed as a "package" (Howlett & Rayner 2013), uncertainty can initially be mitigated by designing it to be resilient (Béland et al. 2020). Resilience can be designed by using diverse, modular mechanisms, and incorporating redundancy (Capano &

Woo 2018). Consideration should also be given to the potential for positive or negative feedback processes that might change mechanisms themselves (Sewerin et al. 2020). These approaches can promote the design of mechanism mixes that create path dependency, helping to “lock-in” desired outcomes (Howlett 2019).

As wicked problems are changed by interventions, even resilient mechanism mixes will require reconfiguration. The reconfigurations needed will depend the type and scale of changes that occur in a system. In cases of large-scale, paradigmatic change, a mechanism mix may require overhaul or replacement with a new “package” of mechanisms (Howlett & Rayner 2013). Perhaps because of the infrequency of paradigmatic change, research in energy policy has found new packages are rarely deployed in practice. More often, new mechanisms are “layered on” (added to) existing mixes (Schmidt & Sewerin 2019), or existing mechanisms are “patched” (restructured) or removed (Kern et al. 2017). Layering does not necessarily disrupt the balance of an existing mix and represents a realistic strategy for reconfiguration (Schmidt & Sewerin 2019).

Any mechanism mix may undergo large changes in fitness due to exogenous shocks to a system, such as changing political regimes. These changes are not always undesirable. Overhauling suboptimal mixes may be impractical under normal circumstances (Béland et al. 2020), as mechanisms can create path-dependency by generating complex supporting social and economic networks, increasing the cost of pursuing alternatives (Pierson 1993). Exogenous shocks can thus afford “traction opportunities” to move a system towards a desired state (Moon et al. 2014). The Covid-19 pandemic has been cited as one such opportunity to enhance political pressure for environmental protection (Evans et al. 2020).

A conceptual model of tropical forest conservation

We present a conceptual model, the M³ Model (**Figure 2**), that illustrates why mixes of mechanisms must be continually reconfigured, and moves away from a focus on incremental changes to individual mechanisms without accommodating the need to reconfigure a mix.

Figure 2. The Multiple Mechanism Mix (M³) Model showing how progress towards a desired conservation outcome (reduced deforestation) can be sustained, and complexity and uncertainty can be managed, by repeatedly reconfiguring a mechanism mix. The M³ Model unfolds from left to right along its horizontal axis (time). For simplicity, the desired conservation outcome is represented as a single target variable, shown on the primary (left) vertical axis and represented by the red dotted line. The secondary (right) vertical axis presents the fitness of a mechanism mix, represented by the black dotted line. Different mechanism mixes are distinguished by light and dark blue areas under the black dotted line. Descriptions of points **i** to **vii** are presented in the main text.

In the M³ Model (**Figure 2**), there is a period of discovery as a wicked problem is identified and initial mechanism(s) are deployed (**i**). Adding mechanisms (**ii**) creates a new mix (Mix 2), which – if mechanisms function as anticipated – may begin to increase the fitness of the

overall mix, slowing deforestation. Layering, patching or removing mechanisms (Mix 3) could increase the fitness of the mix more or less slowly, depending on the time it takes mechanisms to become established, and how they interact. Eventually, if appropriate mechanisms are deployed in complementary mixes, the fitness of the mix should improve and the deforestation rate should begin to fall (iii). Over time, a more optimal mix may be established (Mix 4), producing a decline in the deforestation rate that might be rapid at first (iv) or more steady (v). The fitness of the mix may improve or decline through time (vi), as evolution of the wicked problem renders individual mechanisms, or the mix, more or less effective, or changes their interactions. A decline in the effectiveness of one mechanism does not necessarily produce declining effectiveness in a mix, as feedbacks may reinforce collective effects. At some point, an exogenous shock may occur (vii), causing the fitness of the mix to decline and producing a rebound in the deforestation rate. After an exogenous shock, the system enters a critical phase. The mix may require overhaul (a new package) or more minor adjustment (layering on new mechanisms, or patching or removing existing ones). The possibility of restoring or improving fitness (Mix 5) depends on the capability of stakeholders to identify, analyse, correct and institutionalise understanding of the reasons for failure, and reconfigure the mix (Catalano & Knight, in prep).

Practical improvements for conservation

The M³ Model promotes a holistic mental model of conservation practice (Biggs et al. 2011). It offers four practical benefits for addressing wicked conservation problems, which we illustrate with examples from sustainable supply chain initiatives to reduce deforestation.

First, the model's focus on mechanism mixes makes explicit the need to address multiple interacting variables that drive wicked conservation problems. This emphasises the importance of understanding specific contexts to identify target variables. Although the complexity of some contexts can seem overwhelming (DeFries & Nagendra 2017), the need for a complex response (a mechanism mix) offers an opportunity: as there is no single,

perfect solution, there may be multiple options for addressing a problem. This counters the misplaced tendency to search for panaceas: portable solutions presumed to apply to a wide range of problems (Ostrom 2007). For example, the High Carbon Stock Approach (HCSA), a mechanism developed in Southeast Asia for conserving forests in oil palm developments, was expected to be globally-applicable (Lyons-White et al. 2020). Its use has encountered problems in highly-forested countries in Africa, where it may conflict with economic development goals. Improved understanding of national contexts, alongside supporting mechanisms to enhance communities' participation in land-use planning, are needed to promote more effective and equitable forest conservation in diverse tropical forest contexts (Lyons-White et al. 2021).

Second, the model's focus on mechanism mixes, rather than single mechanisms, implies that individual mechanisms should be evaluated in terms of their collective contributions to problem amelioration, rather than as idealised "solutions" (wicked problems have no ideal solutions). This could enhance the value recognised in mechanisms that may otherwise be discarded. For example, the Roundtable on Sustainable Palm Oil's (RSPO) credit-based offsetting system for certifying palm oil consignments as "sustainable" has been compared unfavourably to mechanisms for certifying palm oil supply chains (Gallemore et al. 2018). However, RSPO credits offer flexibility to smaller companies and smallholders that financially struggle to access supply chain certification. Credits could, therefore, play an important role in transforming the industry to a more sustainable model as part of a mix of certification mechanisms (Gallemore & Jespersen 2019). An analytical focus on mechanism mixes has also been found to explain changes in overarching outcome variables more effectively than single mechanisms (Schmidt & Sewerin 2019).

Third, the model's focus on dynamism and uncertainty emphasises the likelihood of failure, which is common in conservation (Catalano et al. 2019), by making the possibility of exogenous shocks, and the impossibility of a perfectly optimal mechanism mix, explicit. The

model aims to reduce the stigma attached to failure (Cope 2011), instead promoting opportunities for learning (Redford & Taber 2000). Learning is essential for effective natural resource management (Anderies et al. 2007) and policymaking (Bennett & Howlett 1992). The M³ Model also promotes a mindset of “informed opportunism” (Knight & Cowling 2007), whereby conservation organisations can plan for changes in their systems, until traction opportunities can be seized (Moon et al. 2014). The focus on dynamism and uncertainty reorients conservation towards the pursuit of net positive outcomes over the long term (e.g., sustained reductions in deforestation) rather than idealised solutions, which do not exist for wicked problems.

Fourth, the model promotes a polycentric approach to governance, which emphasises decentralised decision making (Game et al. 2014), while encouraging conservationists to reflect on the boundaries of their capacity, power and influence (Knight et al. 2019). This reinforces distributed mechanism design and deployment, while encouraging the adoption of realistic targets and mechanisms within organisations’ capacity for implementation. In 2010, for example, the Consumer Goods Forum (CGF) adopted a target of “zero net deforestation by 2020”, but achieving this depended on other stakeholders, including governments. The TFA was established as an international public-private partnership to mobilise stakeholders from governments, business and civil society to achieve the CGF target. The TFA established a “collective action agenda” and, by calling for a “smart mix of measures”, has recognised the need for mechanism mix that includes distributed action by governments in commodity-consuming, as well as commodity-producing, countries (TFA 2020).

Conclusion

The wicked nature of conservation problems is often discussed, but conventional operational models for conservation do not sufficiently address the need to tackle multiple interacting variables which characterise complex contexts. These models are inadequate for addressing wicked problems. With tropical forest conservation targets for 2020 having been missed

(Lyons-White et al. 2020), revised approaches are needed. These include a renewed focus on mixes of mechanisms. We present an operational model for conservation practice, and a conceptual model of tropical forest conservation, which draw on research from the policy sciences, land-use and energy policy, and conservation, to illustrate how mechanism mixes can help tackle wicked conservation problems. Our synthesis emphasises the need for mechanism mixes to be perpetually reconfigured to sustain progress towards desired conservation outcomes. This entails acknowledging that mechanism mixes are necessarily imperfect, which could promote a more positive attitude towards the inevitability of failure and the opportunity it provides to support learning and inspire resilience. Wicked conservation problems like tropical deforestation are enduring. But, armed with mechanism mixes and prepared to reconfigure them, conservation professionals can sustain progress towards elusive conservation goals in the long term.

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