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# Forest transitions: a new conceptual scheme

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**Abstract.** "Forest transitions" have recently received much attention, particularly in the hope that the historical transitions from net deforestation to forest recovery documented in several temperate countries might be reproduced in tropical countries. The analysis of forest transitions, however, has struggled with questions of forest definition and has at times focussed purely on tree cover, irrespective of tree types (e.g. native forest or exotic plantations). Furthermore, it has paid little attention to how categories and definitions of forest are used to political effect or shape how forest change is viewed. In this paper, I propose a new heuristic model to address these lacunae, building on a conception of forests as distinct socio-ecological relationships between people, trees, and other actors that maintain and threaten the forest. The model draws on selected work in the forest transition, land change science, and critical social science literatures. It explicitly forces analysts to see forests as much more than a land cover statistic, particularly as it internalizes consideration of forest characteristics and the differential ways in which forests are produced and thought about. The new heuristic model distinguishes between four component forest transitions: transitions in quantitative forest cover (FT1); in characteristics like species composition or density (FT2); in the ecological, socio-economic, and political processes and relationships that constitute particular forests (FT3); and in forest ideologies, discourses, and stories (FT4). The four are interlinked; the third category emerges as the linchpin. An analysis of forest transformations requires attention to diverse social and ecological processes, to power-laden official categories and classifications, and to the discourses and tropes by which people interpret these changes. Diverse examples are used to illustrate the model components and highlight the utility of considering the four categories of forest transitions.

## 1 Introduction

The idea of nascent tropical forest transitions (FTs) has been one of the more exciting discoveries of recent decades. That some tropical countries are moving from forest loss to forest gain (as did many temperate industrial countries in the 19th and early 20th centuries) is thrilling and has provided much scope for investigation (for instance, Rudel, 2002; Perz and Skole, 2003; Rudel et al., 2005; Meyfroidt and Lambin, 2009; Hecht et al., 2014; de Jong et al., 2017), particularly given that the news is usually about tropical deforestation and the loss of valuable rainforests. I too have jumped on this bandwagon, writing about the forest transition (or potential ones) in places like in places like Costa Rica, Madagascar, and Vietnam (Cochard et al., 2017; Kull et al., 2007; McConnell et al., 2015).

However, the forest transitions literature is predisposed to focus on forest quantity (that is, on tree cover, as measured in hectares or square kilometres), with less attention to forest quality (that is, the characteristics of the forest). There are structural reasons for this. One reason is reliance on data from satellite imagery, which has an easier time distinguishing forest from non-forest than looking at change within forests. A second reason is that a focus on forest cover serves certain rhetorical interests of actors seeking to demonstrate that they are doing something about deforestation or to show an effort towards capturing carbon and offsetting industrial emissions. This has allegedly been the case for places like Vietnam and China, where some forest statistics emphasize forest quantity at the expense of forest quality (McElwee, 2016; Li et al., 2016; Mather, 2014; Lestrelin et al., 2013).

Of course, many forest transition studies responsibly present the caveat that measured changes in forest *cover*

(extent) do not reflect forest *characteristics* (biomass and species composition, for instance) (Meyfroidt and Lambin, 2008a; Lestrelin et al., 2013; Chazdon et al., 2016). For instance, in our work on highland Madagascar (e.g. McConnell et al., 2015), we clearly indicate that increased tree cover consists not of native forest but of exotic species. We then argue for the importance of these trees to people's livelihoods and for this to be seen as a forest transition. But on reflection we missed an opportunity to *redefine* what a "forest transition" is or could be. We could be seen as guilty of inflating a concept that tends to highlight quantitative change in forest cover over qualitative change in what is actually growing in the landscape.

In this paper, I seek inspiration from several fields of study (forest transition, land change science, critical social science) to create a new heuristic model that forces analysts to see forests as much more than a land cover statistic and internalizes consideration of forest characteristics and the differential ways in which forests are produced and thought about. I argue that it is productive to think of four different component forest transitions that together constitute a full understanding of forest change (Fig. 1). The first, FT1, is the traditional use of the concept: a shift from loss to gain in forest *cover*. The second, FT2, builds on the points raised by Chazdon et al. (2016) and many others: not all forests are equal. This component transition is about shifts, disruptions, and perturbations in forest characteristics or "quality" (which can be described both qualitatively and quantitatively). A transformation in forest quality is thus about species composition, fragmentation, structure, and so on. The third component type of forest transition, FT3, focuses on changes in the *processes* that constitute forests, or shifts in the uses, management regimes, policies, and biophysical enabling factors that make a forest. Finally, the fourth type of transition, FT4, is in the *ideas* of what is a forest, what should be a forest, and how a forest is represented and categorized. All four FTs are of course interlinked and come together in contingent ways to produce different instances of forest transition. The value of this approach is that, much more than just pointing to the lack of attention to forest quality in forest transition studies, it focuses attention on the ways in which different processes come together across scales to produce changes in tree cover, forest ecology, and ideas about these "forests" in particular places.

In order to build this argument, in Sect. 2 I first address some of the theories and concepts that lay the groundwork for this proposed new conceptual scheme. Specifically, I look at why it matters to look beyond forest cover in the study of forest transitions and review several alternative ways of conceiving of what a forest is. Then, in Sect. 3, I elaborate the new conceptual model (Fig. 1) and each of its components and inter-linkages, illustrating with examples. Finally, in Sect. 4 I review the implications and questions raised by such an approach, in particular the way in which it represents forest as an ecosocial phenomenon (rather than just as a land cover) and helps to think of transitions in a non-linear, contingent way.

## 2 Thinking about forests

The forest transition idea is simple, useful, and powerful: a turnaround from forest loss to forest gain, linked to broader societal, political, and economic processes. It was first proposed by Mather (1992), and initial studies documented "U-shaped curves" of forest cover correlated with economic development over recent centuries in European and North American contexts. The literature has since diversified immensely (see e.g. reviews in Perz, 2007; Mansfield et al., 2010; Barbier et al., 2010), with case studies on all continents in countries of different development levels, with meta-analyses, with critical attention to nuanced, context-specific drivers and multi-directional forest changes (Verburg et al., 2011; Munroe et al., 2004; Rudel et al., 2002), and with attention from other disciplines such as economics and sociology (Barbier et al., 2017; Perz and Skole, 2003). An important step forward from the initial theoretical model was the identification and description of a variety of different "pathways" leading to forest transitions, including land abandonment due to economic change, targeted forest policies responding to perceived scarcity or conservation needs, smallholder intensification, globalization (including in- and out-migration, remittances, and the circulation neo-liberal and conservation-oriented ideas), and the impacts of war and displacement (Rudel et al., 2005; Kull et al., 2007; Nagendra and Southworth, 2010; Lambin and Meyfroidt, 2010; Hecht et al., 2014). Important critiques have also emerged regarding the ways in which forest transition theory relies on problematic analogies with discredited modernization theories, the way in which it naively credits capitalist development with fostering re-greening, how it focuses too much at the national scale and misses cross-border processes, and that it applies universalized northern hemispheric historical explanations to ongoing short-term dynamics in tropical countries (Perz, 2007; Mansfield et al., 2010; Robbins and Fraser, 2003; Meyfroidt and Lambin, 2009).

The point of the present paper is to contribute to this literature and to enhance and nuance it through a new heuristic model that could be used to address these and other critiques. My entry is through a reconsideration of the object of study: forests and the processes that shape them. The argument is threefold. First, obviously, not all forests are the same, and the diversity that hides behind different forest categories matters: it carries power, it is mobilized to affirm (but also test) various interests, and it is made effective through policy and activism. Second, the above recognition needs to be expanded beyond diversity in biophysical forest categories (species composition, structure, successional state, and so on) to diversity in social–ecological terms. Forests differ in the actions and actors that shape them and the way we think

about them. These social–ecological processes also both constitute and produce forest categories that matter. Finally, one way to apprehend these complexities is to see forests as more than a collection of trees but as contingent, power-laden, dynamic relationships between an assemblage of diverse natural and human actors in particular geographic spaces and times. This latter argument draws inspiration from selected works in critical social science (Kull and Rangan, 2015; Mansfield et al., 2015; Rangan and Kull, 2009) and uses the vocabulary of assemblage theory. Like modern geographical conceptions of "place" (Mansfield et al., 2010), assemblage theory usefully draws attention away from organic, intrinsic wholes (like "forest") to the heterogeneous relations of diverse components that produce contingent outcomes, like different socio-ecological forests (DeLanda, 2006; Mansfield et al., 2015).

### 2.1 Not all "forests" are the same and this matters

Despite the apparent intuitive clarity of the term "forest", challenges emerge when one tries to define and measure forests more specifically. Land change science and related fields have grappled with the forest question in detail (Putz and Redford, 2010). For instance, Chazdon et al. (2016, p. 5) remark that "multiple concepts and definitions of forest now coexist, as they should". A unitary category of "forest" may in fact be getting in the way of more nuanced thinking about landscapes. Here I briefly review three main challenges to the idea of forests before arguing that, instead of necessarily seeking to fix them, it is important to engage with them as constitutive of a broader conception of forests and their transitions.

First, there are *spatio-temporal* challenges in delimiting and defining forests. These are the most familiar to cartographers and remote sensing analysts: where does one draw the line around a forest or what is the threshold to classify a pixel as forest? What is the density of trees, the height of bush, and the level of contiguity (Grainger, 2008)? The accurate documentation of deforestation in Madagascar, for instance, has long been dogged by inconsistent forest definitions (most notably, are mangroves included or not?) as well as by the challenges of comparing data across the years derived from different methods using these inconsistent definitions (McConnell and Kull, 2014).

Second, there are what might be called *ecological* challenges, in the sense that not all forests are composed of the same elements, or these elements may change over time. This is the need not only to identify forest presence/absence, or to distinguish between forest types, but also to judge forest characteristics, features, and quality. If a tropical rainforest is degraded by the selective extraction of all valuable rosewood species, or if the species richness of an endemic woodland is enhanced by invasive exotic pine species, there are clearly important qualitative transformations that should not be ignored.

Third, there are *categorical* challenges. People use diverse schemes to classify forest types as well as non-forests, producing all sorts of analytical challenges in terms of comparability, consistency, and blind spots. Problems may arise in, for example, deciding on criteria to separate adjacent and intermixed forest types or in how particular analytical tools or human factors shape the categories (Kull, 2013). Debate may also occur over the use of categories that are based on presumed "natural" forest types versus those including human-modified forest types (e.g. Ellis and Ramankutty, 2008). Problems also arise when *land cover* is confused with *land use*, as Chazdon et al. (2016) remind us. The former is a biophysical characterisation of what vegetation exists on the land; the latter is about human-directed goals for that land. An area classified as "forest" by a land manager or state may or may not have trees on it; it is more that the manager wants to (or has recently) used it as forestland for timber harvest or conservation or otherwise. The "political forests" of Peluso and Vandergeest (2001) are a case in point: lands that South East Asian governments declare as forest do not necessarily correspond with forest land cover; the goals of such declarations being more about economic, political, and social concerns than strictly land cover. Conversely, trees may grow in land uses not named forests, such as residential zones, gardens, and more.

These complexities are important *not* because they invalidate any consideration of forest change (they may or may not), but because they are *interesting in themselves* and can have impacts on ideas, perceptions, and actions that in turn affect forest use and management. The ways in which forests are measured, categorized, and conceived should be part of a broader concept of forest transitions, for they in turn affect the processes that shape forests and the forests themselves. Forest categories, and diversity that hides behind them, make a difference. They carry power, they are mobilized to affirm or contest various discourses, and they are implemented through policy and activism shaping real landscapes on the ground. For instance, Peluso and Vandergeest (2001) demonstrate how the colonial-era creation of the category of "forest" continues to shape how states imagine and govern land, resources, and people. The designation of state forests went beyond simple territorial claims for economic timber concessions or wildlife conservation, as it shaped the terms of debates about regional landscape futures, redefined people's lives and livelihoods, and institutionalized forest management as a powerful manifestation of state power. These conceptions of forest persist in post-colonial states across their study region of South East Asia and in turn continue to play a role in the processes that shape the biophysical forests.

### 2.2 Forests are produced differently, and this matters

Forests differ from each other and from non-forests not only in terms of biophysical categories (species composition, structure, successional state, and so on) or analytical cate-

gories (land cover, land use, political forests) but also in how they are "produced". Instead of looking at forests as a state, one might look at them as a collection of processes. Instead of defining a forest as a place with many trees, one could see a forest as a place where certain forms of biogeochemical cycles, plant growth and decay, human management, and other processes intersect. Forest *transitions* are then not just changes in numbers or locations of trees but also changes in this portfolio of processes.

To this effect, Mansfield et al. (2015) have contributed a novel and very useful conceptualization of how one might conceive of forests differently. To them, forests are "power-laden, negotiated relationships among various people, trees, understory plants, wildlife, hydrological conditions, and so forth" (Mansfield et al., 2015:285). Based on this conceptualization, they investigated the superficially undistinguishable forests of south-eastern Ohio and saw a number of different "socio-ecological forests that differed in terms of species composition, structure and function, and actions and actors (human and not) deemed necessary for the forest's persistence, as well as those deemed to threaten it" (p. 287). Following these criteria, they describe six different forests that differ relatively subtly in dominant species composition (all based largely on "natural" regeneration of native as well as alien species) but more substantially in ownership, legislation, economic usage, management strategies, and, notably, visions of what the forest is for.

The concept of forests by Mansfield et al. (2015) can be criticized for not articulating specifically how these "power-laden, negotiated relationships among various people, trees, understory plants [etc.]" function, except through selected brief examples. The concept also leaves wide open the modalities of its application. Its theoretical underpinnings are not addressed, though clearly there is a heritage of ideas from actor–network theory (Lave, 2015) or assemblage approaches (DeLanda, 2006) coloured by a healthy dose of political ecology. But the idea of redefining the concept of "forest" to include not only ecological components but also social ones; not only components and actors but also processes and interactions between them; and not only linear, functional, material relationships but also contingent, stochastic, and symbolic relationships is powerful in that it forces analysts to pay attention to these factors from the beginning, not as an afterthought.

Mansfield's concept of forests is useful in that it supplements material concerns with the ideas and visions that different people hold about the role of forests. The realm of ideas, values, and categories plays a non-negligible role in regional landscape transformations (Leach and Mearns, 1996). Haripriya Rangan and I have argued that regional landscape transformations are produced by the interaction of three types of moments of action (Kull and Rangan, 2015; Rangan and Kull, 2009). While the first, the "operational moment", focuses on empirical phenomena in nature and society (in the case of forest transitions, these could be forest clearance, tree colonisation, or land abandonment, measured in terms of tree cover or migration statistics, for instance), the second and third moments of action are – at least initially – in the non-material realm. The second is the "observational moment" and refers to formalized ways of categorizing, classifying, and measuring a phenomenon, undertaken by authorities like government bureaucracies or scientists with purposes of governance or maintaining order. Forest classifications, as problematic as they may be, represent particular sets of ideas, typically held by people in positions of power, which in turn have material impacts, as eminently showed by the Peluso and Vandergeest (2001) "political forests" concept. For instance, the observational moment goes a long way to explain the attitude of Indian state foresters to the spread of invasive mesquite in Rajastan. They welcomed the expansion of the thorny plant, despite local peoples' concerns, because increased tree cover of any kind was classified as meeting reforestation goals by Indian government metrics (Robbins, 2001).

The third type of constitutive action in our model is the "interpretive moment". This refers to the translation of phenomena into narratives, metaphors, or stories by different actors involved, giving meaning and value judgements to them. These emotive elements translate phenomena into feelings and values that suggest rights and wrongs and associated courses of action. They are political in that these ideas influence access to, control over, and the character of different kinds of resources. Activist "save the rainforest" campaigns are one obvious example; more complex ones might be the discourses that Mansfield et al. (2015) document for exurban forest owners in Ohio, mixing ideas of the bounty of forests and aesthetic and recreational benefits with social responsibility to maintain and enhance the forest, which lead to "a forest of elite appreciation and use" (p. 289).

Kull and Rangan (2015) suggest that to understand political ecologies of regional landscape transformations – in our case with respect to weeds, but the idea applies to forest transitions equally well – one needs to take account of these three moments and their interactions. We emphasize how the three moments intersect to make weeds into objects of contention. In the case of forest transitions, the lesson is that power-laden categories (the observational moment) and stories (the interpretive moment) play an important role in characterizing but also influencing and even constituting forest change. Integrating these moments into conceptualizations of forest transitions is important because, for instance, changes in forest quantity may conflict with forest quality (e.g. in the cases of plantations or invasive trees), and thus addressing such conflicts requires that scientists, policymakers, managers, and other actors integrate and engage with power-laden discourses and emotive stories. Investigating the observational and interpretive moments sheds light on the constellation of interests entangled in negotiations over forest change and draws attention to why (and to whom) different aspects of quantitative and qualitative change matter.

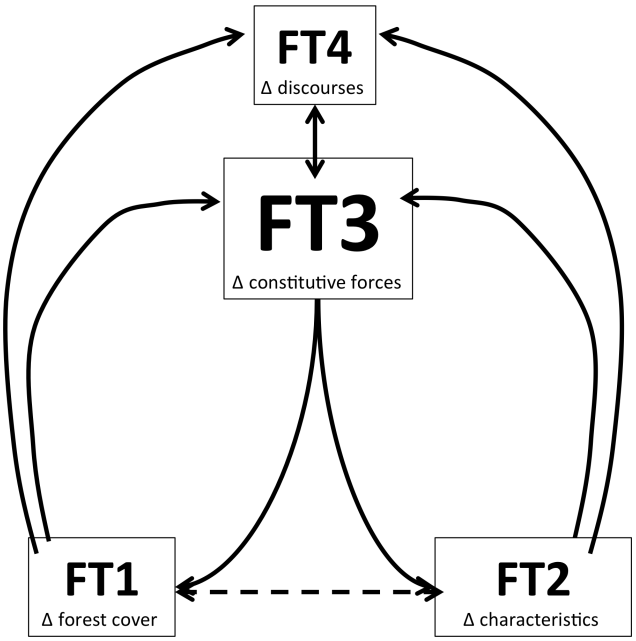


**Figure 1.** A new conceptual model of forest transitions (FT).

## 3 A proposed conceptual model

The new conceptual model of forest transitions proposed here (Fig. 1) seeks to incorporate and build on the above concerns. It seeks to explicitly broaden forest transitions beyond considerations of forest cover to address qualitative aspects of forest characteristics. But it does not stop there; in seeing forests as socio-ecological entities sensu Mansfield et al. (2015), it includes changes to the dynamic processes that shape forests as internal to the concept of forest transitions rather than as external causal factors. Furthermore, building on the insights from Kull and Rangan (2015), it also incorporates attention to the dynamics of the observational and interpretive registers – that is, to changing discourses and values.

In sum, the model suggests that instead of seeing forest transitions simply in terms of forest cover, one should see them as four interlinked types of shifts: changes in the spatial extent of forest cover (FT1); changes in the species composition, structure, and other ecological characteristics of the forest (FT2); changes in the constitutive processes that shape and maintain forests, from biogeochemical cycles and climate, seed dispersal, and herbivory to human exploitation, market demands, seeding and management efforts, and policy decisions (FT3); and, finally, changes in the discursive landscape as to how forests, their characteristics, and their processes are categorized, classified, labelled, valued, judged, and narrated (FT4). These four transitions are not separate and independent – the model describes their interlinkages and influences – nor are all four strictly requisite components of any single forest transition – changes in one component FT may or may not relate to strong changes in another. However, they often do, and this is the point: to push analysts to see these different components, to pay attention to them, and how they converge in particular times and places to produce forest transitions. This seeks to echo the suggestion of Mansfield et al. (2015) to see forests as complex relationships of meanings, human and natural actors, and processes and not just as a collection of trees.

While the model arises out of the forest transition literature, which investigates a specific type of forest change (from historic loss in forest cover to later long-term gain), the model can obviously handle a wider variety of types of changes. As researchers have noted, actual forest transitions are rarely as "clean" as the theoretical models of the U-shaped curve, including multi-directional change (Verburg et al., 2011; Munroe et al., 2004), local-scale complexities hidden by national trends (Rudel et al., 2002), regional variations (Cochard et al., 2017), and shifts in species composition or forest quality (Lamb et al., 2005). Below, I discuss each part of the model.

### 3.1 Transitions in forest cover and forest characteristics

The categories FT1 (forest cover) and FT2 (forest characteristics) require little explanation, as they have received plenty of attention. The former (FT1) is the key variable in the original idea of forest transitions, and today is largely assessed through remotely sensed data or government statistics of forest extent. It could, perhaps, more accurately be termed as a "forest-area transition" (Mather, 1992) or a "tree cover transition" (de Jong, 2010). The latter (FT2) focuses attention on a chief criticism of forest transition theory, that *quality* matters as much as *quantity*. Forest cover may remain unchanged and yet hide drastic dynamics in forest quality (species loss, invasion, impoverished trophic webs, replacement of natural forest with exotic plantations, etc.). For instance, forests in the Jura mountains tended to shift from hardwood dominance to softwood dominance for much of the 20th century (Eschmann et al., 2014). More broadly, a number of temperate American forest trees introduced for the forest industry – such as Douglas fir, black cherry, and black locust – have now become so widespread through plantations and invasion that they change the character of European forests (Krumm and Vítková, 2016). In Vietnam, gross forest cover statistics demonstrating a turnaround mask the fact that a deforestation of natural forest continues (albeit more slowly) and that the additional forest cover largely consists of mono-cropped plantations of exotic Australian acacias (Meyfroidt and Lambin, 2008b; McElwee, 2016; Cochard et al., 2017).

The dashed arrow between FT1 and FT2 represents the influences that one might have on the other. For instance, reduced forest cover may affect genetic diversity due to habitat fragmentation (FT1 →FT2) or the presence of a woody pioneer species may permit a forest to expand in area (FT2→FT1).

### 3.2 Transitions in forest-shaping processes

The category FT3 represents shifts in the material processes and relationships that shape, maintain, expand, decrease, or transform forests. This category is central to the model (Fig. 1), as it provides much of the "why and how" for understanding the resulting ecological and land cover outcomes. It could include a wide variety of shifts, for instance

- climate changes, such as lengthening of growing season or changed precipitation regime, which alters habitat suitability or competitive dynamics;
- the arrival of a "transformer species", an invasive non-native species that changes the nature of a substantial area of an ecosystem;
- a substantial policy change at a local, regional, or national level that changes the conditions for forest management and protection or a change in the implementation and enforcement of such policies;
- the arrival of a new actor, such as a forestry extension agency or development organisation promoting certain types of plantation and land management (de Jong, 2010);
- new or amplified market demand for a particular commodity or a collapse in such demand;
- changes in other land use arenas that affect forests, for instance grazing pressures from goats and sheep.

The cases of Ohio, Vietnam, and South Africa provide three unique examples of such shifts in constitutive processes. First, as described by Mansfield et al. (2015), the forests of south-eastern Ohio include several different coalitions of policies, people, property regimes, and economic activities that produce specific forest types; a FT3 would involve a substantial shift in those variables. The most pertinent process, mentioned across several forest types, is parcelization of forest property through exurban development. Second, in Vietnam, the turnaround in forest cover is very clearly related to some important large-scale shifts in the policy context, including the adoption of specific policies in the 1990s encouraging forest plantation, restricting deforestation, and permitting land tenure reforms devolving rights over woodlots to individual households (Meyfroidt and Lambin, 2008b; McElwee, 2016; Cochard et al., 2017), as well as cross-border market demand from China and displaced native hardwood exploitation in Laos (Meyfroidt and Lambin, 2009). Finally, in South Africa, the 1990s witnessed a raft of political and economic shifts that reshaped the conditions in which simultaneously useful and invasive Australian wattle trees grow in the country. In particular, post-Apartheid policies enshrined new approaches to scarce water resources, biodiversity protection, and poverty eradication that led to strict controls on continued commercial wattle plantations as well as major control efforts targeting invasive stands of wattles. The latter included rural job-creation weed-cutting programs as well as the release of biological control agents like insects and pathogens (Carruthers et al., 2011; van Wilgen et al., 2001).

Transitions in this category are central in explaining changes in tree cover (FT3→FT1) and forest characteristics (FT3→FT2). Indeed, classical forest transition theory is largely about linking FT3-style changes – like economic growth, rural-to-urban out-migration, land abandonment, conservation policies, or incentives for forest plantation activities – to forest cover outcomes (FT1) (Lambin and Meyfroidt, 2010; de Jong et al., 2017). It is not a major step from there to considering the effects of similar processes on the characteristics of forests (FT2).

As the model indicates, causality can also flow in the opposite direction (FT1→FT3; FT2→FT3). In the former case, an apocryphal example might be the impact of the total loss of forest on Easter Island on the resident population's agronomic system and livelihoods. More concretely, reduced forest cover might, for instance, lead to complex changes in precipitation and hydrologic regimes or to scarcity-caused increased market demand for wood products or wood fuel. In 17th century Europe certain forests were depleted, leading to state assertions of rights over those forests (Mather et al., 1999). An example of the latter case would be the impact of the near-extinction of a valuable species (or, alternatively, the rapid extension of a problematic invasive species) on forest policies and management actions.

### 3.3 Transitions in forest discourses and ideas

While FT3 addresses the material constitutive processes of forests, FT4 looks instead at changes in values, ideas, and meanings. While the two are often related it is worth separating them out in order to permit more focussed attention on what we called the observational and interpretive moments (Kull and Rangan, 2015). Shifts in how humans think about, talk about, and classify forests are important elements in explaining related changes in forest constitutive processes, in forest cover, and in forest characteristics. A quite simple example is the discursive shift that occurs when forests are talked about as "jungle" or as "rainforest". The former, a word inherited and altered from its Hindi origins, has come to denote a tropical humid forestlands overgrown to the point of hiding dangerous tigers or enemy soldiers and thus evoking fear or suffering, whereas the latter evokes a kind of ecological reverence for the biodiversity and hidden gems of such areas and the need to preserve them. The former needs to be tamed; the latter needs to be protected.

One kind of conceptual shift is a formal redefinition of categories, such as those made by governments and which have flow-on effects on management (Chazdon et al., 2016). As stated earlier, the ways in which forests are measured, categorized, and conceived affect the processes that shape forests

and the forests themselves. Forest categories carry power; they represent dominant world views or permit dissenting interpretations. When South East Asian states formally delimited areas as "forest", defined in a way that implied state control and gave power to a forest bureaucracy, it challenged the livelihoods of resident people and reshaped forest imaginaries, governance, and management (Peluso and Vandergeest, 2001). Different international, national, and scientific forest classifications vary in whether they consider oil palm orchards as forest (Chazdon et al., 2016); obviously such classification shifts can have a great influence on national policies seeking to profit from carbon markets and avoid blame for deforestation.

Less tangible are the conceptual, discursive shifts that change how forests and forest change are communicated in terms of normative or interpretive hierarchies. The jungle-rainforest shift mentioned above is one such shift, linked to intense advocacy campaigning on the subject of Amazonian deforestation in the 1980s. Historically, an important shift in Europe and America was that which originated in the 19th century Romantic movement in literature and art, which likewise signalled a broader cultural shift from seeing forests as a just a resource, as a reserve for agricultural expansion, or as a dangerous home to wolves to seeing forests as sublime, aesthetic, and representing a value in themselves. Decades of environmental education and awareness efforts by WWF and other NGOs in Madagascar have sought to bring about exactly this kind of a change in consciousness on the part of Malagasy decision makers and farmers (Ormsby, 2008).

Such shifts can be also seen as changes in overarching mindsets that condition the ways in which a society justifies certain interventions. This is particularly clear in terms of how non-native forest trees have been thought about in different regional and historical contexts. For instance, attitudes towards Australian acacias in receiving countries varied from ideas focussed on improving and enhancing the forest flora – particularly in drier, open landscapes like South Africa or Algeria – to a more economic ethos centred on industrial development and later to competing sets of ethos focussed on either livelihoods, aesthetics, or the threat to native species (Carruthers et al., 2011). Similarly, Starfinger et al. (2003) document how evolving perceptions of the value or disutility of black cherry in Germany motivated management strategies much more than any empirical evidence ever did. This is not to say that empirical evidence does not matter, but value-laden discourses set the bar for what evidence will be accepted (or not), what problem will be discussed (or not), and what evidence will be sought (or not).

New terms promoted by interest groups – whether civil society, governments, academics, or industry – are sometimes explicitly targeted to lead to discursive transformations. One might think of the rebranding of logging forests as "tree farms" (a publicity coup by the Weyerhaeuser Timber Company; Sharp, 1949) or the introduction of the idea of "novel ecosystems" or "emerging ecosystems" in order to normalize the idea and value of forests other than pristine, native ones, such as those with plenty of introduced species and a legacy of human intervention (e.g. Hobbs et al., 2013).

People come to care about categories and terminologies due to their ideological and material consequences. Current debates in conservation between those who promote a concentration of resources on core, intact, wild forests and those who promote the potentialities of anthropogenic forests are struggles over what forests are and which forests matter. This "land sparing/land sharing" debate has important implications for rural residents – the former model prioritizes formal state-led conservation territories and productivist (often larger-scale) agriculture, while the latter prioritizes rural smallholders and informal mixes (Dressler et al., 2016).

These shifts in values, definitions, and discourses are obviously related to shifts in the constitutive processes (that is, FT4→FT3). Shifts in categories or values lead to on-the-ground consequences as the values, definitions, or discourses are translated into policies, market demand, dispatch of actors to implement actions, and so on. For instance, broad-scale reconsiderations of the value of forests for wild species, hydrology, recreation, etc. played a major role in the conservation movement and its establishment of national parks and blocking of forest degradation. As mentioned above, management actions aimed at black cherry in German forestry interpreted and filtered empirical evidence through perceptions and values (Starfinger et al., 2003). More recently, as climate change and carbon markets began to overtake biodiversity conservation as global keywords in the 2000s, forests were reassessed in terms of their carbon sequestration capacity and policy instruments began focussing not just on protected areas and species protection but also on maintaining carbon stocks.

The direction of influence can also be reversed (FT3→FT4). Processes like species invasion, an economic boom, or transformed property institutions might lead to a change in discourses about forests. For instance, climate change and its impacts – such as more extreme events like droughts and floods and stronger cyclones – might be said to contribute to more concern for protecting forest areas as carbon sinks, hydrological sponges, or physical barriers to natural hazards. Likewise, discursive transitions may occur as a direct response to transitions in forest cover (FT1→FT4) or forest characteristics (FT2→FT4), for instance when drastic forest loss or transformation leads to a reconceptualization of forests or an awakening of forest concern.

## 4 Discussion and conclusion

What are the implications of adopting such a model of forest transition, one that internalizes changes in the constitutive processes, discourses, and values together with the more purely "ecologically" describable changes in forest cover and characteristics?

First, quite simply the model forces analysts to see forests as much more than a land cover statistic or remote sensing category to be counted. It avoids a superficial (beauty is just skin deep) version of forest transitions. More specifically, the model takes seriously the idea of forests as time-bound assemblages of diverse human and non-human actors and processes, and not just as mythical, eternal, rarely realized ideals of natural entities, and thus accords importance and attention to those actors and processes. In doing so, furthermore, it makes discourses, semantics, and politics part and parcel of what forests and forest transitions are. A different way to say this is that the model includes not only outcomes but also perceptions and processes. It forces attention not only on the "real" (like empirical measurements of tree cover or timber trade statistics) but also on conceptions and values (like shifts in what is considered to count as tree cover and how it is measured). In this way the model moves towards a critical realist philosophy that allows for alternating back and forth between empirical realities and the social processes that produce our understandings of those realities (Forsyth, 2003; Sayer, 2000).

A second important implication of the model is that it focuses on *changes causing changes*. The model (Fig. 1) is based on the relationships between transitions. In traditional "box and arrow" models, the boxes are reserved for states (or stocks) like forest cover, and the arrows are for the transitions (or flows). In a mathematical sense, we have moved from a model of first derivatives to second derivatives, where the arrows between the boxes are influences of one transition on another. This allows the model to focus on causative processes and their interrelations. This is somewhat akin to the ways in which systems ecology and related fields have focussed on "regime shifts" and particularly on the linkages between regime shifts across different scales or sub-systems or on "cascading" regime shifts (Kinzig et al., 2006; Leadley et al., 2014). This is useful because of the complex ways in which ecosystems, economies, societies, etc. are interlinked at multiple scales and across space and time. However, there are two differences here. One is that the model proposed here does not limit the kinds of changes and transformations of interest to those that are fast, major, and irreversible (which tend to be the key elements in definitions of regime shift). Second, because it deals with the discursive and conceptual realm, the present model needs to remain open to more contingency, relativity, stochastic noise, and interpretation than is normally the case in systems ecology (Kull et al., 2017).

Finally, this model cannot be plugged into a quantitative analysis or translated into uniform policy prescriptions to encourage forest transitions across the world. It can, however, inform research and policy. For example, in a recently initiated interdisciplinary research collaboration with Vietnamese colleagues about the forest transition in Thua Thien-Hue province, we emphasized the sustainability and quality of ongoing forest dynamics and incorporated subsidiary projects focussed on each of the four FTs. Likewise, a government forest agency could use the heuristic model to aid strategic reflection on the roles it plays in guiding forest change – such agencies are typically key actors in FT3 via policy and management decisions; they produce information on FT1 and FT2, and they play a role in the production of forest discourses (FT4). In both research and policy, it may be unrealistic to expect any individual to develop detailed analyses of the four FTs; however, through collaborations and interdisciplinary exchange, cross-fertilization is facilitated and a synthetic view can emerge. In sum, the model serves as a heuristic device to promote more integrative socio-ecological analyses, across the natural science–social science divide, of the diverse historical and current transformations occurring in forests, their characteristics, and how we think of them. It sees forests as not simply measurable by cover statistics or simply expandable or shrinkable by a tweak of a policy dial. Instead, it promotes an analytical view of forests as contingent, path-dependent entities shaped by a variety of actors (including humans and their associated interpretations and perceptions, as well as non-humans) and whose dynamics have cascading effects on each other.

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