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Raising the carbonized forest: Science and technologies of singularization

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Abstract

Recognizing the potential of forests to store carbon, various policies and programs have emerged to enhance this potential as a climate mitigation strategy. While the effectiveness of these policies is highly debated, there can be no doubt that they have profoundly affected how forests are conceptualized, valued, and governed. In this article, we discuss how science supports this increasing carbonization of forests not just by focusing knowledge production processes on carbon, but also by supporting policies and programs that aim to efficiently manage forests to optimize their carbon value. We situate this process in a longer history to show how science operates as technology of singularization that, guided by principles of optimization and efficiency, contributes to the depoliticization and normalization of specific versions of the forest that foreground singular priority values, while subsuming and marginalizing of other ways of knowing, valuing, and living with forests. Although emerging practices in techno-science, including the adoption of smart technologies and automated forms of data generation and analysis, can potentially enhance understanding of multiple forest values, we argue that they are likely to intensify singularization and create ever tighter relationships between knowledge production and forest management. We conclude by discussing the need to counter and refuse singularization.

Keywords

REDD+, climate change, forest governance, governmentality, science and technology studies

The carbonization of the forest

Forests have historically captured the imagination of environmentalists and policy makers as prime examples of pristine nature, inhabited by vast biodiversity and harboring a wealth of natural resources. For this reason, there is much emphasis on the diversity of forest values, interpretations, practices, and realities. However, the history of forests has shown that in different moments in time, locations, and

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social spheres, forest policies have given priority to the mobilization and exploitation of specific forest values. Currently, we see that in response to increasing attention to climate change, forests are recognized as an important climate mitigation strategy due to their potential to store carbon. As part of this recognition, several policies and programs have been launched to stimulate the planting of trees and the protection and restoration of forests. One of these is the global mechanism called REDD+,[1] a voluntary mechanism under the United Nations Framework Convention on Climate Change that is aimed at providing compensation to Global South actors to conserve or restore their forests. REDD+ initiatives can vary from national subsidy systems to market-based schemes that enable companies to offset their carbon emissions by paying for the planting of trees, or the protection or restoration of forests (Shapiro-Garza, 2013). REDD+ is an example of a wider development that conceptualizes nature in terms of ecosystem services and enables economic and transactional relations between those that exploit and destroy nature and those that protect it.

Non-governmental organizations (NGOs) and policy makers in climate and conservation domains have embraced REDD+ programs because they are seen as so-called triple win solutions. Promoting the role of forests as climate solutions, so the story goes, would attract new resources to the conservation, restoration, and expansion of forests and this effort will also benefit other forest values, including biodiversity, and the livelihoods of people that live in and off the forest. Despite its triple-win promises, results have been disappointing. One important reason is that REDD+ remains underfunded and the financial revenues that forest managers receive are not competitive with other more profitable types of land-use (Fletcher, 2023). Moreover, while some REDD+ projects have demonstrated local benefits, a large number of cases shows negative consequences, including the enclosure of forests and the displacement of local residents (Asiyanbi and Lund, 2020; Kansanga and Luginaah, 2019; Milne et al., 2019), and difficult tradeoffs with efforts to protect biodiversity (Phelps et al., 2012). While this is not the place to expand on this in detail, a clear picture is emerging that none of the presumed triple benefits of REDD+ have materialized at scale and that in some cases, the effects have even been negative. Also more generally, ecosystem services projects have yielded mixed results at best (Turnhout et al., 2021). Some local successes notwithstanding, it is evident that they have overwhelmingly not been able to affect ever-increasing rates of nature's destruction.

Despite this lack of evidence of effectiveness, one indisputable achievement of these policies and programs has been the carbonization of the forest; an increasing focus on carbon sequestration as the primary value that forests provide. This carbonization comes with important implications which are related to what Sultana (2022) has called climate coloniality. The global urgency of climate change is used to justify land grabs and enclosures in the Global South to enable continued carbon emissions in the North. This not only puts unjust burdens on local communities, but also fails to address the structural and more remote causes of climate change and deforestation, including large scale agriculture (Skutsch and Turnhout, 2020). Even more so, REDD+ facilitates the economic interests behind these causes by financializing forests (Fletcher et al., 2016) and by what Callon et al. (2002) have called singularization, referring to the practices through which economic actors (producers, consumers, marketing professionals, etc.) construct commodities as singular, discrete entities that can be bought and sold and that can be compared to other goods based on sets of common qualities. In the case of REDD+, singularization occurs by expressing avoided or negative carbon emissions in terms of the common metric of carbon dioxide equivalent (Layfield, 2013). This makes the carbon emissions of economic or societal activities equivalent with the carbon stored in forests (Lövbrand and Stripple, 2011). Subsequently, financial exchanges between those that emit and those that store carbon become possible, facilitated by the creation of a carbon market which attaches monetary value to this metric. In so doing, it becomes possible for economic actors in the Global North to continue carbon emissions and offset these emissions by buying carbon credits from REDD+ projects.

Science plays an important role in forest carbon policies and management strategies by enabling this commensuration and exchange. In parallel with the development of REDD+, major research efforts have been geared toward monitoring and measuring the carbon content of forests with a view toward being able to report and verify the results of forest carbon projects and allow for results-based carbon payments, trade, and offsetting to occur. These research efforts, in turn, serve to legitimize and expand forest carbon policies and interventions which further consolidate a focus on the carbon value of forests. The rise of the net zero discourse in the climate domain after the 2021 Glasgow convention provides an example of this. The concept of net zero implies that what matters is that the result of balancing emissions and storage of carbon is zero and it relies on so-called negative emission technologies, including the planting of trees and other vegetation, underground storage of carbon, or technologies that directly capture carbon dioxide from the air. Since Glasgow, many companies have made net zero pledges, and these pledges rely to a significant and unrealistic extent on negative emission technologies to compensate for the carbon that these companies plan to continue to emit (Dyke et al., 2021). This is how net zero is a red herring. Not only is it extremely implausible that negative emissions will ever be effective at the scale needed, the focus on negative emissions also distracts attention away from measures that focus on emission reductions (Carton et al., 2020; Low and Boettcher, 2020). Under net zero, forest management is narrowly conceptualized as a climate solution. But it is a stop-gap solution since it does not address the root causes of continued and accelerating climate change and it reproduces historical injustices and inequities.

Our discussion of the carbonization of the forest points to the risks of singling out specific forest values and developing policies and management strategies that aim to efficiently govern the forest in ways that optimize these priority values. The optimization of forests for carbon, and the technical, logistical, and governmental apparatuses employed to do so, have not just failed to halt the destruction of forests but also produced injustices and inequities, ignored the structural causes of forest loss, and undermined the plurality of social and ecological values of forests as commons (also see Osborne, 2015).

In this perspective article, we offer a critical discussion of the role of techno-science in these processes.[2] Our argument develops as follows. First, we draw on critical scholarship in geography and science and technology studies to develop a conceptualization of science as technology of singularization and underscore its key roles in creating the perfect and efficient forest that is optimized to produce specific priority forest values, and in perpetuating associated policies and management strategies. We will then zoom in on emerging smart digital forest technologies. While digital technologies are often heralded for their potential to contribute to diversity and empowerment, our discussion points to the risk that they will continue, or even intensify singularization. We conclude by discussing what would be needed to counter or resist singularization and enable a multiple forest, or, to paraphrase the well-known Zapatistas expression, a forest in which many forests fit.[3]

Science as technology of singularization

The contribution of science to forest policy and management has long historical—colonial—roots (Galudra and Sirait, 2009; Vinyeta, 2022). It has been foundational in the development of scientific forestry which originated in Germany in the late-18th century and spread to other countries and colonized territories during the 19th century (Agrawal, 2005; Scott, 1998). According to scientific forestry, the perfect forest is a forest that produces homogeneous, fast growing trees of similar age which makes harvest easy, cheap, and predictable. The failures of optimizing forests for timber production are perhaps best described in Scott's (1998) *Seeing like a State*. As Scott demonstrates, the main objective of forest management was to recreate forests so that they would match as closely as possible with the theoretical ideal of the *normal-baum*. As such, forest management provides an example of Latour's (1983) famous expression "give me a laboratory, and I will raise the world" (p. 141). But, forcing reality to live up to theoretical ideals comes with consequences (also see Van der Ploeg, 2002). Indeed, scholars have long pointed out the many paradoxes and limitations of scientific forestry (Hansen and Lund, 2017; Langston, 1996; Mathews, 2011). The ideal forest turned out to be dysfunctional; not only because it did not provide for the many other functions of forests, but also because it proved to be vulnerable to disease and storm damage, ultimately endangering the timber value it was created for.

As with forest carbon, scientific forestry offers another example of the risks of allowing a single-minded resource gaze to monopolize the conceptualization of forests. As Luke (1995) has cogently argued, "before technologies turn its matter and energy into products, nature already is transformed discursively into 'natural resources'" (p. 58). These scientific conceptualizations and associated policies and management practices are underpinned by a modernist worldview that sees nature as consisting of separate fungible objects that can be exploited without consequences or ethical problems; a worldview that Césaire (1972) has aptly called thingification. In this worldview, nature as thing or object is separated from the subject who, as Quijano (2007) explains is the "bearer of 'reason,' while the 'object,' is not only external to it, but different in nature. In fact, it is 'nature'" (pp. 172–173). This is the worldview that continues to underpin the exploitation of specific othered—or natured—humans, animals, and other life forms, whether under colonialism, capitalism, slavery, industrial animal production, or patriarchy (Merchant, 1980; Mies, 1986).

This also holds for conservation. Although conservation is often seen as the opposite of exploitation, they are in many ways mirror images. First of all, conservation cannot be understood without exploitation: early conservation efforts, which can be traced back to 17th-century colonial rule, particularly forest management and wildlife hunting regulation, aimed to protect the natural resources nature provides against overexploitation (Grove, 1995). Modern notions of conservation, which emerged in the late-19th century in elite circles, resulted from a confrontation with the consequences of the unfettered exploitation and destruction of nature through industrialization and urbanization. Second, conservation is built on the same thingified worldview that underlies exploitation. In this worldview, forests are cast as the ultimate wilderness; undisturbed by and separated from humans, with science tasked to measure, compare, and assess their biodiversity values (Turnhout and Purvis, 2020). This knowledge is subsequently used to inform policies and management strategies that aim to optimize biodiversity values. As with forest carbon, we see not just a focus on specific objects and values, but also a lack of effectiveness of conservation in halting biodiversity loss, and the reproduction of coloniality. Biodiversity science has justified the creation of protected areas in the Global South and, it is deeply implicated in the inequities and injustices that these protected areas have created (Kashwan et al., 2021; Massarella et al., 2021). Moreover, it has done this while keeping a blind eye to the actual root causes of destruction and failing to address the interests of the western, colonial and capitalist elites that founded the conservation movement, and that also fund it.

What we see, is that in these two examples, scientific knowledge serves extraction and exploitation. This holds for multiple forms of geological, chemical, biological, and ecological knowledges which have historically enabled particular life-forms or materials to be identified and enrolled as resources within economies of production and consumption, and which have facilitated the colonization and control of territories and populations to enable such forms of extraction (Byrd, 2011; Goldberg-Hiller and Silva, 2015; McKittrick, 2021; Sammler and Lynch, 2021; Seth, 2009; Yusoff, 2018). Science does this by producing knowledge that brings into being particular versions of reality that conform with specific priority values, and by enabling policy and management to efficiently control and extract these values. The implications of this extend beyond epistemology. To the extent that the values that are prioritized in these realities will end up in measurements and representations, phenomena will be forced to match epistemology rather than the other way around. Since this imposition never fully succeeds and contingencies, excesses, surprises, and spillovers are inevitable, policies that are based on these measurements and representations often fail, even against their own narrow standards of effectiveness, and create new problems (Kaika, 2017; Sadowski, 2024).

Despite such failures, knowledge production processes and associated policies become locked in and resistant to change. As science produces ever more and ever more precise knowledge about the forest in ways that fit with specific priority values, these versions of the forest will become naturalized, and the policies that derive from them will be increasingly seen as rational, and resistant to change (Turnhout, 2024). In such manner, science operates as technology of singularization. Our understanding of singularization shares with Callon et al. (2002) a focus on standardized metrics that enable exchange but calls attention to the specific role of science and technology and extends critical examination of the consequences of singularization beyond trade and markets to historical and current processes of domination, extraction, and exploitation of human and non-human life forms and territories. We use the notion of technology in a Foucauldian sense to underscore the performative and political implications of science and its function as a tool that mobilizes and results from power, reflects political rationalities and objectives, but is nevertheless primarily seen as apolitical (Dean, 2010; Foucault, 1977). According to Swyngedouw (2009), these developments reflect a broader post-political turn in which politics is "reduced to the administration and management of processes whose parameters are defined by consensual socio-scientific knowledges" (p. 609). Through technologies of singularization, forest management is rendered technical (Li, 2007) and is subjected to anti-politics (Ferguson, 1994) as struggles over forest realities, values, and futures become reduced to questions of measurement, calculability, and exchange.

Depoliticization is key to the continued reproduction of singularization. By promoting and creating depoliticized conceptualizations of what the forest is, its value, and its management, science is able to project seemingly neutral principles of efficiency, optimization, rationality, and objectivity, thereby foreclosing possibilities for political contestation. While knowledge about the diversity of forest values exists, depoliticization constrains the political potency of this knowledge. In the case of forests, for example, singularization has been effective in keeping the wider political-economic root causes of forest destruction out of sight as potentially more effective and legitimate objects of policy and management. Similarly, we have seen in the case of cities that knowledge systems constituted around digital data production and analysis have been highly effective at silencing traditional sites of political contestation by prefiguring acceptable forms of discourse and knowledge production about urban problems (Klauser et al., 2014; Vanolo, 2014). The efficient measurement and visualization of urban problems (pollution, traffic congestion, sanitation, etc.) helps create markets for new kinds of interventions while drawing attention away from systemic causes or the diverse experiences and perceptions of differently-situated urban residents.

In the next section, we consider the emergence of smart digital forest systems and their relation to singularization. Activists and scholars have long noted that broader forms of knowledge exist beyond dominant science and global governance schemes (i.e. Chao and Enari, 2021). This suggests that there is potential to diversify forest knowledge production by allowing a broader range of actors the opportunity to produce and communicate knowledge about forests in new forms. Yet, the question is to what extent smart digital forest systems can effectively be mobilized to counteract singularization. It is to this question that we turn below.

The smartification of the forest

The notion of smart has become popular in the context of performance management and suggests that effective individuals and organizations set targets that are specific, measurable, achievable, realistic, and timely (Wood, 2011). Measurement is an indispensable component of smart logics since the measurement of performance in achieving targets equips managers with knowledge that enables continued control, optimization, and efficiency (Turnhout et al., 2015). Reflecting on the implementation of REDD+, Osborne (2015) highlights how carbon "must be extracted from its supporting context through techniques of measurement, calculation, and monitoring" (p. 67) in order to be optimized and integrated into carbon markets or other forms of carbon forestry management. Technologies of singularization, including but not limited to emerging smart digital technologies, thus, help forest management practices to become SMART; capable of producing and using scientific data and expertise to ensure the efficiency of forests in producing those values that matter according to stated priorities.

Smart forest systems for measuring and monitoring build on existing practices that use satellite-based remote sensing, aerial lidar, photography and similar techniques that are used to monitor changes in forests or conduct forest carbon inventories (Stephens et al., 2012). However, these forms of knowledge production come with certain limitations, which present challenges to the smooth integration of forest carbon as an object of management, governance, or commodification. Remote sensing techniques for large areas typically offered imagery only at very coarse resolutions, while techniques capable of finer resolutions were very costly and were thus only deployed at small scales and at infrequent temporal intervals. The long-term evolution of environmental remote sensing techniques has generally focused on improving spatial and temporal resolution to enable more frequent and more fine-grained data about forests and other environments (Boyd and Danson, 2005; Lechner et al., 2020).

New smart digital systems aim to overcome these limitations. Smart forest systems make use of new techniques enabled by digitalization, including low-cost drones equipped with LiDAR, new Internet of Things (IoT) sensors, and apps and platforms for crowdsourcing data, among other tools, to produce new kinds of data about forests (Adams, 2019; Gabrys, 2020). These techniques drastically increase the amount, resolution, and frequency of data, including potentially real-time data at the scale of individual trees. These practices mirror experiences of smartification in other realms, such as the smart city or smart home, in which specific processes or actors increasingly become the identified as discretized objects for observation, datafication, optimization, automation, and regulation (Gabrys, 2020).

Among the various use cases for smart forest technology, researchers, and forest managers hope to collect fine-resolution data about the carbon storage of forests and even individual trees. A representative from Vodafone's Smart Forest initiative makes the goal of singularization explicit, stating, "The project will also help us to gather *more data*, which is critical to targeting efforts to measure the contribution of *individual trees* to climate change."[4] Beyond highlighting the goal of singularization, this statement demonstrates a key point in the smartification of various spaces and forms of governance. As the spatial and temporal resolution of forest data is refined toward increasingly granular level (the real-time monitoring of individual trees as an end goal if not an immediate practice), the quantity of data grows exponentially. This sheer amount of data requires new forms of automated data analysis and modeling, including the use of computer algorithms of various sorts to identify patterns, predict future changes, and detect anomalies—creating what Adams (2019) calls "conservation by algorithm." Furthermore, as Goldstein (2022) points out in her work on a REDD+ project in Indonesia, the increasing quantity of data "can initiate a self-reinforcing feedback loop in which the drive for more data leads to more uncertainty, which in turn spurs the pursuit of more data in lieu of action, stymying other forms of project implementation" (p. 2).

In their reflection on smart systems in tropical forest conservation in Kibale National Park in Uganda, Sarkar and Chapman (2021) explain that

> Sensors are efficient at monitoring what they are designed to sense, but they may not provide needed context. For example, drones can monitor if canopy trees flower and fruit, but they will not record when small seeds are aborted. Someone collecting data from under a tree will note such events. Similarly, by using camera traps one could document a population decline in a species, but not be able to document the cause. If the cause was a disease outbreak, a person monitoring tracking stations would smell the rotting carcasses and likely identify the cause. (p. 3)

As with knowledge production more generally, data collection and analysis come with implications for what the objects of knowledge are made to become. As Amoore and Piotukh (2015) explain, "data analytics are instruments of perception: they carve out images; reduce heterogeneous objects to a homogeneous space; and stitch together qualitatively different things such that attributes can be rendered quantifiable" (p. 344). In other words, the act of big data generation and analysis "inscribes the very perception of the world in which we live, govern and are governed" (Amoore and Piotukh, 2015). The data produced by digital sensors and the conclusions drawn through algorithmic analysis become the "truth" of the forest for the sake of forest governance. This truth of the forest is made up of ever smaller units, drawing attention to *singular* aspects of a phenomenon. Analytical focus in smart city systems, for instance, may shift attention from the city as a complex whole to increasingly narrowly defined systems or spaces therein, attempting to isolate an object of governance from its broader entanglements and socio-material context and reduce that object to a single (or small number of) key indicator(s). Similarly, in the case explored by Sarkar and Chapman (2021), they find that the forms of data capture and the consequent forms of decision-making enabled by smart systems potentially constrain the ways forests are known and governed by separating data from the context of its production. Amoore and Piotukh (2015) describe this phenomenon as big data leading to increasingly "little analytics." In the case of the smart forest, we can see how increasingly large data sets about increasingly granular characteristics of a forest allow zooming in on individual trees, and the carbon content of trees, which then become the objects of automated data generation and analysis, policies, or the creation of new markets. While the decontextualization of data is not in itself new, the scale, quantity, speed, and variety of digital data allow this to happen with unprecedented intensity. Meanwhile the modes of data collection themselves enact changes in who is involved in such processes and thus what kinds of knowledge might be available to help contextualize the data. Millner et al. (2024), for instance, highlight the rise of "drone outsourcing." As small NGOs and community organizations lack the time, expertise, or resources needed to carry out drone monitoring, they increasingly contract large international NGOs or private firms to conduct this monitoring for them.

Sarkar and Chapman (2021) further highlight how smart forest systems introduce new actors into forest conservation efforts, namely tech corporations that stand to profit, explaining: "Driven by the extraction imperative, the smart forests also represent a hitherto untapped data domain" (p. 4). The involvement of these corporations and the technologies they market exacerbate austerity measures and shift responsibility for the production of conservation knowledge—while also prefiguring the form that this knowledge should take. Problematically, the outsourcing and automation of these activities to third-party firms "undercuts the aims of poverty alleviation and involvement of local communities in conservation and may exacerbate marginalization" (Sarkar and Chapman, 2021: 4). As the authors point out, in contexts like Uganda, it is likely both more cost-efficient and more socially and politically desirable to contract human conservation workers for environmental data collection—a modality of data collection that could also potentially produce more contextual data.

Smart monitoring, big data, and data analytics focusing on carbon, coupled with the financial incentives of REDD+ and the business interests and logics of digital tech corporations produce a governmental apparatus through which a specific form of global forest/climate governance becomes actionable. By turning the forest into individual trees, and individual trees into carbon sequestration machines, the focus is put on specific forested localities. This enables policies that allow responsibility and blame to be assigned to the local and individual scale, to individual actors, communities, and forest managers, even when their contribution to deforestation or their ability to halt deforestation is inevitably limited (Skutsch and Turnhout, 2020). While this outcome is not pre-determined by the technology itself, the kinds of data produced call attention to specific local sites and activities of concern, rather than to the broader drivers of those activities. This is seen repeatedly in the emerging scholarship on digital conservation. Drawing on case studies from Guatemala, Borneo, and India, Millner et al.'s (2024) show "how drones can act within state forests to discipline and control subjects, contributing toward securitisation processes or even functioning as a technology of fear" (p. 33). For instance, in the case study in India, drone surveillance was used to deter illegal access to protected forests, while activities such as "the collection of minor forest produce, such as fodder grass and firewood, are legally permitted in the buffer zones." The authors found that marginalized groups from "scheduled tribes or scheduled castes" were more likely to be subject to such surveillance. Ritts et al. (2024) highlight similar dynamics in their study of digital acoustic monitoring, which, they argue, implements new forms of environmentality and spatial power in the territories where they are deployed. By surveilling and policing the boundaries and permitted uses of forest resources, practices of drone monitoring and digital acoustic monitoring help reinforce ideas about where forest destruction originates and who is potentially responsible. Smart digital forest systems, at least as they are deployed in mainstream conservation efforts, are thus likely to result in not just a continuation but also an intensification of the processes of singularization discussed in the previous sections, driven by the optimization of a single value and managed by powerful and remote political and economic interests.

This is a clear example of what Robbins (2019 [2011]: 13) terms apolitical ecology as opposed to political ecology, in that it "blames proximate and local forces" rather than "identifying broader systems" that drive deforestation and climate change. Political ecologists have long explored how colonial management and political economic forces, rather than localized actions and behaviors in isolation, are systemic drivers of environmental destruction (Grossman, 1997; Rasul, 2007). Many of the technologies discussed here call increased attention specifically to "local forces" or help pinpoint specific sites or actors as threats, but do not help elucidate the broader systems in which those sites and actors are entangled. Yet, by locating blame locally, the proposed solution to environmental destruction in specific places is often to further incorporate these territories and populations into those neo/colonial governance relations or global market forces that also drive forest destruction. Such forms of knowledge, then, enable and justify neo/colonial and paternalistic governance interventions directed at local populations who, under these logics, are deemed incapable of governing themselves and their own resources. It is in this way that smartification not just fits well with, but also continues to strengthen the post-political condition in climate and environmental governance. Moreover, the amount of data and analysis further consolidates epistemological lock-in so that what is important about forests in knowledge and policy will increasingly be defined in terms of carbon. While data may be shared and used by diverse actors, the carbon lock-in restricts the kinds of data that are produced and used and the kinds of policy options that become possible to implement, deliberate, or oppose, thereby placing radical alternative forests out of sight.

This is not to claim that digital conservation technologies are adopted uncritically by all users. For instance, in their work on digital conservation in Myanmar, Goldstein and Faxon (2022) show how

> rather than assume more data are desirable for all actors . . . actors selectively and strategically engage new platforms and tools based on different understandings of the role of increased data transparency in environmental governance that are based on their relations with and within the legacy of the surveillance state. (p. 42)

This is also not to claim that other forest values and knowledges do not exist or could not be pursued through digital systems. It has been suggested that digitalization can contribute to accountability and even the redistribution of power or resistance because it can enable diverse actors to collect data, for instance, about illegal poaching or logging (Zhang and Da Silva, 2023). Paneque-Gálvez et al. (2017) and Millner (2020) show the potential of low-cost drone use on the part of Indigenous communities to facilitate new forms of local control over environmental monitoring and management and support contestation of formal forest knowledge. As Paneque-Gálvez et al. (2017) argue,

> drone imagery creates new territorial representations, and therefore knowledge, that add up to the spatial knowledge that indigenous peoples possess about their territory. The implications of this new knowledge and the "right to look" of traditionally marginalized peoples are potentially far-reaching. (p. 15)

While this suggests that smart digital technologies can potentially complicate singular approaches to forest values and create knowledge about alternative forest values, it is clear that realizing this potential is not self-evident. The proliferation of new technologies for data collection and processing will not in itself be sufficient to disrupt the locked in process of ongoing singularization driven by measurement, efficiency, and optimization. One reason is that few participatory or community-based approaches to digital monitoring have critically addressed the logics of digitality itself (Franklin, 2015), which involves the slicing up of forests into discreet units of data, known as dividuals (D'Amato, 2019; Han, 2015) and which informs the systems of management and control that these dividuals are slotted into. Consequently, smart digital systems are easily coopted into dominant policy and knowledge production practices, unless they are accompanied by explicit strategies for participation and policy engagement and advocacy (McCall and Dunn, 2012). As Paneque-Gálvez et al. (2017) point out, challenging and disrupting singularization will have to involve broader struggles about who has the "right to look," whose knowledge is valued, and what forests result from this. We reflect on this question further in the final section.

A forest of many forests

The argument of this article has been that science has historically acted and continues to act as technologies of singularization that work to consolidate and strengthen specific versions of the forest that are represented through priority values, specifically carbon. Through science, the carbonized forest continues to be raised as a depoliticized object of knowledge production and governance, resulting in policies that reproduce injustices and inequities while failing to halt deforestation or climate change. In view of their capacity to generate and analyze large amounts of data, digital technologies are often seen as powerful tools to diversify knowledge and raise awareness about under-represented issues, including the multiple dimensions and values of forests. However, attempts to critically and creatively appropriate digital technologies for these purposes have been constrained, both by the logics of digitality itself and by the broader political economic relations and interests involved in mainstream digital development (Andrejevic, 2019; Lynch, 2020). This means that smart forest systems are likely to reproduce locked in practices and associated power relations and even strengthen and intensify them, not only through the amount of data they produce, but also by projecting a fresh veneer of scientific objectivity through claims of being smart or data-driven.

What we conclude from this is that effectively raising alternative forests requires the explicit challenging of singularization and the postpolitical governance regime it enables. It requires the politicization of the question of what the forest is and critical interrogation of what knowledges of the forest are rendered relevant, what knowledges are excluded, and with what consequences. Although it remains an open question whether these expectations are realistic—after all, can the master's tools ever dismantle the master's house? (Lorde, 1983)—this will require forest knowledge practices, and science more generally, to refuse values of control, efficiency, and optimization and replace them with values of emancipation, justice, and pluralism. In this effort, we think alongside theorizations of Indigenous politics of refusal (Simpson, 2007). This might mean "saying no to the institutional demand for more knowledge" and/or refusing the disciplining and certainty of colonial knowledge regimes while embracing an "anticolonial stance of humility" (Rivera, 2023: 305–306). In a similar way, Singh (2017) articulates this question of humility as a refusal of mastery, arguing that

> while the rhetoric and activism of decolonialism have decried mastery in its expressly colonial form, they have failed to account for the ways that mastery has continued to propagate in other, but critically related, forms and practices of both political and mundane life. (pp. 150–151)

In identifying the desire for mastery as core to coloniality, Singh's project works toward "unthinking mastery." Along these lines, an anti-colonial knowledge politics must, therefore, account for the desire for mastery in practices of knowledge production and promote forms of knowledge that explicitly resist this desire but rather promote "practices of accountability and restitution" (Rivera, 2023: 306). Reflecting on the singularization of forests and the practices and infrastructures that have historically (re)produced them, we might think through anti-colonial knowledge politics – a politics that is based in humility and reciprocity, as well as in struggle and refusal, and that supports the dynamic emergence of a forest in which many forests can flourish.

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Notes

1. REDD+ stands for Reducing Emissions from Deforestation and forest Degradation in developing countries.
2. We acknowledge our positionality, and complicity, as critical scholars based at a technical university in The Netherlands where we witness and engage with natural and technical scientists that contribute to the processes that we discuss.
3. The original expression "un mundo donde quepan muchos mundos" (a world in which many worlds fit) is part of the fourth declaration of the Lacandona Jungle by the Zapatistas movement.
4. Retrieved 7 July 2023 from https://www.vodafone.co.uk/newscentre/press-release/defra-and-forest-research-safeguard-uk-forests-tackle-climate-change-iot/ (italics added).

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