The Global Forest Transition is a human affair.

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This article builds on an original idea of CG. SS lead the writing. CG, SS, VG, RV, SW, CK, MS, BR, HM, BN, and JR wrote the initial draft. CV, FT, JO, VG, HS, FQ, POW, JFB, AD and JG reviewed the initial draft. CG and POW conceptualized the figures.

Keywords

Forest transition, sustainable transformation, boundary objects, games, decision-making, agency

 doi:10.20944/preprints202003.0087.v1

Abstract

Forests across the world stand at the crossroad with climate and land use changes shaping their future. Despite the demonstration of political will and global efforts, forest loss, fragmentation and land degradation continue unabated. No clear evidence exists that these initiatives are working. Why are policies designed to halt deforestation and increase restoration of forest landscapes failing? A key reason for this apparent ineffectiveness lies in the failure to recognize the agency of the stakeholders involved and the adaptive capacities of the systems we seek to steer. Landscapes do not happen. We make them. They are the result of the sum of individual actions and decisions made by all stakeholders, and the interactions between these and biophysical processes. Likewise, forest transitions are not ecological, but social and behavioral. They are a product of the way humans manage ecosystems. Decision-makers need to integrate better representations of people's agency in their mental models. We suggest possible solution pathways to overcome this key current barrier. These involve eliciting mental models behind policy decision, changing perspectives to better understand divergent points of view and refining strategies through explicit theories of change. Games designed to represent the constraints and opportunities that exist in the landscapes can help decision makers in these task.

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1. Introduction

1.1. Context

Forests across the world stand at the crossroads. Climate change[1] and land use change[2,3] will shape their future. These two processes work at different time scales: decades to centuries for changes in temperature and rainfall patterns set against years and sometimes months for agriculture conversion, infrastructure development, logging operations, and political regime shifts. Agriculture is the main driver of deforestation.[4,5] Net deforestation in the tropics dominates,[6] with various regional drivers:[7] ranching and soybean expansion in Latin America,[8–10] subsistence agriculture in Africa[11,12] and small-holder farming linked to industrial plantations in Asia[8,13]. According to Global Forest Watch, annual tree cover loss reached 29.7 million hectares globally in 2016, a 51% increase compared to 2015. In the tropics, 12 million hectares—an area the size of Belgium—were lost in 2018 alone.[14]

1.2. International efforts/ pledges

Multiple initiatives worldwide, including the Convention on Biological Diversity (CBD), Aichi Target 15,[15] the United Nations Framework Convention on Climate Change (UNFCCC), Reducing Emissions from Deforestation and Degradation (REDD+) goal,[16] the Bonn Challenge, the Rio+20 land degradation neutrality goal[17] and SDG 15[18] had already made manifest their ambition to reverse these trends. By the beginning of 2018, close to 500 companies in the food and agriculture sector pledged to eliminate deforestation from their supply chains, and the number of commitments continues to grow.[19] The New York Declaration on Forests, the Initiative 20x20, the African Forest Landscape Restoration Initiative (AFR100) and similar initiatives seek to restore deforested and degraded land. The Bonn Challenge Barometer of Progress reports that 47 countries are pledging more than 160 million hectares for Forest Landscape Restoration through voluntary, non-binding initiatives, and 43.7 Mha were reported as being restored.[20] More recently, the World Economic Forum launched in February this year the 1t.org project, a global initiative to grow, restore and conserve 1 trillion trees around the world. With strong political back up, they join other similarly named initiatives (Plant for the Planet, the Trillion Tree Campaign and Trillion Trees), aiming to unite governments, the civil society, companies and private individuals in a global scale nature restoration movement. Despite repeated failures to meet many earlier targets, these efforts show the collective ambition to preserve forests remains strong (Figure 1).

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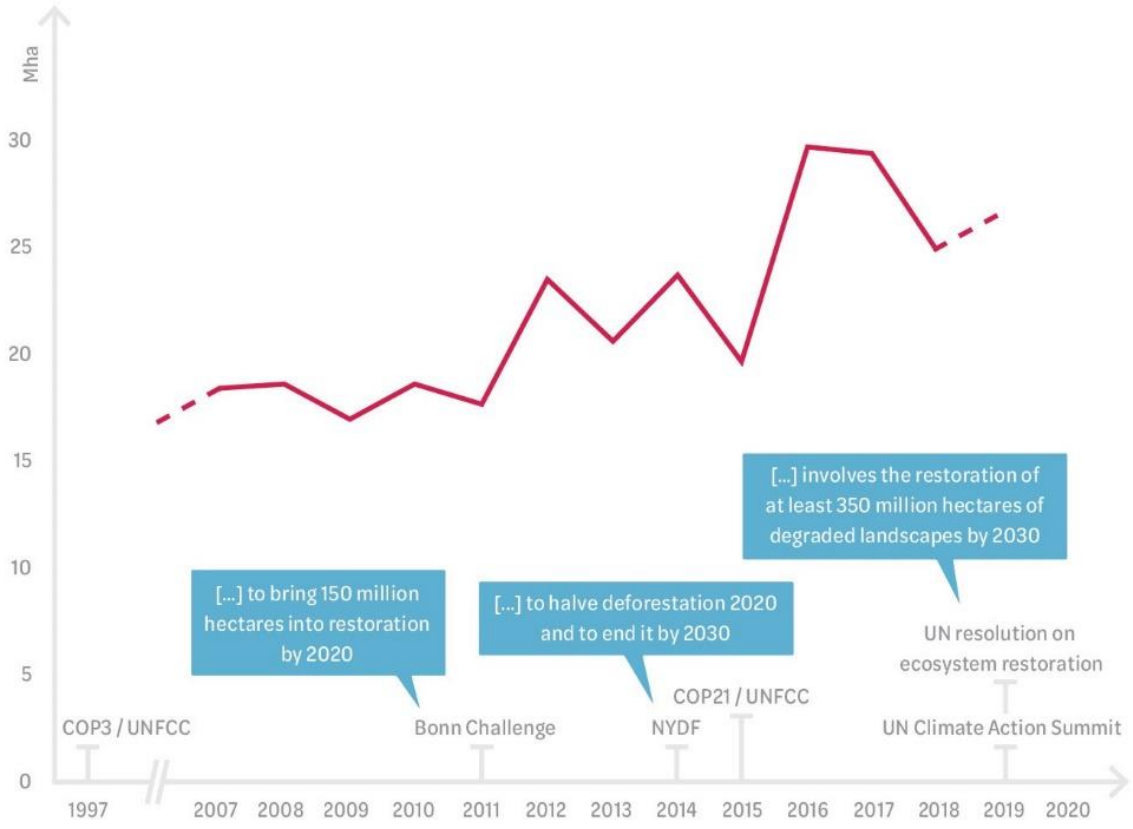
1.3. Problem statement



[Figure 1. Detected tree cover loss and institutional timelines. (data by Global Forest Watch; tree canopy density >30%)]

Despite the demonstration of political will and global efforts, forest loss, fragmentation and land degradation continue unabated and are reaching a critical point.[21] No clear evidence exists that the current restoration initiatives are working (Figure 1). Despite corporate commitments, commodity-driven deforestation persists,[7] and new evidence suggests that targets were set without considering biophysical capacities of the system.[22] Successes here and there do not register at the global scale, and at best tell the story of battles won but of a losing war. Why are policies designed to halt deforestation and increase restoration of forest landscapes apparently missing their target? We hypothesize a key reason for ineffectiveness lies in a failure to recognize the agency of the many stakeholders involved—their capacity to act independently and to make their own free choices—and the adaptive capacities of the systems we seek to steer. Landscapes do not simply happen, we make theme. They are the result of the sum of individual actions and decisions made by all stakeholders, and the interactions between these and biophysical processes.[23] Our guiding research question is: why are policies to halt deforestation and increase

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restoration of forest landscapes winning locally and failing globally? Forest transitions (e.g., from net forest loss to net forest gain, but see next section for definitions) are not ecologically driven, but socially and behaviorally, and are a product of the way that humans govern and manage ecosystems.

1.4. Objectives

In this paper, we provide an overview of why current global policies and initiatives to halt forest degradation and foster restoration fail and suggest possible solution pathways to overcome these key barriers. For this, we first introduce two widely applied theories (forest transition and sustainability transition/transformation) and then elaborate on the reasons for policy failures. In a last section, we propose a radically new approach, where we do away with the assumption that it is feasible or necessary to work towards achieving a common vision for transformation. There, we propose a method that allows stakeholders to align forces despite different and sometimes opposing values and worldviews without the necessity to find beforehand a “common vision”.

2. Transitions (common theories)

2.1. Forest transition theory

Forest transitions—defined as a regional-scale shift from a shrinking to an expanding forest area—serve as a heuristic framework to conceptualize forest landscape change (Figure 2). This framework distinguishes three distinct phases where either (i) fragmentation, (ii) deforestation and degradation or (iii) restoration and reforestation are the main processes shaping the landscape (but see[24] that classify fragmentation as a case of deforestation). This trend is represented with the forest transition curve,[25,26] a theoretical construct that maps changes in forest cover area for a given region or nation over time.[27] Forest quality is not well represented in the forest transition theory, and degradation, if it is higher in the second phase of the transition, can happen all along the forest transition curve. Gillet et al. (2016)[28] shows for central African forest that ecosystems services (such as Non Timber Forest Products), wildlife consumption, and contribution of these products to household incomes and to dietary intake decrease along the forest transition curve.

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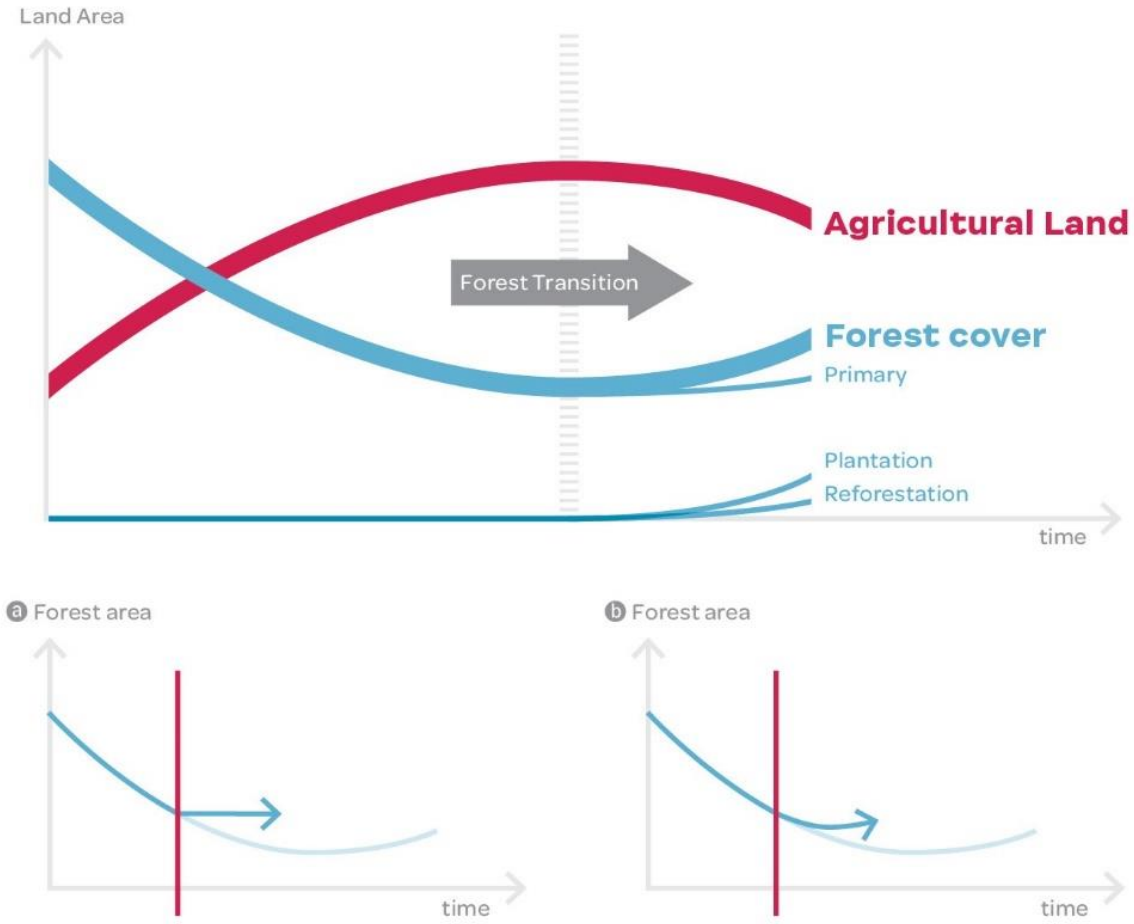

[Figure 2. The Forest Transition Theory is a description of the changes a landscape—initially a country—undergoes when its forest cover stops shrinking and starts expanding despite growing human population, increased technical capacities and changing cultural values. Agriculture expansion being the major driver of forest loss, the curves of forest area and agricultural area complement each other. The recovery of forest area is explained by the expansion of remaining forests, forest landscape restoration and active plantation programs. The forests at the end of the process are different from those at the beginning. Policy interventions can speed up or slow down the transition. A policy to reduce and stop deforestation can at best flatten the curve (a). Forest landscape restoration can potentially redress it up to the maximum ecological potentialities of the locality (b). Halting deforestation and restoring landscapes are equally needed to operate the transition. Modified from[26,29].]

2.2. Sustainability transition theory

Forest transitions are embedded in social transformations that result from technological advances, changes in societal values, new business models, and substantial policy changes.[25,30–32] Over the years academics seeking to understand innovation have developed different analytical frameworks to explain innovation processes and the socio-technical configurations needed for

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change.[33] Two different perspectives have evolved to understand fundamental transformation processes.[34] On one hand research has focused on what[33] refer to as an 'emerging technology perspective', while another perspective investigates broader transition processes. Here we focus on the latter, and specifically on the Multi-Level Perspective MLP theory.[35–37]

The multi-level perspective is a commonly used model to study societal transitions.[33,38] It identifies three levels ranging from macro to micro scale (Figure 3); 1) the macro level includes the broader political and social trends, the values and normative landscape 2) the meso level defines the regimes, the rules and routines that define the "way of doing things", e.g. the production system including rules and actors from industry, policy, science and users, and 3) the micro level where experimentation with novel technologies, practices, and policies, collectively referred to as innovations, takes place. Experimentation takes place in so-called 'niches' where innovations are shielded from regime influences (e.g.,[39,40] but can be expanded to "spaces where networks of actors experiment with, and mutually adapt, greener organizational forms and eco-friendly technologies".[41] The MLP also describes under which conditions a stable regime may radically change through a "regime shift".[42] A shift is possible when novel practices mature, gain traction and replace dominant practices in the regime. In the case of sustainability, this only happens when sufficient pressure is put on the regime by the normative landscape to create a state of openness to adopt innovations (Figure 3). The depletion of ozone layer and the subsequent adoption of the Montreal Protocol exemplifies such a situation.

Examples of successful transitions come foremost from sectors with a strong technological character, like energy and transport sectors. Due to economies of scale, the costs of innovations can be considerably reduced to make them much more competitive. A forest transition in rural tropical areas, however, often involves uptake of sustainable and ecofriendly agricultural practices. Such forms of agriculture internalize external costs, which makes them much more costly and therefore less competitive to the incumbent agricultural system. Moreover, since agricultural practices are 'place based', development of ecofriendly agriculture does not profit from any economies of scale nor are they strongly technologically driven. This makes the uptake of ecofriendly agriculture, to support the forest transition, highly unlikely and governance solutions that have driven other well-studied transitions cannot be readily applied here. It therefore requires the development of new transition mechanisms. One seemingly evident option would be that the existing socio-technical regime itself needs to be adapted by policy makers.[43] This, however, is far from easy due to the strong path-dependencies that have been developed over the years in the incumbent socio-technical agricultural system[44] and the prevalence of other pressing issues,

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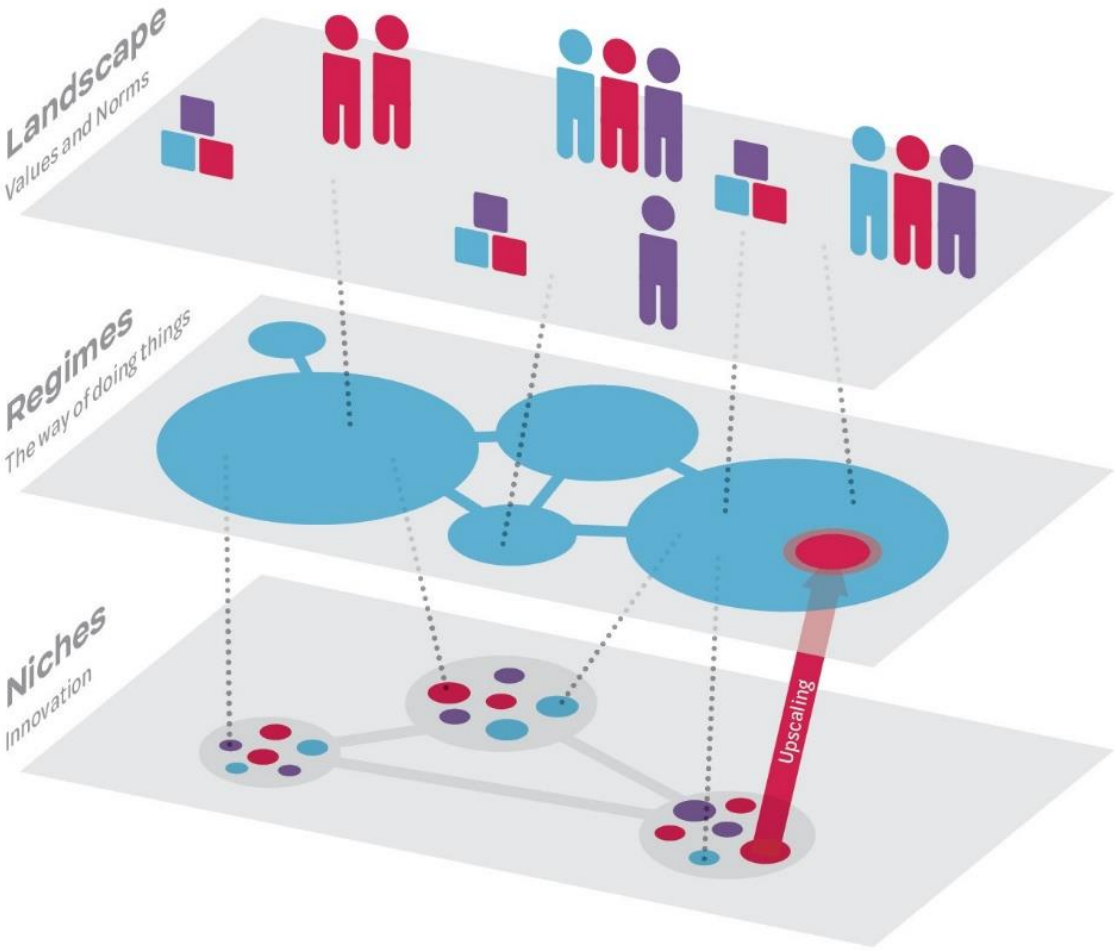
such as poverty, health and geo-political tensions. Transition is thought to require a new 'shared vision' on what agriculture should do and what external effects should be addressed. The inability to create such shared visions may suggest we are far from creating ecofriendly agriculture to support forest transitions.



[Figure 3. The multi-level perspective theory framework. The normative landscapes represents the norms and values that shape our collective enterprise. The regimes capture the rules and processes that define "the way of doing things". Innovation happens at local scales, in niches protected from the regimes. According to this theory, upscaling of innovation by change agents can create regime shifts, redefining why we do things, but this requires pressure from the normative landscape. (adapted from[45])]

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3. Reasons for policy failures

3.1. System lock-ins

Forest transitions face two major obstacles. First, successful transitions are mostly driven by clear objectives, like the delivery of climate neutral solutions in the energy transition.[46] Forest transitions, however, focus on broad sustainability objectives that address 'wicked' problems. A wicked problem, by definition, resists classical problem-solving approaches, due to the inability or unwillingness of stakeholders to agree on problem definition, to changing requirements, and the prevalence of unresolvable uncertainties.[47,48] Reductionist approaches, breaking down a wicked problem into smaller, more manageable problems, or authoritarian ones that impose the definition of the problem to other stakeholders, fail to achieve long-term resolution and to promote the societal transformation needed to foster forest transitions.[21] Wicked problems resist taming and bite back.

Second, existing market and land policy distortions underprice the use of natural resources, making business as usual production systems more competitive in the short term.[49] Innovations to tackle forest loss and degradation are generally based on policy instruments (e.g. certification, support and financing of ecosystem services, offset requirements)[50–52] that are designed to internalize environmental costs in production of ecosystem goods and are, hence, more expensive to implement. For example, forest management certification was promoted as a market-based solution to the failure of public policies to protect forest resources.[50,53] Especially forest communities, due to the costs involved, however, have limited its adoption. Where adopted, it has promoted and shaped sustainability transition processes by introducing new concepts in national policy arenas[54,55] but simply scaling the current certification models will not lead to a regime shift. The status quo needs to change in order to make sustainable forest transitions happen.

3.2. People, their values and beliefs

It is ultimately people's actions—migrating in or out, investing in tree planting, allowing land to lie fallow—that determine whether a transition will occur.[56] These actions, or inactions thereof, are driven by economic factors and markets, policies, and social norms, rules and beliefs around land use and management, and above all, by the free will of the agents making decisions: their agency (Box 1). In the end, we all make choices and decisions that ultimately affect the demands on landscapes.[57]

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Social groups actively fabricate their knowledge and versions of reality through everyday interactions. Actors work within biophysical constraints, regulatory structures, complex social networks and power imbalances that invite, discourage or forbid certain actions. Individuals are not passive rule-followers but actively create, use and reproduce social norms—the unwritten rules that people adhere. This understanding of the group rules by the individual might be accurate or not. Different individuals may share the same understanding, or not. One's expectations of others' behaviors and attitudes affect one's decisions[58] For example, if community members believe that other farmers overharvest forest products, they may change their harvesting behavior to go along with the new norm they perceive, irrespective of whether the initial belief is justified or not. In doing so, they begin a self-reinforcing pattern that leads to forest degradation. Behavioral expectations can be self-fulling. Actors establish linkages between the processes of the forest transitions. Thus, these transitions become socially constructed, with actors holding expectations that may or may not be based on correct perceptions of physical realities or laws, group norms and individual capabilities. Understanding social perceptions, rules and norms is therefore essential to drive social, and ultimately ecological, change.

To foster forest transition, we must understand the interconnections between forest changes, the ecosystem services produced by them along the process, and the social perceptions, rules and norms (values) that decision-makers at different scales hold over them and how this then affects decision-making.[59–61] The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) has stressed the importance of inclusive valuation.[62] Its recently approved regional assessments highlight how diverse values and value systems shape interactions between people and nature including the use, management and conservation of nature's contributions to people.[63,64] They describe how incorporating a diversity of social values into decision-making processes can contribute to successfully designing and implementing effective conservation and sustainable use plans, as well as to achieving the Sustainable Development Goals (SDGs).[64,65] Values—but also current emotions, preferences and personalities of decision makers, or the characteristics of options[66]—drive decisions.[67] Therefore recognizing the role and personal contexts of local decision-makers and decision-influencers in fostering—or preventing—forest transitions is key to understanding how to support and promote forest recovery. However, there is more than values at play.

The systemic shifts required for the forest transition to happen are unlikely to follow from a gradual change in values held by decision makers. They demand rapid large-scale behavioral transition that will only occur if social norms change.[58] We resist changing our values, since these define

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our identity.[68] Awareness creation activities aiming at changing values will meet with limited success, unless targeted at young people whose identities and values are not yet crystallized.[69]

Actions are driven by values but also by beliefs.[70] We make decisions based on what we want (our desires) filtered by what we think will happen (our beliefs).[71] It does not matter that these beliefs are justified or not. In fact the “illusion of understanding”, a set of over simplistic, unjustified assumptions about complex and uncertain topics, proves to be a powerful driver of action.[72] However, the closer our mental models are to the actual network of causal links that shapes the landscapes, the smaller the gap between the intended consequences of our actions and their effective impact.[71] In addition, since our behavior is influenced by our expectations of others’ behaviors and attitudes[73] whether correct or incorrect, changing these expectations can produce abrupt shifts in behavior.[58,73]

4. Bringing about radical transformations

Contrary to what is generally admitted, we propose that it will be very expensive, perhaps even futile to invest in trying to change the values of the decision makers in order to bring about the transformations required to reverse the negative trends of forest change, and other similar systemic environmental transformations. Developing a common vision of what the world should be will be difficult, exhausting, and possibly impossible if the values held are at loggerheads. More importantly, it is not required. For collaboration between agents to emerge, they do not need to agree on a common objective beyond letting the other party live another day. It is sufficient that they agree on how the world works and (therefore) how it may change.

The initial representation of a problem, known as problem framing, may be the most crucial single factor governing the likelihood of problem solution.[74] A critical role of science and policy engagement is to support the framing of new policy problems and solutions.[75] Scientists and experts generally approach such tasks by exploring the major underlying factors impeding and driving progress towards sustainable forest transitions. They focus on the reasons the system changes. Yet, as we have discussed, wicked problems notoriously resist these approaches.

4.1. Agreeing on how things are

We propose that a path less trodden for policies and interventions is to provide reasons for people to change their expectations.[73] It means working on creating agreement around a common understanding of how things are (descriptive approaches) instead of focusing on how things should be (normative ones). It means asking “How things are” rather than asking “Why they should

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work that way".[72] In so doing, three things happen. First, people can relate to their empirical knowledge of the system and feel secure if their own perception of reality is represented adequately in the discussion. Second, by being exposed to the realities perceived by the other parties, surprises will arise, as they suddenly shift their point of view. Third, a common description of how things are independently of the values we attach to them serves as common entry point to build trust between parties, a solid foundation for any landscape approach.[23] These processes do not require altruism to be shared between parties. They do not void the necessity of strategic foresight by all parties.[76] They do require pragmatism and sound methods to be successful.

The classic role assigned to scientific research is to generate new knowledge that will change our understanding of what the system actually is, establishing trends and ascertaining new orders of magnitude. This is akin to exploring the "What" of forest landscape change. The map of Intact Forest Landscapes[77] played such a role. By creating a new point of view on forests, a new layer of information, it initiated a policy transformation that led eight years later to the adoption of new management standards in Forest Stewardship Council certified concessions.[78] The estimation of the number of trees on earth[79] had a similar impact, transforming the Billion Trees campaign into the Trillion Trees campaign, when decision makers realized the magnitude of the processes they wanted to influence. More recently, the estimation of the earth tree restoration potential played a similar role, changing the public perception of the value of forest as a natural climate solution.[22] Understanding the changes in forest cover, and measuring whether and to what extent they degraded or expanded, is therefore crucially important to put topics on the agenda. A descriptive framework that quantifies and monitors the status of forests can contribute to modify individuals' perceptions and evolve social norms toward a more unified vision, reducing false understanding of individuals in a group. However, given that actual definitions of forests are political statements, simply agreeing on what to monitor already proves a challenge. Quantitative monitoring frameworks are needed but will not suffice to create the transformations we call upon.

4.2. Becoming self-aware

By articulating the hypotheses that underlie potential pathways to change and making anticipated cause-effect relationships explicit, a Theory of Change and other similar approaches make it possible to document and examine assumptions, causality and the steps along a project development pathway.[80] It focuses attention on "How" the system works as opposed to "Why" it should work in a certain way. Such a reflexive process improves the chance of designing and implementing successful projects.[81] The participatory nature of a Theory of Change development and refinement is a key to success.[80,82]

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A widespread use of a Theory of Change both as a process and product in the development of policies and projects tackling deforestation, forest degradation and reforestation, would contribute to more realistic long-term goal setting, allowing for learning and adaptive management. It facilitates transparency on collective beliefs and reveals differences in the assumptions among stakeholders. If framed not as normative issue, but rather as a description of the status quo, the use of a Theory of Change helps stakeholders that may not all agree on an overarching objective to smooth the way for reflection and shared negotiation of common or compatible goals and solutions. As a dynamic process, the Theory of Change can support the collective testing of assumptions within the intervention. As outcomes begin to be realized, both the logic and the assumptions of the policies and projects are revisited to ensure change is taking place as intended. A key aspect of the process is to strengthen stakeholder ownerships, continuously revisit pathways of change, while ensuring that the scenarios being produced are relevant to policy makers and practitioners.

Understood as such, a Theory of Change thus outlines a strategy to achieve a stated objective. It is first developed based on the mental model of the decision-makers. It necessarily includes statements on the expectations on how stakeholders will respond to initiatives. Through the process of revisiting it, the mental model can be refined. With a Theory of Change, thus, come two keys for success: the elicitation of mental models that allow self-awareness and the design of a process of learning that allows the models to be refined.

Flaws and inaccuracies in the mental models, however, will be costly, create delays or even foster opposition. A bad strategy yields no results and runs the risk of returning to square one, with laudable targets but no effective way to achieve them. There are ways to fast track the lengthy and potentially tedious process of testing and validating one's mental models. They involve exploring common futures through exploring and discovering rather than visioning alternative options. The essence of such prospective analysis is to explore possible futures. Not to predict what will happen but to highlight the forces that drive the system, in order to make better decisions today about the future. Yet the complexity of the landscapes we address defy the cognitive capacities of most of us. As with a game of chess, with its 10^{120} estimated variations,[83] it is easier to explore the behavior of a system using a board and pieces than to play with a blindfold. We need games and we need to play them.[84,85]

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4.3. Learning by playing

Boundary objects are adaptable to different viewpoints and robust enough to maintain identity across them.[85] Their development and manipulation helps people cope with complexity. Boundary objects can be developed to understand landscapes and their changes (Figure 4). We call this the constructivist approach to future exploration.[47] It involves the elicitation of the mental models that underlie the action. It requires the transformation of these mental models into a tangible format such as a game.

Developed through participatory processes, a game can represent all the crucial actors, resources, processes and interactions—ecological, social, economic and political—relevant to the discussion[86] (Figure 4). Such a game is then understood as the combination of tokens (what the system is), a set of commonly agreed upon rules (how the system works) and players.[84] Playing the game lets stakeholders confront their understanding of the system with the narrative presented by the game. The game poses challenges to the players, responds to their decisions and invites them to think strategically. They can then confront their strategies to the strategies developed by the other players, and to the engine of the game—the core rules that define what is possible. This process acts as a reality check of the assumptions participants have. It allows creating consensus on how the system works, when they agree the rules represent the system they are familiar with. Games enable stakeholders to share and confront their perceptions to better grasp the complexities of the system, to explore alternative futures in a low-risk environment, and to negotiate new forms of collective action.[87] The insights so gained can then be translated into real life first as a refined Theory of Change, and then as policies. This is the process that negotiators of the Forest Stewardship Council Regional Working Group for High Conservation Value Areas experimented in August 2017 in Brazzaville. They used MineSet, a game developed to explore the links between mining and logging activities, to agree on the definition of regional indicators for Intact Forest Landscapes.[88]

Any method that confronts mental models through the construction of boundary objects would contribute to the same objective. Why focus on games particularly? Because to overcome the cognitive biases that prevent changes to our mental models, there are few better ways than to force people to take a new vantage point and to look carefully at what can be seen from that point.[84] When faced with a situation that is beyond their control, yet in a safe environment, participants become alert, a state that makes it easier for them to reflect and learn. Games play thus the role of the third key for success, providing tools and methods to improve the capacity to learn of the participants.

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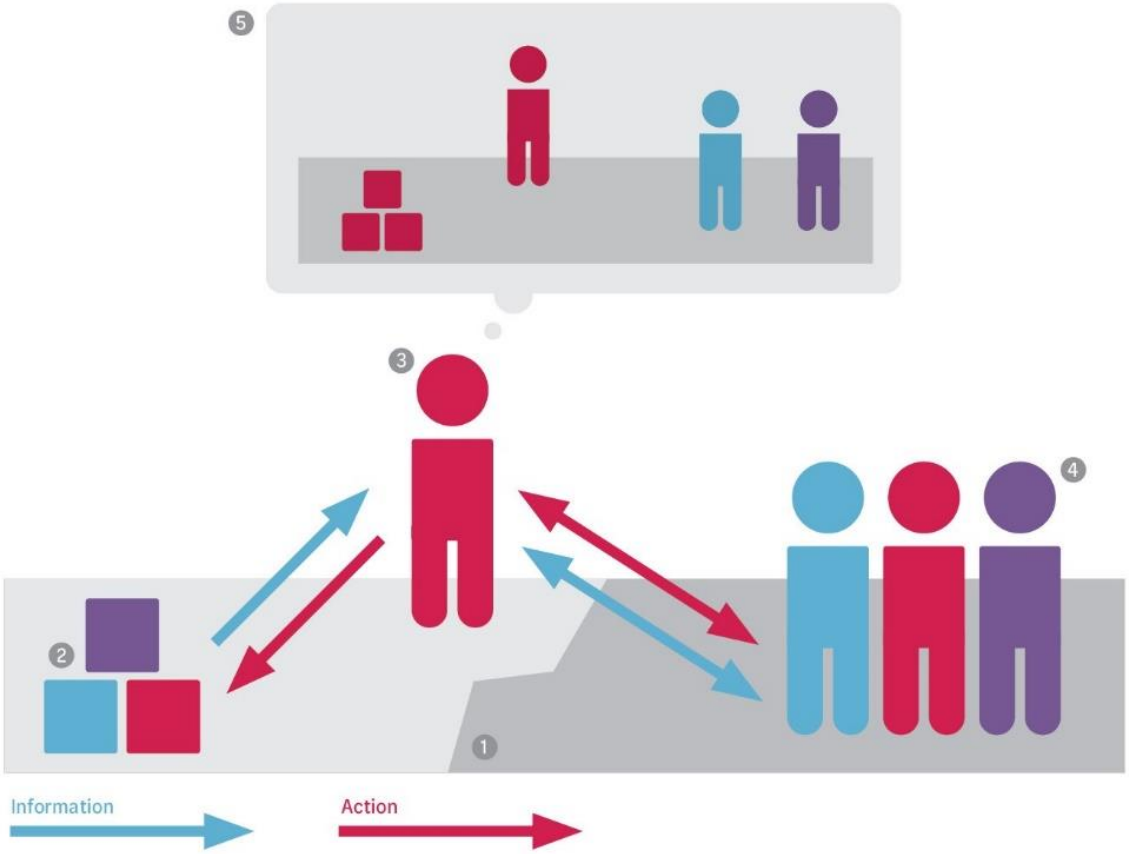

[Figure 4. Model Framework. The games we develop use the basic architecture common to most multi-agent systems, applied to landscape and natural resources management. A first layer details the physical landscape and its heterogeneity (1). Resources, including ecosystem goods, are present in this landscape, and each resource has its own sub-model to describe its dynamics (2). Stakeholders are represented as agents and have different qualities of life, access to capitals, knowledge and skills (3). Stakeholders manage the land and the resources based on their needs, capacities and aspirations. In addition, stakeholders are embedded in a policy, social and institutional environment made of other agents (4) with whom they interact and that contributes to shape their strategies. The crucial element is the mental model of the agent (5), her perceived environment, which will condition the choices she makes.]

Once land-use futures and pathways of change are outlined, policy innovations and new business models stemming from that process can help foster transitions. Decision-makers need to map policy innovations and business models that suggest alternative pathways away from business as usual by challenging the existing regimes of forest governance. They can look for innovations that aim to destabilize the incumbent regime, introduce change to existing practices and provide alternative pathways. As forest governance is fragmented across jurisdictions and includes multiple actors, the identification can span from local levels to international politics. This may affect national arrangements[89–91]—including governance instruments by state, markets and civil

society as well as hybrid modes of governance, such as public–private partnerships (e.g. logging concessions and co-management of resources, cf.[92] It may also influence social–private partnerships such as community "conservancies" and payments for ecosystem services (PES).[93,94] Identifying synergies between various policy innovations and business models can strengthen policy environments that foster transitions.[95]

Besides identifying policy innovations and business models, decision-makers need to identify the individuals, groups or organizations (vic. boundary partners) whom to influence to achieve transformational change.[96] The selection of boundary partners should strategically target a wide range of actors involved in land use sectors, including firms, investors, users, NGOs, and various government agencies. Although we advocate change through collaboration and co-creation through exploration of common futures and changed expectations, changing status quo may also require actors who employ destructive change strategies, such as confrontational campaigns and demonstrations.[97] All these process enter in the revision of the Theory of Change. The journey to transformation is already well underway.

5. Conclusions

Climate and land use influence forests globally. Forest cover loss and forest degradation have negative impacts on biodiversity and the provision of ecosystem services originating from forest systems, and reduce the capacity of forests to contribute to climate mitigation through carbon sequestration. This is balanced by the extraction of timber and other goods originating from the forests, more space allocated to agricultural production and infrastructure, and the ensuing economic and social changes. Deforestation happens because locally, and in the short run, it is the most logic and rewarding course of action. To counteract this, a number of global initiatives and policy instruments have been created to halt forest loss. Yet forest loss continues. National forest transitions consist of a multitude of local forest transitions that arise from local decisions. What is required is a planetary forest transition, with local forests transitions arising from local decisions aggregating at the regional, national and finally global level. These decisions are shaped by local norms and the expectations people have on other people's decisions. This self-referencing process leads to a self-reinforcing pattern of landscape change that can be broken by an abrupt change in perceptions about how the world really works.

Fostering forest transitions thus requires decision-makers at all levels to better understand their own perceptions and values as well as those of the other stakeholders involved. This is true for all decision-makers, be they working their fields, sitting in a minister's office, or on a Board. The

 doi:10.20944/preprints202003.0087.v1

higher the power of the decision-maker, the more pressing the need. Until this happens, policies risk continuing to target the wrong stakeholders for the wrong reasons.

We have highlighted the three keys to invoke radical change: (1) self-awareness of the mental models of how the system works, (2) the adoption of a process to revise and improve these mental models through a participatory process like the Theory of Change, and (3) the use of games and other boundary objects that decrease cognitive obstacles to learning and prevent self-actualization. These three elements are reminiscent of the three loops of learning identified in the field of cognitive sciences. In adopting them, decision makers will address directly human agency, the Gordian knot at the root of deforestation and forest degradation. We need that to design more meaningful and effective strategies and policies.

Acknowledgments

This paper is the result of the discussions held by the Fostering Forest Transitions: Scenarios of Biodiversity and Landscape Change (ForSet) project consortium. We are thankful to Sylvain Mazas for designing the figures.

References

1 Houghton, R.A., Nassikas, A.A. 2018. Negative emissions from stopping deforestation and forest degradation, globally. Global Change Biology 24(1):350–359.

2 Meyfroidt, P. and Lambin, E.F. 2011. Global forest transition: prospects for an end to deforestation. Annual Review of Environment and Resources 36(1):343–371.

3 Aguiar, A.P.D., Vieira, I.C.G., Assis, T.O., Dalla-Nora, E.L., Toledo, P.M., Oliveira Santos-Junior, R.A. et al. 2016. Land use change emission scenarios: Anticipating a forest transition process in the Brazilian Amazon. Global Change Biology 22(5):1821–1840.

4 Geist, H.J. and Lambin, E.F. 2002. Proximate causes and underlying driving forces of tropical deforestationtropical forests are disappearing as the result of many pressures, both local and regional, acting in various combinations in different geographical locations. BioScience 52(2):143–150.

5 Kissinger, G., Herold, M. and de Sy, V. 2012. Drivers of deforestation and forest degradation: A synthesis report for REDD+ policymakers. The Government of the UK and Norway.

6 Song, X.P., Hansen, M.C., Stehman, S.V., Potapov, P.V., Tyukavina, A., et al. 2018. Global land change from 1982 to 2016. Nature 560(7720):639–643.

7 Curtis, P.G., Slay, C.M., Harris, N.L., Tyukavina, A. and Hansen, M.C. 2018. Classifying drivers of global forest loss. Science 361(6407):1108–1111.

8 Rudel, T.K., DeFries, R., Asner, G.P. and Laurance, W.F. 2009. Changing drivers of deforestation and new opportunities for conservation. Conservation Biology 23(6):1396–1405.

9 Verburg, R., Rodrigues Filho, S., Lindoso, D., Debortoli, N, Litre, G. and Bursztyn, M. 2014. The impact of commodity price and conservation policy scenarios on deforestation and agricultural land use in a frontier area within the Amazon. Land Use Policy 37:14–16.

10 Tyukavina, A., Hansen, M.C., Potapov, P.V., Stehman, S.V., Smith-Rodriguez, K., et al. 2017. Types and rates of forest disturbance in Brazilian Legal Amazon, 2000–2013. Science Advances 3(4):e1601047.

11 Hosonuma, N., Herold, M., De Sy, V., De Fries, R.S., Brockhaus, M., et al. 2012. An assessment of deforestation and forest degradation drivers in developing countries. Environmental Research Letters 7(4):044009.

12 Tyukavina, A., Hansen, M.C., Potapov, P., Parker, D., Okpa, C., et al. 2018. Congo Basin forest loss dominated by increasing smallholder clearing. Science Advances 4(11):eaat2993.

13 Turubanova, S., Potapov, P.V., Tyukavina, A. and Hansen, M.C. 2018. Ongoing primary forest loss in Brazil, Democratic Republic of the Congo, and Indonesia. Environmental Research Letters 13(7):074028.

14 Weisse, M. and Goldman, E.D. Global tree cover loss rose 51 percent in 2016. Available at http://www.wri.org/blog/2017/10/global-tree-cover-loss-rose-51-percent-2016.

15 CBD (2010) Strategic Plan for Biodiversity 2011–2020 and the Aichi Targets. CBD, Montreal, Canada.

16 UNFCC. 2013. Warsaw Framework for REDD-plus. Secretariat of the United Nations Framework Convention to Combat Climate Change, Bonn, Germany.

17 United Nations. 2012. Rio +20: The Future We Want. United Nations Convention on Sustainable Development, Rio de Janeiro, Brazil.

18 United Nations. 2015. Transforming our world: the 2030 Agenda for Sustainable Development. United Nations, New York, USA.

19 Rogerson, S. 2019. Forest 500 Annual Report 2018—the Countdown to 2020. Global Canopy, Oxford, UK. Available at https://forest500.org/sites/default/files/forest500_annualreport2018_0_1.pdf

20 Dave, R., Saint-Laurent, C., Murray, L., Antunes Daldegan, G., Brouwer, R., et al. 2019. Second Bonn Challenge progress report. Application of the Barometer in 2018. Gland, Switzerland: IUCN. xii +80pp.

21 Taubert, F., Fischer, R., Groeneveld, J., Lehmann, S., Müller, M.S., et al. 2018. Global patterns of tropical forest fragmentation. Nature 554:519–522.

22 Bastin, J.-F., Finegold, Y., Garcia, C., Mollicone, D., Rezende, M., Routh, D., Zohner, C.M. and Crowther, T.W. 2019. The global tree restoration potential. Science 365(6448):76–79.

23 Sayer, J., Sunderland, T., Ghazoul, J., Pfund, J.-L., Sheil, D., et al. 2013. Ten principles for a landscape approach to reconciling agriculture, conservation, and other competing land uses. Proceedings of the National Academy of Sciences of the United States of America 110(21):8349–8356.

24 Bogaert, J., Ceulemans, R. and Van Eysenrode, D.S. 2004. Decision tree algorithm for detection of spatial processes in landscape transformation. Environmental Management 33(1):62–73.

25 Rudel, T.K., Coomes, O.T., Moran, E., Achard, F., Angelsen, A., et al. 2005. Forest transitions: towards a global understanding of land use change. Global Environmental Change 15(1):23–31.

26 Lambin, E.F. and Meyfroidt, P. 2010. Land use transitions: Socio-ecological feedback versus socio-economic change. Land Use Policy 27(2):108–118.

27 Mather, A.S. 1992 The forest transition. Area 24(4):367–379.

28 Gillet, P., Vermeulen, C., Doucet, J.-L., Codina, E. and Lehnebach, C. 2016. What are the impacts of deforestation on the harvest of non-timber forest products in Central Africa? Forests 7:106.

29 Barbier, E.B. and Tesfaw, A. 2015. Explaining forest transitions: The role of governance. Ecological Economics 119:252–261.

30 Meyfroidt, P., Chowdhury, R.R., de Bremond, A., Ellis, E.C., Erb, K.H., et al. (2018). Middle-range theories of land system change. Global Environmental Change 53:52–67.

31 Kull, C.A. 2017. Forest transitions: a new conceptual scheme. Geographica Helvetica 72:465–474.

32 Meyfroidt, P., Rudel, T.K. and Lambin, E.F. 2010. Forest transitions, trade, and the global displacement of land use. Proceedings of the National Academy of Sciences of the United States of America 107(49):20917–20922.

33 Markard, J., Raven, R. and Truffer, B. 2012. Sustainability transitions: An emerging field of research and its prospects. Research Policy 41:955–967.

34 Meelen, T. and Farla, J. 2013. Towards an integrated framework for analysing sustainable innovation policy. Technology Analysis & Strategic Management 25(8):957–970.

35 Geels, F.W. and Schot, J. 2007. Typology of sociotechnical transition pathways. Research Policy 36(3):399–417.

36 Geels, F.W., Sovacool, B.K., Schwanen, T. and Sorrell, S. 2017b. The socio-technical dynamics of low-carbon transitions. Joule 1(3):463–479.

37 Geels, F.W., Sovacool, B.K., Schwanen, T., Sorrell, S. 2017a. Sociotechnical transitions for deep decarbonization. Science 357(6357):1242–1244.

38 Smith, A., Stirling, A. and Berkhout, F. 2005. The governance of sustainable socio-technical transitions. Research Policy 34:1491–1510.

39 Kemp, R., Schot, J. and Hoogma, R. 1998. Regime shifts to sustainability through processes of niche formation: the approach of strategic niche management. Technology Analysis & Strategic Management 10(2):175–198.

40 Rip, A. and Kemp, R. 1998. Technological change. In: Human Choice and Climate Change. Rayner, S. and Malone, E.L. (eds.), pp. 327–399. Battelle Press, Columbus, Ohio, USA.

41 Smith, A. 2007. Translating sustainabilities between green niches and socio-technical regimes. Technology Analysis & Strategic Management 19(4):427–450.

42 Kemp, R. 1994. Technology and the transition to environmental sustainability. Futures 26:1023–1046.

43 Wilson, G.A. 2007. Multifunctional Agriculture. A transtition theory perspective. CABI Publishing, Cambridge, MA, USA.

44 North, D.C. 1990. Institutions, Institutional Change and Economic Performance. Cambridge University Press, Cambridge, UK.

45 Geels, F.W. 2002. Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study. Research Policy 31:1257–1274.

46 Jacobsson, S. and Lauber, V. 2006. The politics and policy of energy system transformation—explaining the German diffusion of renewable energy technology. Energy Policy 34(3):256–276.

47 Redpath, S.M., Keane, A., Andrén, H., Baynham-Herd, Z., Bunnefeld, N., et al. 2018. Games as tools to address conservation conflicts. Trends in Ecology & Evolution 33(6):415–426.

48 Head, B.W. and Alford, J. 2013. Wicked problems: Implications for public policy and management. Administration & Society 47(6):711–739.

49 Barbier, E.B. 2011. Transaction costs and the transition to environmentally sustainable development. Environmental Innovation and Societal Transitions 1(1):58–69.

50 Cashore, B. and Stone, M.W. 2012. Can legality verification rescue global forest governance?: Analyzing the potential of public and private policy intersection to ameliorate forest challenges in Southeast Asia. Forest Policy and Economics 18: 13–22.

51 Pirard, R. 2012. Market-based instruments for biodiversity and ecosystem services: A lexicon. Environmental Science & Policy 19–20:59–68.

52 Cadman, T.,Maraseni, T., Ma, H.O. and Lopez-Casero, F. 2017. 'Five years of REDD+ governance: The use of market mechanisms as a response to anthropogenic climate change. Forest Policy and Economics 79:8–16.

53 Auld, G., Gulbrandsen, L.H. and McDermott, C.L. 2008. Certification schemes and the impacts on forests and forestry. Annual Review of Environment and Resources 33:187–211.

54 Manning, S. and Reinecke, J. 2016. A modular governance architecture in-the-making: How transnational standard-setters govern sustainability transitions. Research Policy 45(3):618–633.

55 Savilaakso, S., Cerruti, P., Montoya Zumaeta, J. G. and Ruslandi. 2016. Conserving biodiversity and improving human livelihoods through interaction between public regulation and forest management certification. In: Certification and Biodiversity—How Voluntary Certification Standards Impact Biodiversity and Human Livelihoods. Pavel Castka, D.L., Diana Shand, Doris Cellarius, Tim Healy, Aroha Te Pareake Mead, Marina Rosales Benites De Franco, Anastasiya Timoshyna (eds.), pp.74–90. Gland, Switzerland: IUCN. Available at http://www.cifor.org/publications/pdf_files/Books/CSavilaakso1601.pdf

56 Rudel, T.K., Bates, D. and Machinguiashi, R. 2004. A tropical forest transition? agricultural change, out-migration, and secondary forests in the Ecuadorian Amazon. Annals of the Association of American Geographers 92(1):87–102.

57 Waeber, P.O., Stoudmann, N., Ghazoul, J., Wilmé, L.; Sayer, J.; et al. 2020. Choices we make: rethinking decision-making in the context of climate crisis. Preprints. https://doi.org/10.20944/preprints202001.0339.v1

58 Nyborg, K., Anderies, J.M., Dannenberg, A., Lindahl, T., Schill, C., et al. 2016. Social norms as solutions. Science 354(6308):42–43.

59 Daily, G.C., Polasky, S., Goldstein, J., Kareiva, P.M., Mooney, H.A., et al. 2009. Ecosystem services in decision making: time to deliver. Frontiers in Ecology and the Environment 7(1):21–28.

60 Jacobs, S., Dendoncker, N., Martín-López, B., Barton, D.N., Gomez-Baggethun, et al. 2016. A new valuation school: Integrating diverse values of nature in resource and land use decisions. Ecosystem Services 22:213–220.

61 Saarikoski, H., Mustajoki, J., Barton, D.N., Geneletti, D., Langemeyer, J. 2016. Multi-criteria decision analysis and cost-benefit analysis: comparing alternative frameworks for integrated valuation of ecosystem services. Ecosystem Services 22:238–249.

62 Pascual, U., Balvanera, P., Díaz, S., Pataki, G., Roth, E., et al. 2017. Valuing nature's contributions to people: the IPBES approach. Current Opinion in Environmental Sustainability 26–27: 7–16.

63 IPBES. 2018a. Summary for policymakers of the regional assessment report on biodiversity and ecosystem services for Asia and the Pacific of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. IPBES secretariat, Bonn, Germany.

64 IPBES. 2018b. Summary for policymakers of the regional assessment report on biodiversity and ecosystem services for the Americas of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. IPBES secretariat, Bonn, Germany.

65 IPBES. 2018c. Summary for policymakers of the regional assessment report on biodiversity and ecosystem services for Europe and Central Asia of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. IPBES secretariat, Bonn, Germany.

66 Lerner, J.S., Li, Y., Valdesolo, P. and Kassam, K.S. 2015. Emotion and decision making. Annual Review of Psychology 66:799–823.

67 Kahneman, D. and Tversky, A. 1984. Choices, values, and frames. American Psychologist 39(4):341–350.

68 Schwartz, S.H. 1992. Universals in the content and structure of values: Theoretical advances and empirical tests in 20 countries. In: Advances in Experimental Social Psychology. Zanna, M.P. (ed.), pp. 1–65. Academic Press, San Diego, USA.

69 Schwartz, S.H., Melech, G., Lehmann, A., Burgess, S., Harris, M. and Owens, V. 2001. Extending the cross-cultural validity of the theory of basic human values with a different method of measurement. Journal of Cross-Cultural Psychology 32(5):519–542.

70 Eccles, J.S. and Wigfield, A. 2002. Motivational beliefs, values, and goals. Annual Review of Psychology 53(1):109–132.

71 Bratman, M. 1987. Intentions, plans, and practical reason. Harvard University Press, Cambridge, MA.

72 Fernbach, P.M., Rogers, T., Fox, C.R. and Sloman, S.A. 2013. Political extremism is supported by an illusion of understanding. Psychological Science 24(6):939–946.

73 Young, H.P. 2015. The evolution of social norms. Annual Review of Economics 7(1):

74 Bardwell, L.V. 1991. Problem-framing: A perspective on environmental problem-solving. Environmental Management 15(5):603–612.

75 Pregernig, M. 2014. Framings of science-policy interactions and their discursive and institutional effects: examples from conservation and environmental policy. Biodiversity and Conservation 23(14):3615–3639.

76 Mermet, L. 2011. Strategic Environmental Management Analysis: Addressing the Blind Spots of Collaborative Approaches.IDDR, Paris, France.

77 Potapov, P., Yaroshenko, A., Turubanova, S., Dubinin, M., Laestadius, L., et al. 2008. Mapping the world's intact forest landscapes by remote sensing. Ecology and Society 13(2):51. https://www.ecologyandsociety.org/vol13/iss2/art51/

78 Kleinschroth, F., Garcia, C. and Ghazoul, J. 2018. Reconciling certification and intact forest landscape conservation. Ambio 48:153–159.

79 Crowther, T.W., Glick, H.B., Covey, K.R., Bettigole, C., Maynard, D. S., et al. 2015. Mapping tree density at a global scale. Nature 525:201–205.

80 Stein, D. and Valters, C. 2012. Understanding theory of change in international development. JSRP and TAF collaborative project (JSRP Paper 1). Justice and Security Research Programme, International Development Department, London School of Economics and Political Science, London, UK.

81 Biggs, D., Cooney, R., Roe, D., Dublin, H.T., Allan, J.R. et al. 2017. Developing a theory of change for a community-based response to illegal wildlife trade. Conservation Biology 31(1):5–12.

82 Archibald, T., Sharrock, G., Buckley, J. and Cook, N. 2016. Assumptions, conjectures, and other miracles: The application of evaluative thinking to theory of change models in community development. Evaluation and Program Planning 59:119–127.

83 Shannon, C.E. 1988. Programming a computer for playing chess. In: Computer Chess Compendium. Levy, D. (ed.), pp. 2–13. Springer New York, New York, USA.

84 Speelman, E.N., van Noordwijk, M. and Garcia, C. 2017. Gaming to better manage complex natural resource landscapes. In: Co-investment in Ecosystem Services: Global Lessons from Payment and Incentive Schemes . Sara Namirembe, B.L., van Noordwijk, M. and Minang, P. (ed.). World Agroforestry Center, Nairobi, Kenya.

85 Star, S.L. and Griesemer, J.R. 1989. Institutional ecology, 'translations' and boundary objects: amateurs and professionals in Berkeley's Museum of Vertebrate Zoology, 1907–39. Social Studies of Science 19(3):387–420.

86 Etienne, M., Du Toit, D.R. and Pollard, S. 2011. ARDI: a co-construction method for participatory modeling in natural resources management. Ecology and Society 16(1):44. https://www.ecologyandsociety.org/vol16/iss1/art44/

87 Garcia, C., Dray, A. and Waeber, P. 2016. Learning begins when the game is over: using games to embrace complexity in natural resources management. GAIA—Ecological Perspectives for Science and Society 25(4):289–291.

88 Dillmann, C., Cornioley, T., Chamagne, J. and Garcia, C. 2017. Defining indicators for Intact Forest Landscapes in the Congo Basin using a role-playing game. A joint report ForDev/FSC Congo Basin, Zürich, Switzerland.

89 Arts, B. and Buizer, M. 2009. Forests, discourses, institutions: A discursive-institutional analysis of global forest governance. Forest Policy and Economics 11(5):340–347.

90 Giessen, L. 2013. Reviewing the main characteristics of the international forest regime complex and partial explanations for its fragmentation The International Forestry Review 15(1): 60–70.

91 Primmer, E., Jokinen, P., Blicharska, M., Barton, D.N., Bugter, R. and Potschin, M. 2015. Governance of ecosystem services: a framework for empirical analysis. Ecosystem Services 16:158–166.

92 Karsenty, A. and Vermeulen, C. 2016. Toward “Concessions 2.0”: articulating inclusive and exclusive management in production forests in Central Africa. International Forestry Review 18(S1):13.

93 Lambin, E.F., Meyfroidt, P., Rueda, X., Blackman, A., Börner, J., et al. 2014. Effectiveness and synergies of policy instruments for land use governance in tropical regions. Global Environmental Change 28:129–140.

94 Lemos, M.C. and Agrawal, A. 2006. Environmental governance. Annual Review of Environment and Resources 31:297–325.

95 Fischer, R., Giessen, L. and Günter, S. 2020. Governance effects on deforestation in the tropics: A review of the evidence. Environmental Science & Policy 105:84–101.

96 Earl, S., Carden, F. and Smutylo, T. 2001. Outcome mapping. Building learning and reflection into development programs. Ottawa, Canada: International Development Research Center.

97 Dentoni, D., Waddell, S. and Waddock, S. 2017. Pathways of transformation in global food and agricultural systems: implications from a large systems change theory perspective. Current Opinion in Environmental Sustainability 29:8–13.

 doi:10.20944/preprints202003.0087.v1

98 Sassen, M., Sheil, D., Giller, K.E. and ter Braak, C.J.F. 2013. Complex contexts and dynamic drivers: Understanding four decades of forest loss and recovery in an East African protected area. Biological Conservation 159:257–268.

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Figure captions

Figure 1. Detected tree cover loss and institutional timelines. (data by Global Forest Watch; tree canopy density >30%)

Figure 2. The Forest Transition Theory is a description of the changes a landscape—initially a country—undergoes when its forest cover stops shrinking and starts expanding despite growing human population, increased technical capacities and changing cultural values. Agriculture expansion being the major driver of forest loss, the curves of forest area and agricultural area complement each other. The recovery of forest area is explained by the expansion of remaining forests, forest landscape restoration and active plantation programs. The forests at the end of the process are different from those at the beginning. Policy interventions can speed up or slow down the transition. A policy to reduce and stop deforestation can at best flatten the curve (a). Forest landscape restoration can potentially redress it up to the maximum ecological potentialities of the locality (b). Halting deforestation and restoring landscapes are equally needed to operate the transition. (modified from[26,29].)

Figure 3. The multi-level perspective theory framework. The normative landscapes represents the norms and values that shape our collective enterprise. The regimes capture the rules and processes that define “the way of doing things”. Innovation happens at local scales, in niches protected from the regimes. According to this theory, upscaling of innovation by change agents can create regime shifts, redefining why we do things, but this requires pressure from the normative landscape. (adapted from[45])

Figure 4. Model Framework. The games we develop use the basic architecture common to most multi-agent systems, applied to landscape and natural resources management. A first layer details the physical landscape and its heterogeneity (1). Resources, including ecosystem goods, are present in this landscape, and each resource has its own sub-model to describe its dynamics (2). Stakeholders are represented as agents and have different qualities of life, access to capitals, knowledge and skills (3). Stakeholders manage the land and the resources based on their needs, capacities and aspirations. In addition, stakeholders are embedded in a policy, social and institutional environment made of other agents (4) with whom they interact and that contributes to shape their strategies. The crucial element is the mental model of the agent (5), her perceived environment, which will condition the choices she makes.

Box 1. **Case study: Mount Elgon, Uganda (all references in[98])**

Geography: Mt Elgon is a solitary extinct volcano straddling the Uganda-Kenya border (4321m), located between 0º52’ and 1º25’N, and between 34º14’ and 34º44’E. Below the afroalpine and

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ericaceous zone (from about 3200m), there is an afromontane and an afromontane rainforest zone. The forests and higher elevation areas are protected by a national park and nearly all land within 20 km is under small scale cultivation or grazing. Population densities are high, ranging between 300-1000p/km^2.

History: Mt Elgon was first established as a forest reserve (1929) for timber and water catchment values. Pine plantations replaced some forest in the north (1955) and neighbouring people settled inside the reserve. In 1968, forest management in Uganda was centralized and reserve boundaries were officially demarcated. Under president Idi Amin (1971) and Milton Obote (1978), most forests were encroached by (small scale) farmers. From 1987, efforts to restore forest on Mt Elgon were implemented. First through a forest restoration program, then by increasing the level of protection of the forest to that of a national park (1993), evicting and/or resettling forest residents and cracking down on illegal forest uses. From the 1990s collaborative approaches to forest management were introduced in an effort to reduce conflicts between park management and local residents and improve conservation outcomes. Overall, these interventions have halted forest cover loss and even led to some restoration (Figure B1). However, forest restoration was only successful in a few places, renewed clearing sometimes reversed initial success and restored cover is often highly degraded. Overall recovery is limited and conflicts are still very common. Forest conservation on Mt Elgon in Uganda is a classical illustration of a wicked problem.

Forest transitions on Mt Elgon

Figure B1 shows nested forest transition curves for Mt Elgon in Uganda between 1960 and 2009: for the whole forest zone (green dots) and split among sub-areas. These show the balance of factors supporting forest conservation and forest loss. The study found that single drivers of forest change failed to explain the historical changes on Mt Elgon, especially for forest recovery. Instead, it found that local forest cover trajectories on Mt Elgon were determined by actions driven by local historical cultural preferences around land and forest use, which – over time - interact with changing contexts of markets and market access, conservation policies and their expression in terms of access to resources, and external political interference (Figure B1). For example, in the first phase, population pressure and wealth drive forest clearing, but later there is recovery in wealthy densely populated areas, whilst forest is lost in poor, relatively low population areas.

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Attempts to drive forest recovery on Mt Elgon have not sufficiently recognized the social norms and beliefs that govern people's actions. For example, in one area strong traditional forest use rules broke down after the area was declared a national park, and forest that had resisted previous drivers of deforestation started to be degraded. Efforts to reduce conflict and forest loss through forest resource use agreements have mixed results. They generally do not sufficiently meet people's needs nor give them adequate ownership and are therefore often used as opportunities to access the forest for more destructive activities, as illustrated by field assessments in this study. The relationships among stakeholders on Mt Elgon are characterized by distrust.

Mt Elgon illustrates how forest transitions are embedded in social transformations and the importance of understanding these in order to drive social and therefore ecological change. For example on Mt Elgon, with its enormous population pressure and strong claims on forest resources, conservation managers may have to radically change their perceptions on forest conservation, and accept lower levels of forest intactness that balance longer term minimum conservation needs while meeting local needs for ecosystem services.

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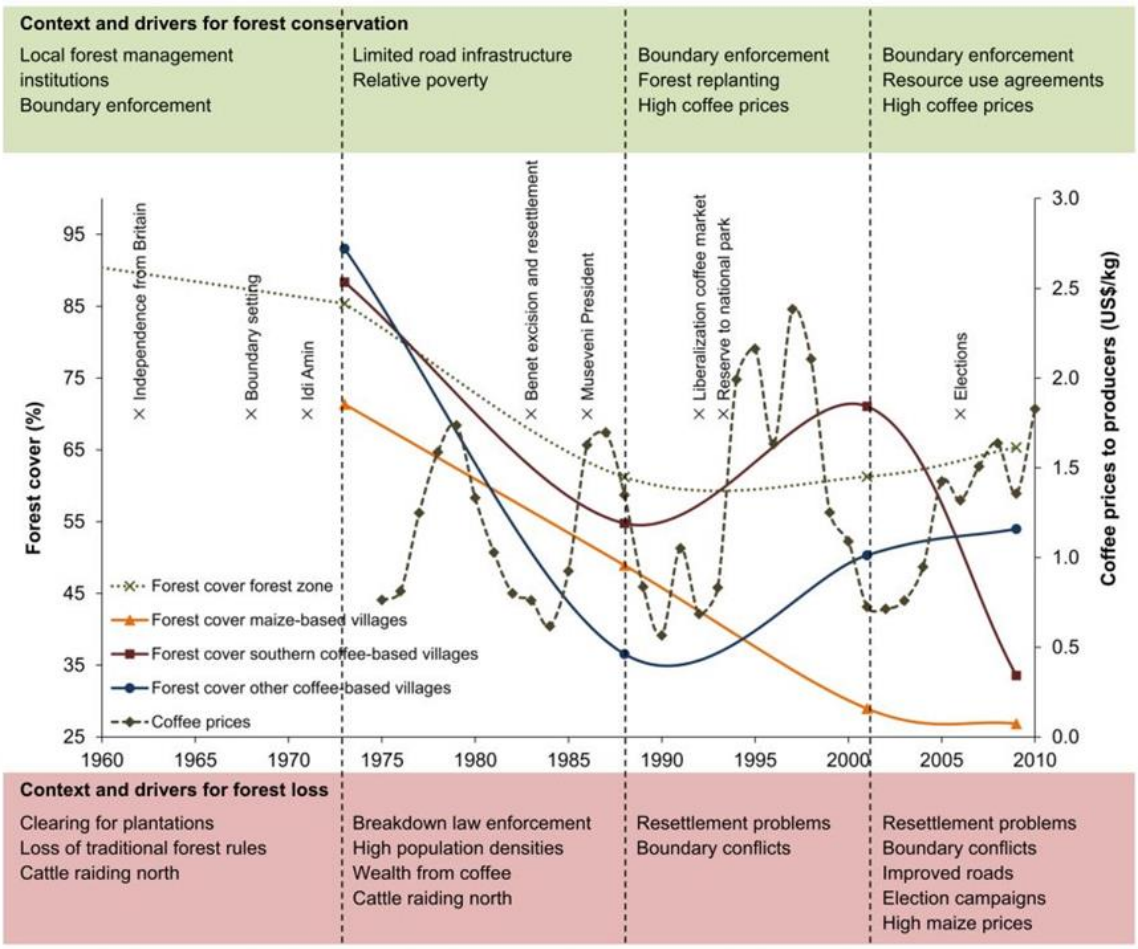

Figure B1: Forest cover change for the forest zone of Mt Elgon, Uganda (green dotted line). The split among different groups of villages (orange, red and blue curves) according to various socio-economic criteria and other contextual factors, helped to understand local variation in forest transition which contributed to the overall forest zone curve. Underlying drivers considered included amongst others prices and markets for major crops, national level politics, population, changing conservation policies (from Sassen et al 2013).