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Ways of Seeing in Environmental Law: How Deforestation Became an Object of Climate Governance

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Ways of Seeing in Environmental Law: How Deforestation Became an Object of Climate Governance

William Boyd*

Few areas of law are as deeply implicated with science and technology as environmental law, yet we have only a cursory understanding of how science and technology shape the field. Environmental law, it seems, has lost sight of the constitutive role that science and technology play in fashioning the problems that it targets for regulation. Too often, the study and practice of environmental law and governance take the object of governance—be it climate change, water pollution, biodiversity, or deforestation—as self-evident, natural, and fully-formed without recognizing the significant scientific and technological investments that go into making such objects and the manner in which such investments shape the possibilities for response. This Article seeks to broaden environmental law’s field of vision, replacing the tendency to naturalize environmental problems with an exploration of how particular scientific and technological knowledge practices make environmental problems into coherent objects of governance. Such knowledge practices, or ways of seeing, are instrumental in shaping regulatory possibilities and must be interrogated directly as key constituents of particular forms of governance. The

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argument is developed through a case study of how tropical deforestation, which accounts for some 15 percent of global carbon dioxide emissions but which was expressly excluded from the Kyoto Protocol, has recently become a viable object of climate governance, demonstrating the fundamental importance of conceptual advances in carbon cycle research, the synoptic view of global land cover change made possible by remote sensing, and new carbon accounting techniques in rendering the problem comprehensible for climate policy. Building on the case study, this Article identifies and elaborates on three general ways of seeing—kind-making, calculability, and equivalence—that operate through particular scientific and technical practices to shape and inform the substance of environmental law, with specific attention to the implications of the overall approach for a comprehensive theory of the field.

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INTRODUCTION

Tropical deforestation has emerged in recent years as an important object of global climate governance, representing a significant departure from past efforts to deal with the problem. Indeed, despite the fact that both tropical deforestation and climate change have been prominent concerns in international environmental policy for almost two decades,

until recently they have been treated largely as separate and distinct, with only limited attention to deforestation's role in climate change.¹ Previous international efforts to halt tropical deforestation have focused instead on biodiversity loss, unsustainable consumption practices, and various legal and institutional shortcomings in tropical forest countries (to name a few), with minimal results in reducing deforestation on any significant scale.² Likewise, the international climate regime expressly excluded emissions from tropical deforestation from the Kyoto Protocol's first commitment period (2008–12),³ creating an immense gap in international climate policy given that tropical deforestation accounts for some 15 percent of global anthropogenic carbon dioxide (CO₂) emissions.⁴

Over the last several years, however, there has been a concerted effort to incorporate emissions from deforestation in climate governance at multiple levels and a growing realization that climate policy may represent the last chance to save tropical forests on any significant scale. Traveling most often under the somewhat cumbersome moniker of

1. See *infra* Parts II.C and III.

2. This is evidenced by the simple fact that deforestation continues virtually unabated at some thirteen million hectares per year. See FOOD & AGRIC. ORG. OF THE UN, GLOBAL FOREST RESOURCES ASSESSMENT 2005: PROGRESS TOWARDS SUSTAINABLE FOREST MANAGEMENT 19 (2005) [hereinafter 2005 FOREST RESOURCE ASSESSMENT] (reporting gross average annual deforestation of 12.9 million hectares per year during 2000–2005).

3. See UN Framework Convention on Climate Change [UNFCCC], *Decision 11/CP.7: Land Use, Land-Use Change, and Forestry*, U.N. Doc. FCCC/CP/2001/13/ Add.1, 60 (Jan. 21, 2002) [hereinafter UNFCCC Land Use] (excluding avoided deforestation activities from the Clean Development Mechanism).

4. The most recent estimates of emissions from forest loss put the contribution of emissions from deforestation, forest degradation, and destruction of peatlands at about 15 percent of total anthropogenic CO₂ emissions. See G.R. van der Werf et al., *CO₂ Emissions from Forest Loss*, 2 NATURE GEOSCIENCE 737, 738 (2009). This represents a decrease from earlier estimates for the 1990s, which estimated that emissions from deforestation accounted for some 20 percent of anthropogenic greenhouse gas emissions. See INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE [IPCC], CLIMATE CHANGE 2007: MITIGATION OF CLIMATE CHANGE: WORKING GROUP III CONTRIBUTION TO THE FOURTH ASSESSMENT REPORT 543 (2007) [hereinafter IPCC WG III REPORT] (reporting that emissions from deforestation in the 1990s were 5.8 billion metric tons (5.8 Gigatonnes or Gt) of CO₂ per year, which is approximately 1.6 Gt of carbon per year); Raymond Gullison et al., *Tropical Forests and Climate Policy*, 316 SCIENCE 985, 985 (2007) (noting that “[t]ropical deforestation released ~1.5 billion metric tons of carbon to the atmosphere annually throughout the 1990s accounting for almost 20 percent of anthropogenic greenhouse gas emissions”). Part of the explanation is that the overall contribution of emissions from deforestation has declined as fossil fuel emissions have continued to grow and deforestation has decreased slightly. See Corinne Le Quéré et al., *Trends in the Sources and Sinks of Carbon Dioxide*, 2 NATURE GEOSCIENCE 831, 832 (2009) (“The relative contribution of LUC [Land Use Change] CO₂ emissions to total anthropogenic CO₂ emissions decreased from 20 percent in 1990–2000 to 12 percent in 2008 owing to increasing fossil fuel emissions and below-average deforestation emissions in 2008.”). Le Quéré et al. attribute the below-average LUC emissions for 2008 (declining from 1.5 billion metric tons of carbon per year to 1.2 billion metric tons) to wet La Niña conditions that “probably limited fire and deforestation rates in southeast Asia, particularly in Indonesia” and the continuation of a decline in deforestation in the Brazilian Amazon. *Id.*

Reducing Emissions from Deforestation and Forest Degradation (REDD), these efforts have effectively reframed the issue from one focused on forests as carbon *sinks*—the dominant framing during the Kyoto Protocol discussions—to one focused on the forest sector as a *source* of emissions, thereby putting the problem in the same regulatory lexicon as fossil fuel emissions and smoothing the way for an integration into climate policy.⁵ The result of these efforts is apparent in the considerable traction that the issue has garnered in the international negotiations regarding a post-2012 climate treaty, in the design of greenhouse gas (GHG) compliance systems in the United States and elsewhere, and in efforts to reorient forest law and governance in key tropical forest countries.⁶

There are multiple explanations for this shift—political, institutional, scientific, and technological—and there is no shortage of persuasive arguments in favor of including deforestation as part of climate protection. Indeed, the larger story of how deforestation is being incorporated into global climate governance, and how this is in turn driving significant changes in laws governing forests and land use throughout the tropics, illustrates the emergence of what could be described as an attempt at “earth systems governance”⁷ and, more

5. See Kyoto Protocol to the UNFCCC art. 3(3), Dec. 10, 1997, U.N. Doc. FCCC/CP/197/L.7/Add.1, 2303 U.N.T.S. 148 [hereinafter Kyoto Protocol] (discussing treatment of forests in accounting for commitments of Annex I Parties); UNFCC Land Use, *supra* note 3, at 60 (restricting forestry activities under the Clean Development Mechanism during the first Kyoto commitment period to afforestation and reforestation). The term REDD was first used in 2005 in a submission at the Montreal UN Framework Convention on Climate Change Conference of the Parties meeting. At the time, the term referred to “Reducing Emissions from Deforestation in Developing Countries.” See UNFCC, SUBMISSION BY THE GOVERNMENTS OF PAPUA NEW GUINEA & COSTA RICA, REDUCING EMISSIONS FROM DEFORESTATION IN DEVELOPING COUNTRIES: APPROACHES TO SIMULATE ACTION (2005) [hereinafter SUBMISSION BY PAPUA NEW GUINEA & COSTA RICA], available at <http://unfccc.int/resource/docs/2005/cop11/eng/misc01.pdf>. Although this terminology is still employed, in recent years REDD has also come to stand for Reducing Emissions from Deforestation and Forest Degradation. See UNFCCC, *Decision 1/CP.13: Bali Action Plan*, U.N. Doc. FCCC/CP/2007/6/Add.1* (Dec. 3, 2007) [hereinafter UNFCCC, *Bali Action Plan*] (calling for “[p]olicy approaches and positive incentives on issues relating to reducing emissions from deforestation and forest degradation in developing countries”); see also *infra* Parts III.B and III.C.

6. See *infra* Part III.C; see also William Boyd, *Deforestation and Emerging Greenhouse Gas Compliance Regimes: Toward a Global Environmental Law of Forests, Carbon, and Climate Governance*, in *DEFORESTATION AND CLIMATE CHANGE: REDUCING CARBON EMISSIONS FROM DEFORESTATION AND FOREST DEGRADATION* (Valentina Bosetti & Ruben Lubowski eds., 2010) (discussing efforts to integrate REDD into climate policy at multiple levels).

7. See, e.g., Frank Biermann & Philip Pattberg, *Global Environmental Governance: Taking Stock, Moving Forward*, 33 ANN. REV. OF ENV'T. & RESOURCES 277, 288 (2008) (describing earth system governance as an effort to expand global environmental governance to take account of the “the ongoing transformation of the entire earth system, from global warming, large scale changes in biogeochemical cycles, to unprecedented rates of species loss”); Eva Lovbrand, Johannes Striiple & Bo Wiman, *Earth System Governmentality: Reflections on*

importantly, what Professors Tseming Yang and Robert Percival describe as “global environmental law.”⁸

As this Article argues, however, a fundamental part of the story involves the cultivation and deployment of a new way of *seeing* the problem of deforestation—that is, a new way of constructing the problem as part of a larger effort to manage the global carbon cycle embodied in particular practices of post-World War II earth systems science, significant advances in satellite-based remote sensing of global land cover change, and the development of legal and accounting frameworks for translating forest carbon into compliance carbon. There is, in short, an important epistemological explanation for how deforestation has become an object of global climate governance, an explanation that merits exploration independent of the larger institutional story.

The premise of this Article, then, is that isolating the epistemological part of the story brings into focus a foundational element of environmental law and governance that is largely neglected in traditional legal scholarship. Such an approach provides the basis for some important theoretical claims about the nature and practice of environmental law and governance, namely, the fundamental role that *ways of seeing* play in the making of environmental law. As used here, the phrase “ways of seeing” is intended to encompass the various practices, conventions, techniques, tools, infrastructures, and institutions that allow certain phenomena to be organized and understood as coherent objects of governance. A central claim is that environmental law has lost sight of the constitutive role that the knowledge practices and supporting infrastructures commonly relegated to the realm of science and technology play in providing form and substance to the field.

Inquiring directly into how these knowledge practices and supporting infrastructures create particular objects of governance promises to deepen current understandings of the intellectual foundations of environmental law and offer some new directions for a positive theory of the discipline. To that effect, this Article argues that the seemingly technical work involved in rendering certain environmental

Science in the Anthropocene, 19 GLOBAL ENVTL. CHANGE 7 (2009), (investigating the “range of practices that have produced the ‘coupled human and ecological system’ as a thinkable and governable domain”); Nicholas A. Robinson, *Legal Systems, Decisionmaking, and the Science of Earth’s Systems: Procedural Missing Links*, 27 ECOLOGY L.Q. 1077 (2001) (discussing implications of earth systems science for law).

8. The multiple and largely complementary initiatives to bring REDD into climate policy—from the design of GHG compliance systems to the reform of forest law and governance in tropical forest countries—exemplify the emergence of “global environmental law,” manifest in the construction of cross-jurisdictional regulatory structures and a growing harmonization of national and sub-national forest law regimes aimed at translating forest carbon into compliance carbon. See Tseming Yang & Robert V. Percival, *The Emergence of Global Environmental Law*, 36 ECOLOGY L.Q. 615 (2009) (discussing concept of “global environmental law”).

problems comprehensible for purposes of environmental law and governance is in fact instrumental in shaping the very possibilities of such governance and must be interrogated directly as part of the construction of particular forms of governance. Drawing on history and philosophy of science,⁹ science and technology studies,¹⁰ the social science literature regarding the manner in which objects of governance are rendered technical and made amenable to certain forms of state intervention,¹¹ and previous work on the intellectual foundations of environmental law,¹² the Article seeks to recover a critical appreciation for the role of science and technology in constructing objects of environmental governance—

9. There is a vast literature on history and philosophy of science. This Article draws primarily on work within these fields that investigates how particular concepts, tools, and other knowledge practices work to organize and stabilize particular understandings of the world, often in ways that are co-constitutive with particular forms of governance. *See, e.g.*, IAN HACKING, *HISTORICAL ONTOLOGY* 4 (2002) (describing his overall approach to a diverse set of intellectual developments—from the emergence of probability to the making of child abuse as a stable category of concern—as one that asks “how . . . various concepts, practices, and corresponding institutions, which we can treat as objects of knowledge, at the same time disclose new possibilities for human choice and action”); Lorraine Daston, *Objectivity and the Escape from Perspective*, 22 *SOC. STUD. SCI.* 597 (1992) (exploring the emergence of different forms of objectivity and their application in various domains); THEODORE M. PORTER, *TRUST IN NUMBERS: THE PURSUIT OF OBJECTIVITY IN SCIENCE AND PUBLIC LIFE* (1995) (tracing the histories of various techniques of quantification and their role in science and public policy); Naomi Oreskes, *Why Believe a Computer? Models, Measures, and Meaning in the Natural World*, in *THE EARTH AROUND US: MAINTAINING A LIVABLE PLANET* (Jill S. Schneiderman ed., 2000) (discussing how modeling practices in the sciences create new objects of knowledge).

10. *See, e.g.*, Sheila Jasanoff, *Ordering Knowledge, Ordering Society*, in *STATES OF KNOWLEDGE: THE CO-PRODUCTION OF SCIENCE AND SOCIAL ORDER* 18–19 (Sheila Jasanoff ed., 2004) (discussing different approaches to knowledge and epistemic authority within the science and technology studies literature); Steven Yearley, *Nature and the Environment in Science and Technology Studies*, in *THE HANDBOOK OF SCIENCE AND TECHNOLOGY STUDIES* 921–23 (Hackett et al. eds., 3d ed. 2008) (discussing increasing attention in science and technology studies to questions of environment and, more specifically, to ways of “knowing nature”).

11. *See, e.g.*, NIKOLAS ROSE, *POWERS OF FREEDOM: REFRAMING POLITICAL THOUGHT* 205 (1999) (“When . . . numbers are used as ‘automatic pilots’ in decision making they transform the thing being measured—segregation, hunger, poverty—into its statistical indicator and displace political disputes into technical disputes about methods.”); JAMES C. SCOTT, *SEEING LIKE A STATE: HOW CERTAIN SCHEMES TO IMPROVE THE HUMAN CONDITION HAVE FAILED* 4–5 (1998) (describing modern “statecraft” as resting on projects intended to simplify and make legible natural and social systems); JAMES FERGUSON, *THE ANTI-POLITICS MACHINE* 256 (1994) (showing, through a detailed case study in Lesotho, how the international “development apparatus” operates as “the principal means through which the question of poverty is depoliticized in the world today”).

12. *See, e.g.*, Laurence Tribe, *Policy Science: Analysis or Ideology?*, 2 *PHIL. & PUB. AFFAIRS* 66, 78 (1972) [hereinafter Tribe, *Policy Science: Analysis or Ideology?*] (seeking “to investigate the ways in which a self-consciously objectivist ideal may substantively structure the characteristics and the conclusions of a given mode of thought”); BRUCE A. ACKERMAN ET AL., *THE UNCERTAIN SEARCH FOR ENVIRONMENTAL QUALITY* 5 (1974) (exploring “the uncertain intellectual foundations of the substance of environmental policy in the United States” through a detailed case study of the deployment of “technocratic intelligence” in the effort to solve the water pollution problem in the Delaware River basin).

focusing on the distinctive ways of seeing that make problems “objective” and “legible” for regulation. Too often, the study and practice of environmental law and governance take the object of governance—be it climate change, water pollution, biodiversity, or deforestation—as self-evident, natural, and fully-formed without recognizing the significant scientific and technological investments that go into making such objects and the manner in which such investments shape the possibilities for response.¹³ To be sure, the literature on epistemic communities pioneered in the study of stratospheric ozone depletion,¹⁴ the perennial concern with technocratic forms of knowledge and decision-making,¹⁵ and the vast literature exploring the role of scientific uncertainty in particular legal and regulatory contexts¹⁶ have highlighted the role of science and technical expertise in environmental law and governance. But these literatures have not been integrated with key insights from science and technology studies regarding how particular knowledge practices are co-constitutive with the nature and practice of governance.¹⁷ Indeed, there seems to be a general perception in environmental law scholarship that science and technology operate as discrete inputs to, and/or neutral tools for, environmental law and governance rather than as active forces in the very construction of those objects of governance through the deployment of specific knowledge practices and particular techniques of

13. See Clark A. Miller & Paul N. Edwards, *Globalization of Climate Science and Climate Politics*, in *CHANGING THE ATMOSPHERE: EXPERT KNOWLEDGE AND ENVIRONMENTAL GOVERNANCE* 1, 5 (Clark A. Miller & Paul N. Edwards eds., 2001) (“Science . . . thus appears less an independent input to global governance than an integral part of it: a human institution deeply engaged in the practice of ordering social and political worlds.”).

14. See Peter M. Haas, *Banning Chlorofluorocarbons: Epistemic Community Efforts to Protect Stratospheric Ozone*, in *KNOWLEDGE, POWER AND INTERNATIONAL POLICY COORDINATION* (Peter M. Haas ed., 1992).

15. The general critique of technocratic forms of decision-making has been a recurring theme in environmental law scholarship for more than thirty years and, of course, draws upon much older philosophical and sociological critiques of instrumental reason. See, e.g., ACKERMAN ET AL., *supra* note 12, at 2–3 (critiquing the shortcomings of “technocratic intelligence” in the effort to model and control pollution in the Delaware River basin); Laurence Tribe, *Technology Assessment and the Fourth Discontinuity: The Limits of Instrumental Rationality*, 46 S. CAL. L. REV. 617, 627 (1973) [hereinafter Tribe, *Technology Assessment and the Fourth Discontinuity*] (focusing on the reductionist tendencies of the policy sciences and the resulting pathologies).

16. See, e.g., Wendy E. Wagner, *The Science Charade in Toxic Risk Regulation*, 95 COLUM. L. REV. 1613 (1995) (discussing ways in which science gets mobilized in toxics regulation); Marcia R. Gelpe & A. Dan Tarlock, *The Uses of Scientific Information in Environmental Decisionmaking*, 48 S. CAL. L. REV. 371 (1974) (exploring the ways in which science informs environmental decisionmaking).

17. See Jasanoff, *supra* note 10, at 19–36 (discussing varieties of the co-production of knowledge and social order). For an earlier effort within legal scholarship that bears some resemblance to this approach, see Tribe, *Policy Science: Analysis or Ideology?*, *supra* note 12, at 67 (asking how “particular modes of analysis in a number of different fields—particular approaches to formulating questions, organizing information, and developing answers—entail fundamental (if often unwitting) commitments to substantive conclusions shaped in characteristic and often unfortunate ways”).

objectification that structure environmental decision-making.¹⁸ Such a perception stems in part from the assumption that scientific understandings of the world “acquire political authority because they mirror the realities of nature”¹⁹ rather than as a result of extensive investments in discerning, formatting, and stabilizing such understandings as particular domains of inquiry. By attending to the actual manner in which scientific and technical knowledge practices are mobilized in environmental law and governance, we gain a more complete understanding of how certain forms of governance become possible, and why they sometimes fall apart.

In the case of tropical deforestation, this is manifest in efforts since the 1980s to conceptualize tropical deforestation as a component of the global carbon cycle, in the ongoing effort to develop and apply new remote sensing techniques to land-cover change as a basis for mapping and quantifying emissions from deforestation at a global scale, and in the effort to translate forest carbon into compliance carbon. Together, these efforts constitute a process of (re)formatting the forest as an object of global carbon governance; that is, these new ways of seeing have rendered a problem previously viewed as one of species loss, North-South commodity linkages, macro-economic imbalances, and institutional shortcomings as a critical component of the climate change challenge that is potentially amenable to treatment in existing and emerging GHG compliance regimes.²⁰ Attending to the role of these knowledge practices and their supporting infrastructures in opening up spaces for global governance, in part by rendering messy social and political problems as technical problems amenable to managerial solutions at a global scale, is a key objective of this Article.

But the implications of such an approach clearly go beyond the deforestation case, providing a basis for rethinking certain assumptions about the nature and practice of environmental law. By focusing on how particular environmental problems get constructed and stabilized as objects of governance, we gain new perspective on the possibilities for (and the limits of) regulation. Environmental law, in this view, depends fundamentally upon particular forms and techniques of objectification, which have heretofore been largely neglected in explanations of the discipline.

To that end, Part I establishes the general theoretical and methodological orientation of the Article, focusing on the role of

18. See, e.g., CASS R. SUNSTEIN, *RISK AND REASON: SAFETY, LAW, AND THE ENVIRONMENT* 108–110, 294 (2002) (discussing role of “science” as key input to risk regulation).

19. Clark Miller, *Climate Science and Global Political Order*, in *STATES OF KNOWLEDGE: THE CO-PRODUCTION OF SCIENCE AND SOCIAL ORDER* 46, 50 (Sheila Jasanoff ed., 2004).

20. See *infra* Parts II–IV.

objectification and ways of seeing in environmental law, and how this relates to existing perspectives on the development of the field. Part II introduces the deforestation case study, tracing the ways in which tropical forests were constituted historically as a unitary, calculable object of global concern during the nineteenth and twentieth centuries and the manner in which the tropical forest crisis of the last several decades has been framed and approached outside of the climate policy context. Part III then discusses briefly the role of tropical deforestation in global climate change, the treatment of forests under the UN Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol, and the ongoing effort to bring emissions from deforestation into emerging GHG compliance regimes. The intent here is simply to illustrate the fact that tropical deforestation has very recently become an important object of climate governance, and to highlight some of the challenges involved in making it so. Part IV then focuses specifically on the underlying knowledge practices and supporting infrastructures that have allowed tropical deforestation to be reformatted as an object of climate governance, with specific attention to three such knowledge practices: *kind-making*, as manifested in carbon cycle research during the post-World War II period; *calculability*, as illustrated by advances in remote sensing and the ability to visualize and map tropical forests on a global scale; and *equivalence*, as realized by the deployment of particular legal and accounting practices for translating forest carbon into compliance carbon. Finally, Part V advances some larger theoretical claims about ways of seeing in environmental law.

I. OBJECTIFICATION AND ENVIRONMENTAL LAW

As a discipline, environmental law has tended to emphasize its roots in economics (with a focus on externalities and cost-benefit balancing), engineering (with a focus on control technologies and margins of safety), ecology (with an emphasis on interconnectedness and dynamic systems), and ethics (with an emphasis on rights and distributive justice).²¹ Very little attention has been given to the ways in which the knowledge practices of science and technology shape the *problems* that

21. See, e.g., RICHARD L. REVESZ, FOUNDATIONS OF ENVIRONMENTAL LAW AND POLICY 2–4 (1997) (describing economic foundations of environmental law); Oliver A. Houck, *Of Bats, Birds, and B-A-T: The Convergent Evolution of Environmental Law*, 63 MISS. L.J. 403, 417–31 (1994) (describing transition to technology-based approaches in major pollution control statutes); Fred P. Bosselman & A. Dan Tarlock, *The Influence of Ecological Science on American Law: An Introduction*, 69 CHI.-KENT L. REV. 847, 863 (1994) (arguing that “ecology remains the foundation of environmental law because it informed society about adverse consequences of a wide range of human activity”); MARK SAGOFF, THE ECONOMY OF THE EARTH: PHILOSOPHY, LAW, AND THE ENVIRONMENT 14–17 (1988) (discussing ethical foundations of health, safety, and environmental regulation).

environmental law targets for regulation. The literatures on framing and epistemic communities come closest to such a perspective, although those literatures look more at how people frame and understand problems, often as a reflection of underlying biases or heuristics, or, in the case of epistemic communities, how scientific experts and policy elites frame and legitimate approaches to complex problem areas.²² The approach taken here, in contrast, focuses less on framing, important as it is, than on objectification and the particular ways that science and technology create and condition the possibilities for particular framings. Such an approach has some affinity with the work of legal scholars and social scientists interested in bringing the insights of science and technology studies into the study of law, regulation, and governance as well as those interested in the broader question of “how law knows.”²³

22. On epistemic communities, see Peter M. Haas, *Epistemic Communities*, in THE OXFORD HANDBOOK OF INTERNATIONAL ENVIRONMENTAL LAW 791 (Daniel Bodansky, Jutta Brunée & Ellen Hey eds., 2007); Peter M. Haas, *Introduction: Epistemic Communities and International Policy Coordination*, in KNOWLEDGE, POWER, AND INTERNATIONAL POLICY COORDINATION 1 (Peter M. Haas ed., 1992). There is a large and diverse social science literature on framing, including significant work in behavioral economics and the policy sciences, that has had considerable influence on legal scholarship. See, e.g., Amos Tversky & Daniel Kahneman, *Rational Choice and the Framing of Decisions*, 59 J. BUS. S251, S270–75 (1986) (discussing how the framing of particular choices affects decision making in situations of risk); B. Dan Wood & Alesha Doan, *The Politics of Problem Definition: Applying and Testing Threshold Models*, 47 AM. J. POL. SCI. 640, 640 (2003) (reviewing political science literature directed at understanding “how and why conditions become defined as public problems”). Of more direct relevance to this project are studies that investigate how “issue framing” and the construction of global environmental problems influence governance approaches. See, e.g., Josee van Eijndhoven et al., *The Long-Term Development of Global Environmental Risk Management: Conclusions and Implications for the Future*, in 2 LEARNING TO MANAGE GLOBAL ENVIRONMENTAL RISKS: A FUNCTIONAL ANALYSIS OF SOCIAL RESPONSES TO CLIMATE CHANGE, OZONE DEPLETION, AND ACID RAIN 192 (Social Learning Group, eds.) (2001) (discussing the importance of issue framing in constructing frameworks for effective governance of global environmental problems); Peter J. Taylor & Frederick H. Buttel, *How Do We Know We Have Global Environmental Problems? Science and the Globalization of Environmental Discourse*, 23 GEOFORUM 405, 406 (1992) (pointing to the ways in which the science of global environmental change facilitates “certain courses of action . . . over others, not just in the use or misuse of science, but in its very formulation—the problems chosen, categories used, relationships investigated, and confirming evidence required”) (citations omitted).

23. See, e.g., Shelia Jasanoff, *Making Order: Law and Science in Action*, in THE HANDBOOK OF SCIENCE AND TECHNOLOGY STUDIES 761–86 (Edward J. Hackett et al. eds., 2008) (reviewing science and technology studies literature on law, with specific attention to law’s epistemic authority and knowledge practices); Annelise Riles, *A New Agenda for the Cultural Study of Law: Taking on the Technicalities*, 53 BUFF. L. REV. 973, 985–89 (2005) (discussing relevance of science and technology studies to an understanding of particular legal technologies, in her case modern conflict-of-laws doctrine); Austin Sarat et al., *Complexity, Contingency, and Change in Law’s Knowledge Practices: An Introduction*, in HOW LAW KNOWS 9 (Austin Sarat et al. eds., 2007) (“From the rules of evidence to the technologies of risk management, from the practices of racial profiling to the development of trade knowledge, from the generation of independent knowledge practices to law’s dependence on outside expertise, even a brief survey shows that law knows in many different ways, that its knowledge practices are contingent, responsive to context, and that they change over time.”); Mariana Valverde et al., *Legal*

To that effect, it is notable that we lack a well-developed intellectual history of environmental law that takes seriously scientific and technological ways of seeing. Of course, there have been countless law review articles on the varied and variable ways that science gets used and abused in legal proceedings of one kind or another²⁴ and no shortage of reverential invocations of the importance of science—in substance and procedure—as a model for law and policy.²⁵ But there is virtually nothing on the ways in which the actual knowledge practices of science and technology shape and inform the nature and practice of environmental law.²⁶ Nothing (or almost nothing), in other words, that digs into the ways in which particular scientific and technological ways of seeing render certain problems comprehensible for purposes of environmental governance.

By offering a novel orientation for environmental law scholarship, one that aims at a more comprehensive appreciation of the ways in which knowledge practices or ways of seeing organize and shape objects of governance, this Article seeks to fill some of these gaps. As such, it draws inspiration from earlier work by legal scholars such as Professors Laurence Tribe and Bruce Ackerman who interrogated some of the specific knowledge practices involved in environmental policy making, including what Ackerman and his co-authors referred to as “technocratic intelligence.”²⁷ The approach taken here also draws on contemporary environmental law scholarship such as the work of Professors Dan Tarlock and Jonathan Weiner, who have explored the ways in which

Knowledges of Risk, in LAW AND RISK 86–87 (Law Commission of Canada ed., 2005) (discussing how different “risk knowledge practices” are shaped and deployed by participants in “particular legal networks”).

24. See, e.g., Wagner, *supra* note 16. See also the collection of essays in RESCUING SCIENCE FROM POLITICS: REGULATION AND THE DISTORTION OF SCIENTIFIC RESEARCH (Wendy Wagner & Rena Steinzor eds., 2006).

25. See, e.g., CASS R. SUNSTEIN, RISK AND REASON: SAFETY, LAW, AND THE ENVIRONMENT 294 (2002) (characterizing book as “a celebration of the centrality of science and expertise to the law of risk”).

26. Shelia Jasanoff’s work is a notable exception. See, e.g., SHELIA JASANOFF, THE FIFTH BRANCH: SCIENCE ADVISERS AS POLICYMAKERS 17–19 (1990) (proposing an alternative approach to understanding the interaction between scientific experts and the regulatory process based on an historical, interdisciplinary case-study method that draws upon insights from science and technology studies).

27. See, e.g., Tribe, *Policy Science: Analysis or Ideology?*, *supra* note 12; Tribe, *Technology Assessment and the Fourth Discontinuity*, *supra* note 15, at 627 (characterizing the reductionist tendencies of the policy sciences and the resulting pathologies in terms of how particular problems are framed and interrogated); ACKERMAN ET AL., *supra* note 12, at 5 (exploring “the uncertain intellectual foundations of the substance of environmental policy in the United States today” through an exhaustive case study of “technocratic intelligence” and its application to pollution control in the Delaware River basin).

specific ecological ideas have shaped environmental law,²⁸ and Professor Douglas Kysar, who has sought to understand the normative implications of what he calls “pre-analytic vision” for environmental law and the perils of the technocratic quest to build an objective, welfarist foundation for environmental policy choices.²⁹ What unites these different scholars for purposes of this Article is the fact that all of them, in one way or another, have sought to understand how specific concepts and framings from the natural and social sciences have shaped environmental law. All of them have sought, in other words, to understand how environmental law frames its subject matter.

In building on the work of these scholars, this Article focuses less on the paradigms or background assumptions that shape a particular approach to environmental law than on the concepts, practices, and tools that discern and stabilize the objects or problems that animate the field. The orientation is similar in some respects to the work of Professors Jim Salzman and J.B. Ruhl on the fungibility problem in environmental trading markets, with their attention to “what is actually being traded” in such markets and the challenges of developing currencies or proxies as a means of commodifying certain environmental benefits.³⁰ At a more

28. See, e.g., A. Dan Tarlock, *The Nonequilibrium Paradigm in Ecology and the Partial Unraveling of Environmental Law*, 27 LOY. L.A. L. REV. 1121 (1994) (providing an overview of how the shift in ecology from the older “balance of nature” concept that characterized systems ecology in the post-World War II period to the “non-equilibrium paradigm” has reshaped environmental law); Jonathan Baert Wiener, *Law and the New Ecology: Evolution, Categories, and Consequences*, 22 ECOLOGY L.Q. 325, 329 (1995) (discussing the influence of mid-twentieth century ecological ideas such as the balance of nature on environmental law); see also Harry N. Scheiber, *From Science to Law to Politics: An Historical View of the Ecosystem Idea and its Effect on Resource Management*, 24 ECOLOGY L.Q. 631, 635 (1997) (exploring how the “scientific vision, and the methodology of ecological investigation,” provided the foundation for the ecosystem management approach to marine fisheries).

29. See Douglas A. Kysar, *Law, Environment, and Vision*, 97 NW. U. L. REV. 675, 677 (2003) (focusing on the “fundamental conceptual flaw in our background assumptions about the natural world and its relation to our economic activity”—what Kysar calls “pre-analytic vision”—that drives mainstream economic thought and, by extension, modern environmental decision making in ways that are unsustainable); see also Douglas A. Kysar, *REGULATING FROM NOWHERE: ENVIRONMENTAL LAW AND THE SEARCH FOR OBJECTIVITY* (2010) (discussing the narrow and misguided rationalities of strict welfarist approaches, manifest in tools such as quantitative risk assessment and cost-benefit analysis, to environmental policy-making); Douglas A. Kysar, *Climate Change, Cultural Transformation, and Comprehensive Rationality*, 31 B.C. ENVTL. AFF. L. REV. 555, 586 (2004) [hereinafter Kysar, *Climate Change, Cultural Transformation, and Comprehensive Rationality*] (discussing how “the very structure of the CBA [Cost-Benefit Analysis] project” tends “to obscure difficult judgments through mischaracterization or misspecification”).

30. See James Salzman & J.B. Ruhl, *Currencies and the Commodification of Environmental Law*, 53 STAN. L. REV. 607, 611 (2000); see also Carol M. Rose, *From H₂O to CO₂: Lessons of Water Rights for Carbon Trading*, 50 ARIZ. L. REV. 91 (2008) (discussing tradeoffs between precision and alienability in the creation of entitlements for environmental trading markets); Carol M. Rose, *Environmental Law Grows Up (More or Less), and What Science Can Do to Help*, 9 LEWIS & CLARK L. REV. 273, 283 (2005) (concluding that one of the main reasons why

abstract level, it reflects a concern with what Christopher Stone, in another context, referred to as “legal ontology”—a focus on how certain objects, in his case “natural objects” such as trees, are conceptualized and made amenable (or not) to certain types of legal regimes.³¹ By focusing on how the object of governance itself—whether water pollution, global climate change, biodiversity, or deforestation—has come to be organized and understood as such, the intent is to resist the tendency to naturalize environmental problems and instead take environmental law scholarship in a direction that is more sensitive to the historical epistemology of the field.

The term historical epistemology may seem odd to some readers, juxtaposing two seemingly disparate fields of inquiry. Of course, the label itself is far less important than the mode of inquiry it represents. As understood here, historical epistemology starts from the premise that our concepts, tools, and styles of reasoning—our knowledge practices—have histories and those histories matter, not only in understanding the origins and meanings of particular knowledge practices, but also in understanding the effects that such knowledge practices have in shaping our views of the world and concomitant modes of governing.³²

cap-and-trade has not been deployed more widely is the “unsolved problem” of “measurement” of quality improvements associated with trading).

31. See Christopher D. Stone, *Should Trees Have Standing?—Toward Legal Rights for Natural Objects*, 45 S. CAL. L. REV. 450, 456 n.26 (1972) (discussing the difficult ontological choices involved in selecting and framing a particular “natural object,” which will in turn have “a strong influence on the shape of the legal system”).

32. See Lorraine Daston, *Historical Epistemology*, in QUESTIONS OF EVIDENCE: PROOF, PRACTICE, AND PERSUASION ACROSS THE DISCIPLINES, 243, 282–83 (James Chandler et al. eds., 1991) (describing “historical epistemology” as the “history of the categories that structure our thought, pattern our arguments and proofs, and certify our standards for explanation”); IAN HACKING, *HISTORICAL ONTOLOGY* 8 (2002) (“The ideas examined by historical epistemology are the ones we use to organize the field of knowledge and inquiry. They are, often despite appearances, historical and ‘situated’.”); MARY POOVEY, *A HISTORY OF THE MODERN FACT: PROBLEMS OF KNOWLEDGE IN THE SCIENCES OF WEALTH AND SOCIETY* 7 (1998) (“Insofar as historical epistemology assumes that the categories by which knowledge is organized—not only epistemological units like facts, but also institutionalized units like disciplines and professional societies—inform *what* can be known at any given time, as well as *how* this knowledge can be used, historical epistemology is a study of determination and effects. Insofar as historical epistemology assumes that the categories by which knowledge is organized change over time, it is less a study of the inexorable march of ‘science’ toward a fully adequate description of nature than an investigation of those developments that have increasingly made Westerners believe that this march is underway.”). Much of the research carried out under the banner of historical epistemology draws inspiration from earlier work by Michel Foucault, among others. See, e.g., MICHEL FOUCAULT, *THE ORDER OF THINGS: AN ARCHAEOLOGY OF THE HUMAN SCIENCES* xxii (Vintage Books 1994) (1970) (“[W]hat I am attempting to bring to light is the epistemological field, the *episteme* in which knowledge, envisaged apart from all criteria having reference to its rational value or to its objective forms, grounds its positivity and thereby manifests a history which is not that of its growing perfection, but rather that of its conditions of possibility . . .”).

Such a perspective highlights three important sets of knowledge practices that are instrumental in constructing many of the objects of environmental law: (1) *kind-making*, the role of particular knowledge practices and their supporting infrastructures in creating the categories or kinds that define and structure environmental problems (think, for example, of the enormous effort that has gone into making global climate change a stable object of inquiry and governance); (2) *calculability*, the constellation of practices that give a particular problem the necessary stability and coherence across space and time in order to sustain it as an object of governance (manifest, for example, in the radically enhanced ability to monitor toxic substances in the environment, the modeling and simulation of global climate change, and remote sensing of land use, to name a few); and (3) *equivalence*, the translation of heterogeneous phenomena into common, fungible units or “currencies” as a basis for particular regulatory strategies (something that is particularly evident in the climate policy context where carbon is rapidly becoming the coin of the realm, but which extends to other environmental trading markets and beyond).³³ Focusing on these ways of seeing provides a new point of departure for understanding the “making of environmental law”³⁴ with important theoretical, methodological, and normative implications.

Indeed, any mature positive theory of environmental law—that is, a theory of how and why environmental law does its work—must account for the way that its subject matter comes to be organized as such. Any comprehensive explanation of the “making of environmental law,” in other words, must attend to the specific knowledge practices that shape the field rather than focusing exclusively on legal, institutional, or political questions. If one accepts this, then the making of environmental law becomes more than a story about efforts to manage spillovers and externalities, commons problems of various kinds, or various sorts of ecological and human harm, more than a story about the particular policy choices and legal practices involved in governing such problems. It becomes a story also about how certain ways of seeing these problems became possible, and how these ways of seeing have shaped and conditioned the possibilities for response. Such ways of seeing, moreover, (and this is the methodological point) must be investigated as historically situated practices—a point that, if taken seriously, opens up an expansive domain for future research oriented toward the ways in which particular problems, concepts, and knowledge practices have emerged within the

33. See, e.g., Salzman & Ruhl, *supra* note 30 (raising important questions about the feasibility of efforts to create common currencies for diverse and heterogeneous phenomena in the context of environmental trading markets); see also *infra* Part IV.C.

34. The phrase is from RICHARD J. LAZARUS, *THE MAKING OF ENVIRONMENTAL LAW* (2004).

field of environmental law. Finally, there are obvious normative implications embedded within such an approach, a full discussion of which is beyond the scope of this Article; namely, the ways in which particular ways of seeing valorize certain claims or interests vis-à-vis others, the manner in which messy social and political problems are rendered technical through particular knowledge practices, and the manner in which certain modes and scales of governance are privileged relative to others by virtue of how objects of governance are defined.

The following three Parts explore these claims through a study of how tropical deforestation has been reformatted as a viable object of climate governance. The intent is to use the case study as a way of situating and grounding the theoretical claims that will be elaborated further in Part V. The deforestation story, in other words, allows us to see how the specific knowledge practices of kind-making, calculability, and equivalence are worked out in a concrete historical setting—how the actual process of objectification is happening in a particular case—offering a rehearsal of sorts for the more general theoretical discussion in Part V.

II. TROPICAL DEFORESTATION AS A GLOBAL PROBLEM

Forests have long occupied a prominent place in the western imagination, from the very idea of wilderness to contemporary narratives of global ecological destruction.³⁵ Likewise, the regulation of forest access and use has long been a focus of governing elites, illustrated most prominently in the modern era by the criminalization of customary forest uses throughout the world and the development of extensive bureaucratic systems for managing “state” forests.³⁶ During the eighteenth and nineteenth centuries, efforts to rationalize and professionalize state forestry led to a distinctive European model of “scientific forestry” built on a managerial logic of simplification and control—a new way of seeing forests as objects of calculation and state regulation that was soon exported throughout the world as part of the colonial enterprise.³⁷

35. See ROBERT POGUE HARRISON, *FORESTS: THE SHADOW OF CIVILIZATION* (1992) [hereinafter HARRISON, *SHADOW OF CIVILIZATION*]; SIMON SCHAMA, *LANDSCAPE AND MEMORY* (1995); MICHAEL WILLIAMS, *DEFORESTING THE EARTH: FROM PREHISTORY TO GLOBAL CRISIS* (2003) [hereinafter WILLIAMS, *DEFORESTING THE EARTH*].

36. See, e.g., EDWARD P. THOMPSON, *WHIGS AND HUNTERS: THE ORIGINS OF THE BLACK ACT* (1975); NANCY LEE PELUSO, *RICH FORESTS, POOR PEOPLE: RESOURCE CONTROL AND RESISTANCE IN JAVA* 8–17 (1992); HARRISON, *SHADOW OF CIVILIZATION*, *supra* note 35, at 69 (documenting the origins of the word *forest* as “a juridical term referring to land that had been placed off limits by a royal decree” and discussing the emergence of a specific domain of “forest laws” for punishing those who encroached upon these domains).

37. See, e.g., Henry E. Lowood, *The Calculating Forester: Quantification, Cameral Science, and the Emergence of Scientific Forestry Management in Germany*, in *THE QUANTIFYING SPIRIT IN THE 18TH CENTURY* 315, 317 (Tore Frängsmyr, J.L. Heilbron & Robin E. Rider eds., 1990)

Embedded within this new way of seeing was a tendency to view forests as a global resource and, accordingly, a capacity to frame tropical deforestation as a global crisis. As elaborated in Part IV below, these two perspectives—forests as calculable object and as global resource—together provide the provenance for contemporary efforts to frame tropical deforestation as an object of global carbon governance. The remainder of this Part will elaborate on the global framing of tropical forests during the last century and the dominant ways of approaching the tropical forest crisis since the 1980s.

A. *Constructing the Global Forest*

Although widespread concern regarding tropical deforestation as a *global* problem is of relatively recent vintage, a number of forestry professionals in the late nineteenth and early twentieth centuries did seek to call attention to the destruction of tropical forests.³⁸ Motivated primarily by the prospect of global timber shortage, which was in part a projection of the resource conservation ethos that dominated national forest departments, these forest professionals launched a series of piecemeal efforts to assess the state of the world's forest resources and their capacity to meet growing economic demands.³⁹ These early assessments proved instrumental in constructing the concept of a "global forest":

After 1920, forests everywhere in the world were coming under scrutiny and being assessed. What happened in one part of the world had repercussions in another part. Of course, that had always been true, but now it was clearly recognized that individual forests were "only segments of a great whole." The "forest" was now being looked at as not only a global resource but an object of knowledge, a large-scale conceptual entity that could be visualized, managed, made productive, and "economized."⁴⁰

(tracing the history of forest science and quantitative approaches to forest management to the rise of cameral sciences in Germany during second half of the 18th century); SCOTT, *supra* note 11, at 11–22 (1998) (discussing the history of scientific forestry as a history of state-directed simplification and legibility); ARUN AGRAWAL, ENVIRONMENTALITY: TECHNOLOGIES OF GOVERNMENT AND THE MAKING OF SUBJECTS 32, 58–59 (2005) ("Representation by numbers transformed beliefs among foresters about ideal forests and made possible the reworking of existing vegetation in terms of scientific forestry, sustainable yields, and profit maximization. . . . Numbers and statistics made it possible to constitute forests.").

38. See, e.g., Raphael Zon, *Forests and Human Progress*, 10 GEOGRAPHICAL REV. 139, 163 (1920) ("Over a large part of the world the forest is now conquered.").

39. See WILLIAMS, DEFORESTING THE EARTH, *supra* note 35, at 393–95 (documenting early twentieth century concerns of a global timber famine and the concomitant effort to assess the state of the world's forest resources).

40. *Id.* at 395.

Forest inventories, of course, had long been central features of governmental strategies to rationalize forest management. Developed by German foresters in the late eighteenth and early nineteenth centuries, these techniques spread throughout the world as key elements of a new “scientific forestry,” emphasizing the rational and efficient management of natural resources.⁴¹ Professional foresters in the United States, many of whom were trained in the tradition of German forestry, initiated efforts to inventory and quantify standing timber in federal forest reserves during the early twentieth century,⁴² and soon expanded these efforts to forests throughout the country. Animated by the so-called gospel of efficiency, these early assessments sought to quantify the timber available in the face of what some saw as an impending timber shortage, with the overall goal of providing a basis for rational resource management.⁴³ Far more than a gigantic timber cruise, these efforts represented a powerful new way of seeing the forest and rendering it calculable in service to the principles of scientific management.⁴⁴

Such efforts were soon transplanted to the global scale, with the earliest attempt at a comprehensive assessment of global forest resources prepared in 1910 by the U.S. Forest Service.⁴⁵ Daunting challenges confronted such an assessment, and a coordinated push for a global forest resource assessment did not emerge until shortly after World War II when the recently established United Nations Food and Agriculture Organization (FAO) launched a World Forest Inventory, responding to the same concerns about timber shortages that animated many national-

41. See Lowood, *supra* note 37, at 341 (discussing the spread of quantitative approaches to forest science from Germany to French and English colonies and to the United States during the nineteenth century); S. RAVI RAJAN, *MODERNIZING NATURE: FORESTRY AND IMPERIAL ECO-DEVELOPMENT 1800–1950*, at 55 (2006) (“By the end of the nineteenth century . . . [w]here there had once been state-sponsored forest destruction, there were now extensive state-sponsored regimes of scientific resource management.”).

42. See MICHAEL WILLIAMS, *AMERICANS AND THEIR FORESTS: A HISTORICAL GEOGRAPHY* 430–40 (1989) (discussing forest inventory efforts in the United States in the late nineteenth and early twentieth centuries); HENRY CLEPPER, *PROFESSIONAL FORESTRY IN THE UNITED STATES* 266–67 (1971) (discussing the emergence of a Continuous Forest Inventory (CFI) system in the United States during the 1930s).

43. SAMUEL P. HAYS, *CONSERVATION AND THE GOSPEL OF EFFICIENCY: THE PROGRESSIVE CONSERVATION MOVEMENT, 1890–1920*, at 27–48 (1959) (discussing concerns about the waste and destruction of the nation’s timber resources during the late nineteenth century and the push for a program of “scientific management”).

44. See, e.g., David Demeritt, *Scientific Forest Conservation and the Statistical Picturing of Nature’s Limits in the Progressive-Era United States*, 19 *ENV’T & PLAN. D: SOC’Y & SPACE* 431, 433 (2001) (discussing efforts to develop “new techniques of quantitative picturing” of forest resources in the United States during the late nineteenth and early twentieth centuries and how this “quantitative picturing provided both the context and the impetus for the governmental institution of scientific conservation”).

45. RAPHAEL ZON, U.S. DEP’T OF AGRIC., *FOREST SERVICE BULLETIN NO. 83, THE FOREST RESOURCES OF THE WORLD* (1910).

level inventories.⁴⁶ For the next two decades, the organization undertook a series of regional assessments and by the early 1970s began to turn its attention to a more systematic assessment of the state of tropical forests and the impacts of deforestation, reflecting a growing recognition that tropical forests could no longer be viewed as unlimited resources.⁴⁷ More than anything else, however, these early assessments reinforced the basic conclusion that knowledge of the true state of tropical forests was extremely limited.⁴⁸ Given the scale of the task, combined with the lack of capacity and basic infrastructure in many tropical forest countries, some of which were just emerging from colonial rule, it was obvious that the traditional, field-based approaches to forest inventories would not suffice. In response, professional foresters and others looked to new remote sensing techniques as the basis for a fundamentally different approach to global forest resource assessment.⁴⁹ As will be discussed in more detail in Part IV.B below, starting in the mid-1980s, ecologists and others concerned with tropical deforestation began using these techniques to assess the state of tropical forests on regional and, ultimately, global scales, ushering in a new way of seeing that has proved instrumental in reframing tropical forests as an object of global climate governance.

B. *Tropical Forests in Crisis*

One of the more important consequences of the effort to visualize tropical forests as a unitary, calculable object of global concern was the realization that such forests were in crisis. For much of the colonial period, of course, tropical forests were considered so vast as to be unlimited for all intents and purposes.⁵⁰ Empire building and economic expansion both viewed tropical forests as obstacles to progress rather

46. FAO, *Forest Resources of the World*, 2 UNASYLVA 161 (1948); see also P. Holmgren & R. Persson, *Evolution and Prospects of Global Forest Assessments*, 53 UNASYLVA 3, 4 (2002).

47. See, e.g., A. Sommer, *Attempt at an Assessment of the World's Tropical Forests*, 112-13 UNASYLVA 5, 5 (1976) (documenting the change in thinking regarding tropical forests from "a euphoric belief in its unlimited growth . . . as an almost infinite resource" to an awareness of the "limited extension of these forest resources and their gradual regression due to increasing human activities," which placed a premium on a global-level assessment).

48. *Id.* at 5 (describing the available material for conducting a global appraisal of tropical moist forests as "a mass of incomplete data and a number of assumptions"); see also *Editorial: A New Awareness of Terra Incognita*, 28 UNASYLVA 2, 2 (1976) (characterizing the tropical moist forest as "man's least understood ecological formation").

49. See, e.g., Sommer, *supra* note 47, at 5 ("It is only recently that, thanks to the new remote sensing techniques we have at last a tool which can give us an objective and accurate appraisal of the world's forest resources.").

50. See RAJAN, *supra* note 41, at 55 (noting that up until the middle of the nineteenth century "[f]or most colonial administrative officials, forests were a vast and seemingly limitless reservoir of resources for imperial expansion and a hindrance to agricultural development").

than as assets to be protected.⁵¹ By the late nineteenth and early twentieth centuries, however, some in the West began to question this particular ethos, with colonial foresters and others calling attention to the threats facing tropical forests.⁵² Louis Lavauden, a French colonial forester working in Africa, summed up the prevailing view in 1937: “[i]t is only quite recently . . . that the retreat of the equatorial forest has begun to arouse interest.”⁵³ In keeping with the scientific management agenda that had been gaining currency in colonial forest departments since the late nineteenth century, Lavauden bemoaned the wasteful destruction of Africa’s tropical forests:

The conclusion is obvious that forest of this type [tropical moist forest] must be treated with care. The action of Man must never be opposed to that of Nature. The situation calls for a more intelligent and far-sighted view than the one circumscribed by the interests of an individual, a village, or a financial company. How often one sees clearings made in a spirit of hopefulness that, from the agronomic standpoint, has no justification in fact. The forest has been destroyed—and destroyed irretrievably—for a meager and ephemeral profit.⁵⁴

Echoing these concerns, botanists and other scientists involved in the exploration of tropical forests (often as part of the colonial enterprise) called attention to the incalculable losses associated with rapid deforestation. Writing just after World War II, for example, E.J.H. Corner saw in the destruction of tropical forests a grave threat to science: “I fear lest all the virgin lowland forest of the tropics may be destroyed before botany awakes: even our children may never see the objects of our delight which we have not cared for in their vanishing.”⁵⁵ Paul Richards, author of one of the first monograph-length ecological studies of tropical forests, pointed to a range of negative impacts associated with tropical deforestation, including loss of genetic material, reduced precipitation, increased soil erosion, loss of commercially valuable timber species, and the destruction of the “reservoir of natural material represented by the

51. *Id.*; see also WILLIAMS, *DEFORESTING THE EARTH*, *supra* note 35, at 344–79 (documenting European colonial expansion and concomitant destruction of tropical forests after 1750); HARRISON, *SHADOW OF CIVILIZATION*, *supra* note 35, at 133–44 (describing nineteenth century European attitudes toward the vast equatorial forests of central Africa through a discussion of the novels of Joseph Conrad).

52. See RAJAN, *supra* note 41, at 3–6.

53. Louis Lavauden, *The Equatorial Forest of Africa: Its Past, Present, and Future*, 36 J. ROYAL AFRICAN SOC’Y 3, 6 (1937); see also RAJAN, *supra* note 41, at 27, 55–107 (discussing concerns of colonial foresters and others with tropical forest destruction during the nineteenth century).

54. Lavauden, *supra* note 53, at 8.

55. E.J.H. Corner, *Suggestions for Botanical Progress*, 45 NEW PHYTOLOGIST 185, 185–86 (1946).

rain forest flora" that surely contained many other species of "unsuspected value."⁵⁶

Despite such early warnings, widespread recognition that tropical deforestation was a problem of *global* scope did not take hold until the 1970s.⁵⁷ In large part, such concern reflected the belief that tropical forest ecosystems were fragile reservoirs of immense species diversity with limited capacity to regenerate in the wake of extensive clearing for agriculture.⁵⁸ Tropical forests, in other words, began to be seen as "nonrenewable" resources, a view manifest most prominently in the realization that destruction of these ecosystems "would mean the loss of millions and millions of years of evolution, not only of plant and animal species, but also of the most complex biotic communities in the world."⁵⁹

By the 1980s, tropical deforestation had climbed to the top of the world's environmental agenda.⁶⁰ As one prominent ecologist put it:

Rainforests are being steadily depleted in all three major regions of the tropics. If present rates of misuse and overuse persist (and they are likely to accelerate), the biome, now covering 9 million square kilometers, could be reduced to remnant fragments within another half century. This would represent one of the greatest environmental impoverishments in the foreseeable future, and one of the greatest biological debacles to occur on the face of the earth.⁶¹

An explosion of books on the subject ensued, followed by numerous campaigns to save the rainforest with seemingly endless appeals on behalf of any number of threatened amphibians, mammals, and other charismatic (and not-so-charismatic) fauna.⁶² In the decades since,

56. P.W. RICHARDS, *THE TROPICAL RAIN FOREST: AN ECOLOGICAL STUDY* 404-07 (1952) (quoted material at 406).

57. See WILLIAMS, *DEFORESTING THE EARTH*, *supra* note 35, at 442-43.

58. See, e.g., A. Gomez-Pompa et al., *The Tropical Rain Forest: A Nonrenewable Resource*, 177 *SCIENCE* 762, 765 (1972) (concluding that "under present intensive use of land in tropical rain forest regions, the ecosystems are in danger of a mass extinction of most of their species"); see also Eneas Salati & Peter B. Vose, *Depletion of Tropical Rain Forests*, 12 *AMBIO* 67, 70 (1983) ("The urgency of today's deforestation is that the major remaining primary forests are tropical, and occupy an extremely fragile environment on mostly poor soils subject to rapid degradation.").

59. Gomez-Pompa et al., *supra* note 58, at 765.

60. Several government-sponsored reports from the late 1970s and early 1980s sought to document the crisis. See, e.g., U.S. DEP'T OF STATE & AGENCY FOR INT'L DEV., *PROCEEDINGS OF THE U.S. STRATEGY CONFERENCE ON TROPICAL DEFORESTATION* (1978); NORMAN MYERS, NAT'L ACAD. OF SCI., *CONVERSION OF TROPICAL MOIST FORESTS* (1980); WORLD BANK, WORLD RES. INST. & UN DEV. PROGRAM, *TROPICAL FORESTS: A CALL FOR ACTION* (1986). For overviews, see Laura Tangle, *Saving Tropical Forests*, 36 *BIOSCIENCE* 4 (1986) and Brian Johnson, *The Forestry Crisis: What Must be Done*, 13 *AMBIO* 48 (1984).

61. Norman Myers, *The Hamburger Connection: How Central America's Forests Become North America's Hamburgers*, 10 *AMBIO* 2 (1981) [hereinafter Myers, *The Hamburger Connection*].

62. See, e.g., NORMAN MYERS, *THE PRIMARY SOURCE: TROPICAL FORESTS AND OUR FUTURE* (1984); CATHERINE CAUFIELD, *IN THE RAINFOREST: REPORT FROM A STRANGE*,

multiple policy approaches have been advanced to deal with tropical deforestation, each based on a distinctive way of seeing the problem, and none of which have translated into workable solutions at scale—as evidenced by the simple fact that deforestation continues virtually unabated at some thirteen million hectares per year.⁶³

*C. Ways of Seeing, Tropical Deforestation,
and Global Forest Governance*

Generalizations about global forest governance do not come easy. Since the 1980s, with the recognition that tropical forests are in severe global crisis, conservationists and policymakers have jumped from one solution to the next, too often holding onto the false hope that each represented some sort of silver bullet. Early experiments with “debt-for-nature” swaps, for example, which viewed the problem as one of macro-economic imbalances and high developing country debt burdens, generated only a very small amount of debt forgiveness, with minimal acreage protected, while provoking significant concerns over sovereignty and indigenous rights in tropical forest countries.⁶⁴ Similarly, the 1985 Tropical Forestry Action Plan (TFAP),⁶⁵ which focused on weak forest governance and limited institutional capacity in tropical forest countries, failed to appreciate the complex drivers of deforestation and ended up creating national planning exercises that severely discounted the rights and livelihoods of forest-dependent peoples, and actually increased deforestation in some countries by opening up new areas to logging.⁶⁶

Biodiversity, a concept advanced by conservation biologists during the late 1980s and 1990s in order to highlight the massive loss of species

BEAUTIFUL, IMPERILED WORLD (1984); Erik Eckholm, *U.N. and Aid Groups Seek to Save Dwindling Third World Forests*, N.Y. TIMES, Jul. 29, 1985, at A11.

63. See 2005 FOREST RESOURCE ASSESSMENT, *supra* note 2.

64. The concept was first articulated in 1984 in an editorial by Thomas Lovejoy, then vice president of the World Wildlife Fund, in which he suggested that “debtor nations willing to protect natural resources could be made eligible for discounts or credits against their debts.” Thomas E. Lovejoy, *Aid Debtor Nations’ Ecology*, N.Y. TIMES, Oct. 4, 1984, at A31; see also William K. Reilly, *Using International Finance to Further Conservation: The First 15 Years of Debt-for-Nature Swaps*, in SOVEREIGN DEBT AT THE CROSSROADS: CHALLENGES AND PROPOSALS FOR RESOLVING THE THIRD WORLD DEBT CRISIS 197, 197–200 (Chris Jochnick & Fraser A. Preston eds., 2006) (discussing trends in debt-for-nature and opposition on sovereignty grounds); Amanda Lewis, *The Evolving Process of Swapping Debt for Nature*, 10 COLO. J. INT’L ENVTL. L. & POL’Y 431, 460–66 (1999) (discussing key criticisms of debt-for-nature swaps).

65. See FAO, TROPICAL FORESTRY ACTION PLAN (1985). TFAP was a joint effort of FAO, the World Bank, the United Nations Development Program (UNDP), and the World Resources Institute (WRI). See Robert Winterbottom, *The Tropical Forestry Action Plan: Is it Working?*, 15 NAPA BULLETIN 60, 64 (1994).

66. See ROBERT WINTERBOTTOM, TAKING STOCK: THE TROPICAL FORESTRY ACTION PLAN AFTER FIVE YEARS 3, 23–24 (1990) (discussing increased deforestation during the five years, 1985–90, that TFAP was in operation).

and environmental services associated with tropical deforestation,⁶⁷ was memorialized in the 1992 Convention on Biological Diversity.⁶⁸ Viewing tropical deforestation as a fundamental crisis of value, biodiversity advocates facilitated a significant expansion in protected areas⁶⁹ as an effort to triage the accelerating loss of species, and motivated substantial work on valuation of and payments for ecosystem services.⁷⁰ As with previous efforts, however, the biodiversity approach to tropical deforestation, although immensely important in advancing conservation, has been unable to alter the basic incentives driving deforestation and incapable of supporting governance solutions sufficient to address the problem at scale.⁷¹ In similar fashion, efforts to frame tropical

67. See WILLIAMS, *DEFORESTING THE EARTH*, *supra* note 35, at 411 (“The destruction of the world’s botanical abundance and diversity—the bulk of which probably lies in the tropical moist forests—has been the most important factor in the rising awareness and concern about deforestation. Within about 10 years, between 1986 and 1996, biodiversity moved from being an unknown term to becoming a global byword and the subject of an international convention signed by over 150 nations. Indeed, it is almost synonymous with deforestation.”); DAVID TAKACS, *THE IDEA OF BIODIVERSITY: PHILOSOPHIES OF PARADISE* (1996) (tracing history of the biodiversity concept). According to the best estimates of conservation biologists, more than half of the Earth’s terrestrial species live in tropical forests. See MILLENNIUM ECOSYSTEM ASSESSMENT, *ECOSYSTEMS AND HUMAN WELL-BEING: VOLUME 1: CURRENT STATE AND TRENDS* 601 (Rashid Hassan, Robert Scholes & Neville Ash eds., 2005) (“Tropical Forests cover less than 10 percent of the Earth’s land area but harbor between 50 percent and 90 percent of Earth’s terrestrial species.”). Anecdotes of the impossibly luxuriant nature of these forests have become commonplace. E.O. Wilson, for example, tells the story of a single tree in the Peruvian Amazon that contains 43 ant species belonging to 26 genera, roughly equal to the entire ant fauna of the British Isles. See E.O. Wilson, *The Current State of Biological Diversity*, in *BIODIVERSITY* 1, 9 (E.O. Wilson ed., 1988).

68. Convention on Biological Diversity, *opened for signature* June 1992, 31 I.L.M. 818, 1760 U.N.T.S. 143.

69. See Lisa Naughton-Treves et al., *The Role of Protected Areas in Conserving Biodiversity and Sustaining Local Livelihoods*, 30 ANN. REV. ENV’T & RESOURCES 219, 220 (2005) (noting that “[o]ver the past 25 years, the area of land under legal protection has increased exponentially” and that “[d]uring that same period, biodiversity, a term once solely considered by scientists, has moved to center stage of global environmental debates”); see also *id.* at 232–39 (discussing the role of protected areas in conserving tropical forests); Anthony B. Rylands & Katrina Brandon, *Brazilian Protected Areas*, 19 CONSERVATION BIOLOGY 612, 615–16 (2005) (discussing the explosive growth of protected areas in Brazil since the mid-1980s).

70. See, e.g., NAT’L RESEARCH COUNCIL, *VALUING ECOSYSTEM SERVICES: TOWARD BETTER ENVIRONMENTAL DECISION MAKING* (2005); James Salzman et al., *Protecting Ecosystem Services: Science, Economics, and Law*, 20 STAN. ENVTL. L.J. 309 (2001); Barton H. Thompson, Jr., *Markets for Nature*, 25 WM. & MARY ENVTL. L. & POL’Y REV. 26 (2000); Gretchen C. Daily et al., *The Value of Nature and the Nature of Value*, 289 SCIENCE 395 (2000); Robert Costanza et al., *The Value of the World’s Ecosystem Services and Natural Capital*, 387 NATURE 253 (1997).

71. See Daniel C. Nepstad, *Governing the World’s Forests*, in *CONSERVING BIODIVERSITY: REPORT OF THE ASPEN INSTITUTE* 37, 40 (B. Babbitt & J. Sarukhán eds., 2004) (“The number of plant and animal species contained in a forested landscape declines precipitously only as forest clearing surpasses 70 or 80 percent. By focusing on species conservation in the world’s remaining blocks of forest, we run the risk of developing conservation strategies that are simply not ambitious enough.”); MILLENNIUM ECOSYSTEM ASSESSMENT, *supra* note 67, at 34 (concluding

deforestation as a crisis of international trade and unsustainable consumption practices in the North, whether from illegal logging or from trade in agricultural commodities directed at feeding western diets (what one commentator referred to as the “hamburger connection”⁷²), have thus far had no discernible impact on the problem—either through public intergovernmental efforts such as the International Tropical Timber Organization (ITTO)⁷³ or through private forest certification schemes such as the independent Forest Stewardship Council.⁷⁴ Finally, the push since the early 1990s to fashion a comprehensive international legal instrument on forests has been a spectacular failure, foundering on the fundamental conflict between the conception of tropical forests as the “common heritage of mankind” and forests as sovereign national resources, as well as the perennial inadequacy of donor country financing.⁷⁵ Thus, the most recent manifestation of this effort, the UN Forum on Forests,⁷⁶ succeeded, after fifteen years of work to secure a new legal instrument, in adopting the “Non-Legally Binding Instrument on Sustainable Management of All Types of Forests.”⁷⁷ The name says it all.

In sum, the various efforts of the past several decades to construct a workable global forest governance regime have been marked by repeated failures and false starts, with few notable success stories. Despite widespread recognition that tropical forests have been in “crisis” since

that “[t]he mere act of quantifying the value of ecosystem services cannot by itself change the incentives affecting their use or misuse”).

72. Myers, *The Hamburger Connection*, *supra* note 61.

73. The ITTO was established in the 1980s as an intergovernmental forum of producing and consuming countries to promote sustainable management of tropical forests. See Int’l Tropical Timber Org. [ITTO], About ITTO, http://www.itto.int/en/about_itto/ (last visited July 7, 2009); DAVID HUMPHREYS, FOREST POLITICS: THE EVOLUTION OF INTERNATIONAL COOPERATION 55–57 (1996) (discussing shortcomings of the ITTO regime).

74. See Errol Meidinger, *The Administrative Law of Global Private-Public Regulation: The Case of Forestry*, 17 EUR. J. INT’L L. 47, 48 (2006) (Italy) (characterizing forest certification as “an extensive global system of forestry regulation”); Benjamin Cashore et al., *Introduction: Forest Certification in Analytical and Historical Perspective*, in CONFRONTING SUSTAINABILITY: FOREST CERTIFICATION IN DEVELOPING AND TRANSITIONING COUNTRIES 7, 8 (Benjamin Cashore et al. eds., 2006) (observing that “forest certification has had limited uptake in most developing countries”).

75. See Radoslav S. Dimitrov, *Hostage to Norms: States, Institutions and Global Forest Politics*, 5 GLOBAL ENVTL. POL. 1, 7 (2005) (discussing history of efforts to develop international legal instrument on forests).

76. *Id.* at 11 (describing the UN Forum on Forests as “collectively and purposefully designed to be an empty eggshell: it has no mandate for decision-making, leaves everything for countries to do, lets them choose what they want to do, does not provide them with financial assistance to do it, and has no right to hold them accountable for the results of their inaction”).

77. See Katharina Kunzmann, *The Non-Legally Binding Instrument on Sustainable Management of All Types of Forests—Towards a Legal Regime for Sustainable Forest Management?*, 9 GERMAN L.J. 981 (2008) (discussing the 2007 principles, which passed the UN General Assembly in December 2007).

the early 1980s,⁷⁸ the international community has lurched from one policy approach to another, throwing too little money and too many plans at the problem and hoping for the best, without any overall effort to forge a coherent, performance-based approach that addresses directly the structural tensions embedded in forest governance and the basic forces driving forest destruction. Explanations of the failure of global forest governance have focused on a variety of factors, including the tremendous variability in the forces driving deforestation, deep-seated conflicts over sovereignty and control of forest resources, and limited institutional and forest governance capacities at national and sub-national levels.⁷⁹ In short, efforts to frame tropical deforestation as a global problem have not translated into workable solutions in part because deforestation is not a unitary phenomenon amenable to easy generalization, much less global governance. Previous ways of seeing the problem, in other words, have not provided a sufficient foundation for effective governance, raising the important question of whether a climate policy approach to deforestation (a very different way of seeing the problem) will succeed where past efforts have failed.

III. TROPICAL DEFORESTATION AS A CLIMATE PROBLEM

A. *The Nature of the Problem*

Viewed from a global perspective, the scale of tropical deforestation is immense. The FAO's most recent Global Forest Resources Assessment reports that between 2000 and 2005, gross deforestation occurred at an annual rate of 12.9 million hectares per year, driven mainly by conversion of forests to agricultural land.⁸⁰ Since 1980, global forest cover has

78. See, e.g., WORLD COMMISSION ON FORESTS AND SUSTAINABLE DEVELOPMENT, OUR FOREST OUR FUTURE: REPORT OF THE WORLD COMMISSION ON FORESTS AND SUSTAINABLE DEVELOPMENT 2 (1999) (concluding that the world's forests are in severe crisis, threatening the long-term stability of the biosphere).

79. See Nepstad, *supra* note 71, at 45 (summarizing the reasons for failure); Deborah S. Davenport, *An Alternative Explanation for the Failure of the UNCED Forest Negotiations*, 5 GLOBAL ENVTL. POL. 105, 106 (2005) (attributing the failure to establish a global forest convention at the 1992 UN Conference on Environment and Development (UNCED) to a lack of U.S. leadership); Ronnie D. Lipschutz, *Why is There No International Forestry Law?: An Examination of International Forestry Regulation, Both Public and Private*, 19 UCLA J. ENVTL. L. & POL'Y 153, 153 (2001) (arguing that the "political economy and history of national forestry programs," which focused on conserving and managing forests for timber extraction rather than for the maintenance of environmental services, has obstructed progress toward a global forest convention in ways that are more apparent than in the case of other "global commons" issues); HUMPHREYS, *supra* note 73, at 171 (attributing lack of global forest convention to developing country concerns about sovereignty).

80. See 2005 FOREST RESOURCE ASSESSMENT, *supra* note 2, at 13, 19.

declined by some 225 million hectares.⁸¹ In the Amazon alone, roughly 17 percent of the forest—60 million hectares, an area equivalent to the size of France—has been converted to other land uses over the last thirty years.⁸² Under business-as-usual scenarios, deforestation rates are expected to continue in all regions, with particularly high rates in Africa and South America, for a total of just under 600 million hectares in cumulative losses by 2050.⁸³ One recent study of the Amazon, for example, predicted that by 2050, under business-as-usual trends, projected deforestation will have eliminated 40 percent of the existing forest.⁸⁴

And there is a massive amount of carbon at stake. Although forests cover some 30 percent of the land surface of the earth (around 4 billion hectares), they are the most significant reservoir of terrestrial carbon, containing an estimated 77 percent of all carbon stored in vegetation and 39 percent in soils.⁸⁵ Collectively, the earth's forests store almost twice the amount of carbon that is currently in the atmosphere.⁸⁶ Tropical forests alone embody a massive reservoir of terrestrial carbon (between 212 and 340 billion metric tons in above ground biomass) that, if transferred to the atmosphere, would be catastrophic for the climate.⁸⁷ Recent studies have also indicated that tropical forests continue to

81. See JOHAN ELIASCH, CLIMATE CHANGE: FINANCING GLOBAL FORESTS: THE ELIASCH REVIEW 23 (2008).

82. See C. Azevedo-Ramos, *Sustainable Development and Challenging Deforestation in the Brazilian Amazon: The Good, The Bad, and The Ugly*, 59 UNASYLVA 12, 13 (2008).

83. See Jayant Sathaye et al., *GHG Mitigation Potential, Costs and Benefits in Global Forests: A Dynamic Partial Equilibrium Approach* 28 fig.4 (Lawrence Berkeley Nat'l Lab., Working Paper No. 58291, 2005); Manuel Estrada Porrua et al., *Reducing Greenhouse Gas Emissions from Deforestation in Developing Countries: Revisiting the Assumptions* 6 (Tyndall Ctr. for Climate Research, Working Paper 115, 2007).

84. See B.S. Soares-Filo et al., *Modeling Conservation in the Amazon Basin*, 440 NATURE 520, 520 (2006) (predicting that by 2050, under business as usual, projected deforestation trends will eliminate 40 percent of the current 540 million ha (5.3 million km²) of Amazon forests, releasing approximately 117 ± 30 Gt CO₂ (32 ± 8 petagrams of carbon (PgC)) to the atmosphere).

85. See 2005 FOREST RESOURCE ASSESSMENT, *supra* note 2, at xii; IPCC WG III REPORT, *supra* note 4, at 541.

86. See PRENTICE ET AL., CLIMATE CHANGE 2001: THE SCIENTIFIC BASIS: WORKING GROUP I CONTRIBUTION TO THE THIRD ASSESSMENT REPORT OF THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE 188, 192 (J.T. Houghton et al. eds., 2001) [hereinafter 2001 IPCC REPORT] (reporting that the atmosphere contains approximately 730 PgC and that forests and their soils contain an estimated 1146–1240 PgC, or about 1.7 times more carbon than the atmosphere).

87. Global carbon stock estimate for tropical forests is from 2001 IPCC REPORT, *supra* note 86, at 192 tbl.3.2 (reporting estimates of global carbon stocks for tropical forests, including carbon in plants and soil, of 428 to 553 PgC, equivalent to 428 to 553 gigatonnes of carbon (GtC) or 428 to 553 billion metric tons of carbon, and carbon stored in plants in tropical forests of 212 to 340 GtC). For purposes of comparison, total global anthropogenic GHG emissions for 2004 are estimated at 49.0 Gt CO₂-eq (about 13 GtC). See IPCC WG III REPORT, *supra* note 4, at 97 n.1.

sequester significant amounts of additional carbon, close to 20 percent of annual global GHG emissions by some estimates.⁸⁸ Losing such forests would thus prove doubly problematic for the climate, as it would release large amounts of carbon and destroy a potentially very important “natural technology” for carbon capture and sequestration. Under the business-as-usual deforestation projections for the Amazon, some 117 billion tons of CO₂ would be released by 2050 with significant additional losses in sequestration capacity.⁸⁹ Viewed from an economic perspective, one recent estimate puts the costs of additional *climatic* disruption associated with business-as-usual emissions from deforestation at \$1 trillion by the end of this century.⁹⁰ And that number does not even begin to account for the loss of the many social and environmental co-benefits provided by forests.⁹¹

As these figures make clear, climate change is not simply a problem of fossil hydrocarbon combustion, but one that also depends fundamentally on the management of terrestrial carbon. Not only do agriculture and forestry account for a significant share of global anthropogenic GHG emissions (about 30 percent according to the most recent IPCC report),⁹² they also provide potentially significant opportunities for carbon sequestration. Viewed in the aggregate, emissions from deforestation alone, nearly all of which come from tropical deforestation, account for a greater share of global emissions than the entire transportation sector—roughly equivalent to 2005 estimates of annual CO₂ emissions from the United States or China.⁹³ Annual emissions from deforestation also swamp the total reductions expected under the Kyoto Protocol.⁹⁴ At the same time, because

88. See Simon L. Lewis et al., *Increasing Carbon Storage in Intact African Tropical Forests*, 457 NATURE 1003, 1004–05 (2009) (reporting increases in tropical forest carbon stocks in central Africa and extrapolating from this to conclude that tropical forests worldwide have been sequestering some 1.3 billion tons of carbon per year, which is almost 20 percent of global carbon emissions). But see Oliver L. Phillips et al., *Drought Sensitivity of the Amazon Rainforest*, 323 SCIENCE 1344, 1344 (2009) (concluding that the intense drought conditions in the Amazon during 2005 resulted in a significant increase in carbon emissions from the forest).

89. See Soares-Filo et al., *supra* note 84, at 520.

90. See ELIASCH, *supra* note 81, at 28–32.

91. See *id.* at 20, 49, 53.

92. See IPCC WG III REPORT, *supra* note 4, at 105 fig.1.3b (showing agricultural emissions at 13.5 percent, forestry emissions at 17.4 percent, energy supply emissions at 25.9 percent, and transportation emissions at 13.1 percent of global GHG emissions in 2004).

93. See *id.* As noted above, estimates of emissions from deforestation during the 1990s were approximately 1.6 GtC/yr, or about 5.8 GtCO₂/yr. See IPCC WG III REPORT, *supra* note 4, at 105 fig.1.3b, 543. CO₂ emissions in the United States for 2005 were 5.8 Gt/year; Chinese emissions for the same year were 5.1 GtCO₂/yr. See INT’L ENERGY ASS’N, WORLD ENERGY OUTLOOK 2007: CHINA AND INDIA INSIGHTS 199 (2007).

94. See ENERGY INFO. ADMIN., INTERNATIONAL ENERGY OUTLOOK 76 (2006) (estimating energy-related carbon dioxide emissions from participating Kyoto countries at 422

emissions from deforestation account for the largest share of emissions in many developing countries (Indonesia and Brazil, for example, rank among the top five *global* emitters when emissions from deforestation are counted⁹⁵), it is also clear that any international climate regime that is going to include meaningful emissions reductions by developing countries must attend to deforestation.

Simply put, in order to even have a chance to achieve the basic objective of the international climate regime—"stabilization of greenhouse gas concentrations in the atmosphere at a level that would avoid dangerous anthropogenic interference with the climate system"⁹⁶—reducing deforestation must be part of the effort.

B. Forests in the Current International Climate Regime

And yet, despite the significant contribution that deforestation makes to climate change, forests have long vexed international climate policy. Although the regime established by the UNFCCC and elaborated by Kyoto provides a clear foundation for including forests, based largely on a conception of forests as important sinks or reservoirs of carbon, the basic architecture of the regime (as well as climate policy in general) privileges the role of stationary sources, the energy sector, and fossil hydrocarbons, creating a fundamental unease with the technical challenges of incorporating forests and land-use change into an emissions reduction effort.⁹⁷ Consequently, the question of how forests would be accounted for in such a regime proved quite contentious during and after the negotiation of the Kyoto Protocol, leading to an uneven set of rules regarding treatment of forests and land use.⁹⁸ What emerged from the

million metric tons below the reference case in 2010 and 675 million metric tons below the reference case in 2030).

95. See WRI, NAVIGATING THE NUMBERS: GREENHOUSE GAS DATA AND INTERNATIONAL CLIMATE POLICY 111 tbl.2 (2005).

96. UNFCCC art. 2, June 12, 1992, 1771 U.N.T.S. 107, U.N. Doc. A/AC.237/18.

97. The UNFCCC provides that policies and measures to address climate change should be "comprehensive" and "cover all relevant sources, sinks, and reservoirs of greenhouse gases." *Id.* art. 3(3). The Convention further directs the Parties to "[p]romote sustainable development, and promote and cooperate in the conservation and enhancement . . . of sinks and reservoirs of all greenhouse gases . . . including biomass, forests, . . . as well as other terrestrial . . . ecosystems." *Id.* art. 4(d)(1). Building on this, the Kyoto Protocol contains several provisions intended to accommodate forests and land use—also known as Land Use, Land Use Change, and Forestry, or LULUCF. Article 3(3), for example, provides that "removals by sinks resulting from human-induced land-use change and forestry activities, limited to afforestation, reforestation, and deforestation since 1990, measured as verifiable changes in carbon stocks in each commitment period, shall be used to meet the commitments" for the Annex I Parties. Kyoto Protocol, *supra* note 5, art. 3(3). In addition, two of the three "flexibility mechanisms" created by the Kyoto Protocol (Joint Implementation under Article 6 and the Clean Development Mechanism under Article 12) allow for crediting of certain forest-related activities. *Id.* arts. 6, 12.

98. UNFCCC Land Use, *supra* note 3.

2001 Marrakesh Accords, in short, was a fairly liberal approach to accounting for forest carbon activities in the Annex I industrialized countries, and a highly restricted approach to forest projects in developing countries.⁹⁹ Under the Clean Development Mechanism (CDM), all projects aimed at avoiding deforestation in developing countries were excluded from the first Kyoto commitment period (2008–12), creating an immense gap in international climate policy.¹⁰⁰

Much of the opposition to including tropical deforestation in the Kyoto regime was driven by the distinctive politics of the forests issue in the context of larger climate policy debates, with specific concerns that liberal rules for forest sector activities under the CDM would provide a loophole for Annex I countries to avoid making “real” reductions in their energy sectors, and significant apprehension among some tropical forest countries such as Brazil about ceding control over national resources.¹⁰¹ But there were also a number of important technical concerns that posed significant obstacles to inclusion of avoided deforestation in a project-based mechanism such as the CDM. Specifically, concerns regarding leakage,¹⁰² non-permanence,¹⁰³ additionality,¹⁰⁴ and measurement and

99. *Id.*

100. *Id.*; see also Eric C. Bettelheim & Gillonne d'Origny, *Carbon Sinks and Emissions Trading under the Kyoto Protocol: A Legal Analysis*, in CAPTURING CARBON AND CONSERVING BIODIVERSITY: THE MARKET APPROACH 283, 285 (Ian R. Swingland ed., 2004) (emphasizing inconsistency between rules restricting forest activities in developing countries and those that allow Annex I countries to account for all forest activities in their own national accounting).

101. See Cathleen Fogel, *The Local, the Global, and the Kyoto Protocol*, in EARTHL Y POLITICS: LOCAL AND GLOBAL IN ENVIRONMENTAL POLITICS 103, 105 (Sheila Jasanoff & Marybeth Long Martello eds., 2004) (discussing NGO criticisms of Kyoto forest provisions as “loopholes” that would undermine the environmental integrity of the targets).

102. Leakage refers to the concern that the emissions reductions associated with a particular project or activity will simply displace the emissions-generating activity to an area outside the project boundary and, thus, any emissions reduced by the project will “leak” out by virtue of the new activity. See Ian Noble et al., *Implications of Different Definitions and Generic Issues*, in LAND USE, LAND-USE CHANGE AND FORESTRY: A SPECIAL REPORT OF THE IPCC 83–85 (Robert T. Watson et al. eds., 2000) (discussing leakage in the context of land use, land use change and forestry activities); Sandra Brown et al., *Project-Based Activities*, in LAND USE, LAND-USE CHANGE AND FORESTRY: A SPECIAL REPORT OF THE IPCC 308–14 (Robert T. Watson et al. eds., 2000) (discussing challenges of assessing and managing leakage associated with forest carbon project activities).

103. Non-permanence or reversibility refers to the concern that the carbon stored and credited as part of a particular activity will be released in the future. See Noble et al., *supra* note 102, at 85–89 (discussing issues of reversibility associated with land use, land use change, and forestry activities); Brown et al., *supra* note 102, at 315–16 (discussing reversal risks associated with forest carbon project activities).

104. Additionality typically refers to the requirement that any emissions reductions or removals achieved by the project or activity are “additional” to those that would have occurred under business-as-usual. Assessing additionality thus requires careful establishment of reliable baselines in order to evaluate project performance against the business-as-usual scenario. See IPCC WG III REPORT, *supra* note 4, at 809 (defining additionality); Brown et al., *supra* note 102, at 304–08 (discussing issues associated with establishing baselines and assessing additionality for forest carbon project activities).

monitoring were viewed as particularly challenging in the context of avoided deforestation projects. Of these, leakage was considered to be one of the more difficult problems to solve, given the challenges of ensuring that projects aimed at reducing emissions from deforestation would not simply displace emissions from within the project area to areas outside the project boundaries, thereby destroying the environmental integrity of the effort.¹⁰⁵ Non-permanence or reversibility was also considered problematic, as there appeared to be no easy way to guarantee that particular areas of protected forest would not be deforested in future years, or future commitment periods, given the distinctive biological vulnerabilities of forests combined with the lack of basic forest governance and enforcement capabilities in many tropical forest countries.¹⁰⁶ And efforts to establish reliable baselines in order to assess additionality of avoided deforestation projects proved especially challenging.¹⁰⁷ Taken together, these technical challenges underscored the difficulties associated with efforts to make deforestation an object of climate governance and insert it into a regime oriented primarily toward emissions from fossil hydrocarbons. As a result, for several years after the Marrakesh Accords, tropical deforestation was seen as too difficult to deal with through the climate regime—a problem more appropriately handled through other instruments.¹⁰⁸

105. See Noble et al., *supra* note 102, at 83–85 (discussing carbon leakage issues associated with forestry projects); Sandra Brown et al., *Issues and Challenges for Forest-Based Carbon-Offset Projects: A Case Study of the Noel Kempff Climate Action Project in Bolivia*, 5 MITIGATION & ADAPTATION STRATEGIES FOR GLOBAL CHANGE 99, 106–10 (2000) (discussing challenges of mitigating leakage associated with one of the first avoided deforestation projects).

106. See Noble et al., *supra* note 102, at 85–86 (discussing permanence challenges associated with avoided deforestation activities); Johannes Ebeling & Mai Yasué, *Generating Carbon Finance through Avoided Deforestation and Its Potential to Create Climatic, Conservation and Human Development Benefits*, 363 PHIL. TRANSACTIONS ROYAL SOC'Y B 1917, 1919 (2008) (“Permanence of emission reductions was a major controversial issue during earlier climate negotiations regarding the inclusion of forests as carbon sinks in the Kyoto Protocol. The concern was that if a newly created sink is burnt or logged, the sequestered carbon will be released back into the atmosphere and there will be no net emission reduction.”).

107. See P.M. Fearnside, *Saving Tropical Forests as a Global Warming Countermeasure: An Issue that Divides the Environmental Movement*, 39 ECOLOGICAL ECON. 167, 178–79 (2001) (“One of the criticisms frequently raised against including avoided deforestation in the CDM is that it would be impossible to establish reliable baselines. The baseline is the scenario without the mitigation project, which is compared with the observed stocks of carbon after the project to calculate the carbon gain.”).

108. See, e.g., Robert Bonnie et al., *Counting the Costs of Deforestation*, 288 SCIENCE 1763, 1764 (2000) (“Some countries and even environmental organizations believe that these [accounting] complexities cannot be overcome and that forest conservation, therefore, should not be an eligible activity under the CDM.”); Bernhard Schlamadinger et al., *Should We Include Avoidance of Deforestation in the International Response to Climate Change?*, in TROPICAL DEFORESTATION AND CLIMATE CHANGE 53, 54 (Paulo Moutinho & Stephan Schwartzman eds., 2005) (recounting technical arguments against allowing avoided deforestation activities in the Kyoto Protocol).

C. *An Emerging Consensus? Reduced Emissions from Deforestation and Forest Degradation (REDD)*

Since the mid-2000s, however, the frustrations that attended the Kyoto approach to deforestation have given way to a clear shift in favor of including deforestation, along with other forest related activities,¹⁰⁹ in any future international climate regime. The signal event in this respect came in 2005 at the UNFCCC Conference of the Parties (COP) meeting in Montreal, when a group of nine nations led by Papua New Guinea and Costa Rica, and working collectively as the Coalition for Rainforest Nations (CfRN),¹¹⁰ put forward a formal proposal introducing the concept of “Reducing Emissions from Deforestation in Developing Countries.” In addition to providing the first use of the term REDD,¹¹¹ this proposal emphasized both the global significance of emissions from tropical deforestation and the serious gap left open by the lack of any recognition of this problem in the Kyoto Protocol.¹¹² The proposal was simple and direct, calling upon the Parties to the UNFCCC “to take note of present rates of deforestation within developing nations, acknowledge the resulting carbon emissions, and consequently open dialogue to develop scientific, technical, policy, and capacity responses to address such emissions from tropical deforestation.”¹¹³ Most importantly, the proposal stated that Papua New Guinea and Costa Rica, along with other supporting countries, were “prepared to stand accountable for [their] contributions to global climate stability, provided [that] international frameworks are appropriately modified, namely through fair and equitable access to carbon emissions markets.”¹¹⁴

109. Recent discussions within the UNFCCC process have focused on a series of forest-related activities, grouped together as “REDD+,” which include REDD activities as well as conservation, sustainable management, and enhancement of forest carbon stocks. See, e.g., UNFCCC, *Draft Decision -/CP.15: Methodological Guidance for Activities Relating to Reducing Emissions from Deforestation and Forest Degradation and the Role of Conservation, Sustainable Management of Forests and Enhancement of Forest Carbon Stocks in Developing Countries* (2009) [hereinafter UNFCCC, *Methodological Guidance for Activities Relating to REDD*].

110. The original group of countries that supported the proposal by Papua New Guinea and Costa Rica included: Bolivia, Central African Republic, Chile, Congo, Democratic Republic of Congo, Dominican Republic, and Nicaragua. See Coalition for Rainforest Nations [CfRN], <http://www.rainforestcoalition.org/eng/> (last visited June 23, 2009).

111. In subsequent discussions, REDD has come to mean Reduced Emissions from Deforestation and Forest Degradation. See UNFCCC, *Bali Action Plan*, *supra* note 5 (calling for “[p]olicy approaches and positive incentives on issues relating to reducing emissions from deforestation and forest degradation in developing countries”).

112. UNFCCC, *Submission by the Governments of Papua New Guinea & Costa Rica: Reducing Emissions from Deforestation in Developing Countries: Approaches to Simulate Action*, U.N. Doc. FCCC/CP/2005/MISC.1 (Nov. 11, 2005) [hereinafter *Submission by Papua New Guinea & Costa Rica*], available at <http://unfccc.int/resource/docs/2005/cop11/eng/misc01.pdf>.

113. *Id.* at 1.

114. *Id.*

In response, and to the surprise of some observers who recalled the tortured history of forests in the Kyoto negotiations, the COP initiated a two-year process under the auspices of the Subsidiary Body for Science and Technical Advice (SBSTA)—a somewhat obscure organ of the international climate regime that exemplifies the growing importance of expert, quasi-scientific bodies in global environmental governance¹¹⁵—to review relevant scientific and technical issues and to consider “policy approaches and positive incentives” for reducing emissions from deforestation in developing countries.¹¹⁶ Through this process, as well as through broader policy debates on the post-2012 climate regime, REDD has come to occupy an important place on the international climate policy agenda.

Thus, the so-called Bali Roadmap that was agreed to at the December 2007 COP-13 meeting in Bali, Indonesia expressly directs that REDD be included in the negotiations of a post-2012 climate treaty.¹¹⁷ Since the Bali Action Plan, REDD has continued to gain traction in the broader international climate policy community, with general support for including REDD, or what is now referred to as “REDD+,”¹¹⁸ in some form in a post-2012 instrument. Accordingly, at their December 2008 meeting in Poland, the UNFCCC parties put the technical discussions regarding REDD on an accelerated track and established a process to negotiate REDD as part of a new climate treaty.¹¹⁹ More recently, at the

115. See Robin R. Churchill & Geir Ulfstein, *Autonomous Institutional Arrangements in Multilateral Environmental Agreements: A Little-Noticed Phenomenon in International Law*, 94 AM. J. INT'L L. 623, 623 (2000) (discussing key role of subsidiary bodies in elaborating international environmental law); Clark Miller, *Hybrid Management: Boundary Organizations, Science Policy, and Environmental Governance in the Climate Regime*, 26 SCI., TECH. & HUM. VALUES 478, 479–80 (2001) (analyzing the SBSTA as a “boundary organization” that works to “interpret and manage the production of scientific knowledge and its incorporation into policy making”).

116. See UNFCCC, *Reducing Emissions from Deforestation in Developing Countries: Approaches to Stimulate Action: Draft Conclusions Proposed by the President*, ¶ 2, U.N. Doc. FCCC/CP/2005/L.2 (2005).

117. See UNFCCC, *Decision 1/CP.13: Bali Action Plan*, U.N. Doc. FCCC/CP/2007/6/Add.1* (2007). The Bali meeting also took a separate, more detailed REDD decision, encouraging further work on policy approaches and methodological issues as well as the initiation of pilot projects in key countries. See UNFCCC, *Decision 2/CP.13: Reducing Emissions from Deforestation in Developing Countries: Approaches to Stimulate Action*, U.N. Doc. FCCC/CP/2007/6/Add.1* (2007).

118. See UNFCCC, *Methodological Guidance for Activities Relating to REDD*, *supra* note 109.

119. This is reflected most prominently in the draft negotiating text for a new climate treaty put forward by the Ad Hoc Working Group on Long-Term Cooperative Action under the Convention, which contains extensive provisions dealing with REDD+. See, e.g., UNFCCC, Ad Hoc Working Group on Long-Term Cooperative Action under the Convention, *Negotiating Text*, ¶¶ 106–28, U.N. Doc. FCCC/AWGLCA/2009/8 (May 19, 2009). Of course, the results (or lack thereof) of the COP-15 meeting in Copenhagen raise larger questions about the prospects for post-2012 international climate policy.

December 2009 COP-15 meeting in Copenhagen, Denmark, REDD received considerable attention and support, despite the limited overall progress of the meeting. The Copenhagen Accord expressly recognized the “crucial role of reducing emissions from deforestation and forest degradation” and called for the “immediate establishment of a mechanism” to mobilize financial resources from developed countries for capacity building and other REDD related activities.¹²⁰ Several leading industrialized countries, including the United States, pledged substantial financial assistance (some \$3.5 billion) for REDD+ activities over the next three years.¹²¹ And the COP also adopted an important decision on methodological guidance for REDD.¹²² Although it is impossible to predict at this point the precise shape of post-2012 international climate policy, REDD appears very well positioned to play a prominent role.

In its own discussions regarding post-2012 climate policy and revisions to its emissions trading scheme, the European Union has also emphasized the importance of international forest protection,¹²³ and several European governments—the United Kingdom, Germany, and France—have staked out significant positions in support of including deforestation in climate policy.¹²⁴ Likewise, in the United States, leading

120. See UNFCCC, *Draft Decision -/CP.15: Proposal by the President: Copenhagen Accord*, U.N. Doc. FCCC/CP/2009/L.7 (Dec. 18, 2009) (taking note of the Copenhagen Accord), available at http://unfccc.int/files/meetings/cop_15/application/pdf/cop15_cph_auv.pdf.

121. See Beth Daley, *3.5b Pledge Buys Climate Talks; Poorer Nations Hail Tentative Deal to Protect Forests*, BOSTON GLOBE, Dec. 17, 2009, available at http://www.boston.com/lifestyle/green/articles/2009/12/17/35b_pledge_buoys_climate_talks/?page=2.

122. UNFCCC, *Draft Decision -/CP.15: Methodological Guidance for Activities Relating to Reducing Emissions from Deforestation and Forest Degradation and the Role of Conservation, Sustainable Management of Forests and Enhancement of Forest Carbon Stocks in Developing Countries* (2009).

123. See European Commission, *Addressing the Challenges of Deforestation and Forest Degradation to Tackle Climate Change and Biodiversity Loss*, at 10, COM (2008) 645/3 (proposing to dedicate up to five percent of the auction revenues from the EU Emissions Trading Scheme as a source of financing for a Global Forest Carbon Mechanism); *Position of the European Parliament Adopted at First Reading on 17 December 2008 with a View to the Adoption of Directive 2009/.../EC of the European Parliament and of the Council Amending Directive 2003/87/EC so as to Improve and Extend the Greenhouse Gas Emission Allowance Trading System of the Community*, ¶ 36, EP-PE_TC1-COD(2008)0013 (Dec. 17, 2008) (committing the European Union to work toward establishing an internationally recognized system for reducing deforestation within the context of a post-2012 climate agreement).

124. See, e.g., U.K. DEP'T OF ENERGY AND CLIMATE CHANGE, *THE ROAD TO COPENHAGEN: THE UK GOVERNMENT'S CASE FOR AN AMBITIOUS INTERNATIONAL AGREEMENT ON CLIMATE CHANGE* 53–55 (2009) (emphasizing importance of including forests in international climate agreement with goal of halting global forest cover loss by 2030); Sigmar Gabriel, Fed. Env't Minister, F.R.G., *Statement at the International Climate Change Conference in Poznan: Germany's Contribution to Supporting Developing Countries to Reduce Emissions from Deforestation (REDD)* (Dec. 11, 2008) (expressing German government's support for REDD), available at <http://www.bmu.de/english/speeches/doc/42790.php>; Press Release, Common Position of France and Brazil on Climate Change (Nov. 14, 2009) (committing to “ensure the inclusion of REDD in the Copenhagen agreed outcome”), available

cap-and-trade bills proposed during the 110th and 111th Congresses have included provisions that would devote a percentage of U.S. emissions allowances to capacity building and supplemental reductions from forest protection activities in developing countries while also recognizing and crediting reduced emissions from deforestation under international offsets provisions.¹²⁵ At the same time, important environmental and business groups have voiced strong support for including such provisions in U.S. legislation,¹²⁶ and California and other states are actively working to find ways to bring credits for international forest protection efforts into sub-national GHG compliance regimes in the United States.¹²⁷

The growing attention to REDD as part of climate policy is also driving changes in the laws governing forests, land use, and carbon rights in tropical forest countries, putting increasing pressure on previous conceptions of forests as sovereign resources.¹²⁸ Indonesia, for example, recently adopted the world's first national-level REDD regulations, which identify eligible lands for REDD activities, establish requirements

at <https://pastel.diplomatie.gouv.fr/editorial/actual/ael2/bulletin.gb.asp?liste=20091117.gb.html#Chapitre3>.

125. See, e.g., Climate Security Act, S. 3036, 110th Cong. tit. III, pt. H (2008); American Clean Energy and Security Act of 2009, H.R. 2454 [hereinafter Waxman-Markey Bill], 111th Cong. § 743(e) & tit. III, pt. E (2009); Clean Energy Jobs and American Power Act, S. 1733, 111th Cong. §§ 744(e), 753 (2009); American Power Act, S. ____, 111th Cong. § 756(c) (as circulated in draft form May 12, 2010).

126. See, e.g., U.S. CLIMATE ACTION PARTNERSHIP [USCAP], A BLUEPRINT FOR LEGISLATIVE ACTION: CONSENSUS RECOMMENDATIONS FOR U.S. CLIMATE PROTECTION LEGISLATION 5, 10–11 (2009).

127. See CAL. AIR RES. BD., CLIMATE CHANGE PROPOSED SCOPING PLAN 38, 115 (Oct. 2008) (approved Dec. 2008) (identifying the possibility of accepting offsets in a California GHG compliance system from “those jurisdictions that demonstrate performance . . . in reducing emissions or enhancing sequestration through eligible forest carbon activities in accordance with appropriate national or sub-national accounting frameworks”). In November 2008, the Governors of California, Illinois, and Wisconsin signed a series of Memoranda of Understanding (MOUs) with four Brazilian states and two Indonesian provinces calling for cooperation in the development of “rules to ensure that forest-sector emissions reductions and sequestrations, from activities undertaken at the sub-national level, will be real, measurable, verifiable and permanent, and capable of being recognized in compliance mechanisms.” See Memorandum of Understanding Related to Reducing Greenhouse Gas Emissions from Deforestation art. 2(b) (Nov. 18, 2008). The MOU states and provinces, known formally as the Governors’ Climate and Forests Task Force, have expanded their membership to include several additional states and provinces from Brazil, Indonesia, Mexico, and Nigeria and are actively involved in developing recommendations for the relevant regulatory authorities responsible for developing rules that would allow REDD credits into GHG compliance systems. See GOVERNORS’ CLIMATE & FORESTS TASK FORCE, JOINT ACTION PLAN 2 (2009–10), available at <http://www.gcftaskforce.org/documents/GCTF-1000-2009-031.pdf>.

128. See IUCN, LEGAL FRAMEWORKS FOR REDD, IUCN ENVIRONMENTAL POLICY AND LAW PAPER NO. 77 (John Costenbader ed., 2009) (providing overview of REDD legal and policy developments in several tropical forest countries, including Brazil, Cameroon, Guyana, and Papua New Guinea); DAVID TAKACS, FOREST CARBON: LAW AND PROPERTY RIGHTS (2009) (providing overview of legal and policy issues regarding forest carbon in Brazil, Costa Rica, Indonesia, and Madagascar).

and procedures for REDD projects, create a licensing scheme to verify the effectiveness of carbon storage and distribute carbon credits, and expressly contemplate linkage with an international REDD mechanism.¹²⁹ Brazil, which vigorously opposed the inclusion of avoided deforestation under the Kyoto Protocol on sovereignty grounds, amended its national forest law in 2006 to clarify ownership of carbon rights on public concessions,¹³⁰ and created a new institution in 2008, the Amazon Fund, to channel revenues from the donor community to forest protection activities based on national accounting for REDD.¹³¹ In 2009, Brazil also passed legislation intended to simplify the land titling process and allow certain current occupants to gain legal title.¹³² And several Brazilian states are developing sub-national legal and policy frameworks for REDD.¹³³ Finally, some thirty-seven tropical forest countries are seeking to participate in the World Bank's Forest Carbon Partnership Facility (FCPF)—a \$300 million program for building REDD capacity and funding pilot activities in these countries.¹³⁴

Several factors account for this newfound enthusiasm to include deforestation as part of climate policy. First, and most important, there is an increased sense of urgency regarding the problem, marked by the growing realization that stabilizing the composition of the atmosphere at anything remotely close to what scientists consider a prudent level requires addressing emissions from deforestation.¹³⁵ Second, proposed new accounting frameworks to measure emissions from deforestation and account for emissions reductions on the basis of national and sub-national jurisdictions, as opposed to pure project-based accounting, combined with the treatment of the forest sector as a *source* of emissions rather than as a sink, allow for better integration with the existing regulatory

129. See *Tata Cara Pengurangan Emisi Dari Deforestasi Dan Degradasi Hutan (REDD) [Implementation Procedures for Reducing Emissions from Deforestation and Forest Degradation]*, No. P.30/Menhut-II/2009 (2009) (Indon.); *Tata Cara Perizinan Usaha Pemanfaatan Penyerapan Dan/Atau Penyimpanan Karbon Pada Hutan Produksi Dan Hutan Lindung [Procedures for Licensing of Commercial Utilisation of Carbon Sequestration and/or Storage in Production and Protected Forests]*, No. P.36/Menhut-II/2009 (2009) (Indon.).

130. See Lei No. 11.284, de 2 de março de 2006, D.O.U. de 3.3.2006, art. 16, ¶1 (Braz.).

131. See Decreto No. 6.527, de 1º de agosto de 2008, D.O.U. de 4.8.2008 (Braz.). For background on the Amazon Fund, see <http://www.amazonfund.gov.br/>.

132. See *Lula Signs Land Law Aimed at Reforming Amazon*, BOSTON GLOBE, June 26, 2009, available at <http://www.reuters.com/article/idUSTRE55P62M20090626>.

133. The Brazilian state of Amazonas, for example, enacted the country's first state climate change law, which, among other objectives, encourages "the creation of market instruments to enable the execution of projects for reducing deforestation emissions." *Lei sobre Mudanças Climáticas, Conservação Ambiental e Desenvolvimento Sustentável do Amazonas, PEMC-AM* [Law of Climate Change, Environmental Conservation, and Sustainable Development], State Law No. 3135 (June 5, 2007) (State of Amazonas, Brazil) arts. 2(II) & 3(I).

134. See World Bank, *Forest Carbon Partnership Facility, About the FCPF*, <http://www.forestcarbonpartnership.org/fcp/node/12> (last visited July 22, 2009).

135. See *supra* Part III.A.

architecture of mitigation policy and its emphasis on baselines, caps, emissions, and credits for reductions.¹³⁶ Third, rather than follow the failed Kyoto sequence, which sought to bring deforestation (and forest carbon in general) into the climate regime *after* commitments had been negotiated and agreed to, efforts to include forests in the post-2012 framework as well as in national and sub-national compliance regimes have proceeded as part and parcel of the overall effort to agree on reduction targets.¹³⁷ Fourth, capabilities for measuring, monitoring, and verifying reduced emissions from deforestation and forest degradation have improved significantly since Kyoto was negotiated, providing the basis for far more confidence than a decade ago.¹³⁸ Fifth, it has become increasingly clear since deforestation was placed on the international climate agenda in 2005 that it could be an important, perhaps crucial, component of any overall political deal on a post-2012 agreement, by breaking the Kyoto logjam over “common but differentiated responsibilities”¹³⁹ and providing an avenue for developing countries to move toward meaningful emissions reductions commitments.

In sum, there are many reasons why deforestation has emerged as a prominent focus of climate policy in recent years, and there appears to be considerable momentum behind the effort. One of the key claims made by this Article is that the growing acceptance of the issue by policymakers, experts, advocates, and civil society groups derives in part from the increased stability and coherence of deforestation as an object of climate governance. As the next Part will demonstrate, this novel approach to global forest governance did not emerge overnight, but was instead built up over decades on the basis of significant epistemological investments—new ways of seeing capable of rendering the varied and variable processes that constitute tropical deforestation comprehensible for purposes of climate policy. These new ways of seeing, though not sufficient by themselves to ensure the success of a climate policy approach to tropical deforestation, provided a necessary foundation for such efforts by creating the opportunity space (the conditions of possibility) for policy solutions.

136. This basic point was emphasized in the original 2005 submission by Papua New Guinea and Costa Rica: “It must be highlighted that our emphasis is carbon emissions—not ‘sinks’.” See *Submission by Papua New Guinea & Costa Rica*, *supra* note 112, at 8; see also *infra* Part IV.C.

137. See *supra* Part III.B.

138. See *infra* Parts IV.B and C.

139. See UNFCCC, *supra* note 96, art. 3(1) (“The Parties should protect the climate system . . . on the basis of equity and in accordance with their common but differentiated responsibilities and respective capabilities.”); see also Christopher D. Stone, *Common But Differentiated Responsibilities in International Law*, 98 AM. J. INT’L L. 276 (2004).

IV. MAKING DEFORESTATION AN OBJECT OF CLIMATE GOVERNANCE

Tropical deforestation had to be understood as part of the climate problem before it could be approached as an object of climate governance. Although this may seem obvious in the current context, the discussion in Part II above makes clear that many of the previous approaches to tropical deforestation—debt-for-nature, biodiversity, trade and consumption, governance and institutions—rested on different ways of seeing the problem. Each of these perspectives or framings has its own validity in terms of mobilizing efforts to deal with the problem, but each also leads to a distinctive emphasis and choice of policy instruments. As indicated, moreover, even though the climate policy approach to the deforestation problem has been percolating through the international policy community for more than a decade,¹⁴⁰ it has only recently begun to attract significant attention and is still very much “under construction.”

Emphasizing the manner in which tropical deforestation is being made into an object of climate governance directs attention to the knowledge practices and supporting infrastructures that create the conceptual space for understanding and approaching the problem as one that is amenable to a particular regulatory scheme. Rather than take the climate approach to deforestation as self-evident and fully-formed, this Article contends that the phenomena that comprise deforestation had to be actively “formatted” as a coherent object of climate governance—a process that required (and continues to require) significant investments, and one that has important implications for the structure and practice not only of climate policy but also of forest law and governance throughout the world.

Such a perspective represents a departure from standard conceptions of environmental problems in the environmental law and governance literature, which tend to “naturalize” the problems targeted for regulation rather than inquiring into how those problems get constructed as coherent (or not so coherent) objects of governance in the first place. Starting with the object of governance itself, unpacking it, and investigating the history of how it came to be offers a novel approach to the positive theory of environmental law that takes seriously the constitutive role of key scientific and technical knowledge practices in fashioning the subject matter of the field.

In the case of deforestation, two fundamental post-World War II developments in earth systems science provided the foundation for viewing this as a climate problem: carbon cycle research and the application of remote sensing techniques to global land cover change. The first provided the basis for viewing tropical forests as an important

140. See *supra* Part II.

component of the global carbon budget and, consequently, served to highlight the role that tropical deforestation (and land-use change more generally) played in global anthropogenic carbon emissions. This laid the foundation for making deforestation into a particular *kind* of problem (one amenable to global climate governance), illustrating the practice of “kind-making” that will be discussed in Part V. The second key development, remote sensing, allowed for the first truly synoptic view of changes in forest cover, sometimes with dramatic effect as evidenced by early satellite images of deforestation in the Amazon,¹⁴¹ establishing the basis for visualizing forests as terrestrial carbon stocks and as components of the earth’s carbon budget. This provided for a new form of “calculability,” manifest most prominently in the generation of regional and global mappings of forest carbon,¹⁴² that has worked to stabilize and sustain deforestation as an object of climate governance. Together these two developments proved instrumental in rendering the problem comprehensible for purposes of climate governance.

But making deforestation an object of climate governance has also required a third set of activities directed at translating forest carbon into compliance carbon. This ongoing effort involves, among other things, the construction and elaboration of key standards, accounting practices, and legal and institutional infrastructures necessary to “package” forest carbon as a fungible, compliance-grade asset. It involves, in other words, the construction of an equivalence¹⁴³ between forest carbon and other forms of compliance carbon.

141. See G.M. Woodwell et al., *Deforestation in the Tropics: New Measurements in the Amazon Basin Using Landsat and NOAA Advanced Very High Resolution Radiometer Imagery*, 92 J. GEOPHYSICAL RES. 2157, 2157–58 (1987) (providing early images of deforestation in the Brazilian Amazon using data from Landsat and the NOAA Advanced Very High Resolution Radiometer Imagery satellites).

142. See, e.g., Gregory P. Asner, *Tropical Forest Carbon Assessment: Integrating Satellite and Airborne Mapping Approaches*, 4 ENVTL. RES. LETTERS 1, 2–6 (2009) (discussing opportunities to combine satellite-based remote sensing with new airborne techniques for measuring carbon densities to develop high-resolution forest carbon maps as a baseline for monitoring changes in forest carbon stocks going forward). The Woods Hole Research Center has also initiated a multi-year project to develop a pan-tropical map of forest cover and associated carbon stocks in above-ground biomass with the express goal of providing reference maps for future REDD policy mechanisms. See Woods Hole Research Center, Pan-Tropical Mapping of Forest Cover and Above-Ground Carbon Stock, <http://whrc.org/pantropical/index.htm>. Drawing on the work of Asner and others, Google is developing a new platform that will enable “online, global-scale observation and measurement of changes in the earth’s forests” by running high-performance processing of raw satellite data through the “Google cloud.” According to Google, the new technology will provide a low-cost, publicly available, and transparent tool for forest monitoring, reporting and verification (“MRV”) to support emerging REDD policy mechanisms. See Google, *Seeing the Forest Through the Cloud* (Dec. 10, 2009), <http://googleblog.blogspot.com/2009/12/seeing-forest-through-cloud.html>.

143. As used here, the term *equivalence* is intended to capture the various conventions and techniques that allow seemingly disparate phenomena to be held together, creating “things of

Taken together, these efforts to simplify, reduce, and translate tropical forests into compliance carbon are putting significant pressure on previous ways of conceiving and governing forests. In place of traditional approaches to forests as sovereign national resources, forests are now being approached as components of the global carbon cycle and as providers of global public goods.¹⁴⁴ By valorizing the carbon embodied in the standing forest and decoupling it from the forest ecosystem, the integration of forests into emerging GHG compliance regimes represents a potentially fundamental transformation of the law governing forests at multiple levels with significant implications for traditional understandings of national territory and sovereign control of forest resources.

A. *Tropical Forests and the Global Carbon Cycle*

Research on the global carbon cycle during the post-World War II period provided the conceptual foundations for understanding tropical deforestation as a climate problem.¹⁴⁵ Chiefly concerned with understanding and calculating the fluxes among various components of the earth's carbon cycle—the atmosphere, oceans, and terrestrial biota¹⁴⁶—early carbon cycle research rested on a crude understanding of the role of forests in the earth's carbon budget, in large part because of the dominance of geochemists in constructing early models and a strong bias toward the ocean-atmosphere carbon exchange.¹⁴⁷ Indeed, not until the late 1970s did carbon cycle researchers begin to appreciate and incorporate the role of land use in the global carbon cycle, largely as a result of efforts by ecologists to refine the basic models with a better

another order." See ALAIN DESROSIÈRES, *THE POLITICS OF LARGE NUMBERS: A HISTORY OF STATISTICAL REASONING* 9 (Camille Naish trans., 1998).

144. See, e.g., PHILLIPE SANDS, *PRINCIPLES OF INTERNATIONAL ENVIRONMENTAL LAW* 546–47 (2d ed. 2003) ("Attempts by developed countries to 'internationalize' forest issues have so far been unsuccessful in legal terms, and the tropical forest resources of developing countries are carefully guarded as part of the national patrimony of these countries [T]ropical and other forests are not the 'common heritage of mankind' under international law, and were not identified as a 'common concern' to mankind in the forest principles."). Although the current international discussions over REDD have not proposed a specific change in the treatment of tropical forests under international law, it is clear that bringing tropical forests into an international climate regime will increase the pressure for a de facto internationalization of tropical forests given their role in the global carbon cycle and their importance to climate protection efforts.

145. See David M. Hart & David G. Victor, *Scientific Elites and the Making of US Policy for Climate Change Research, 1957-74*, 23 *SOC. STUD. OF SCI.* 643, 647 (1993) (describing the evolution of a coherent climate change research program in the post World War II period as the product of two distinct discourses: one focused on the carbon cycle and the other on atmospheric modeling).

146. *Id.* at 654.

147. See R.A. Houghton, *Balancing the Global Carbon Budget*, 35 *ANN. REV. EARTH & PLANETARY SCI.* 313, 314–15 (2007).

understanding of terrestrial carbon dynamics.¹⁴⁸ By the early 1980s, with growing international attention to the scale and scope of tropical deforestation, a number of ecologists began to argue for including emissions from deforestation and land use in models of the global carbon budget,¹⁴⁹ leading to an extended controversy between geochemists and ecologists over the role of the terrestrial biota in the global carbon cycle.¹⁵⁰ Suffice it to say that the ecologists prevailed. George Woodwell, one of the leading scientists urging climate modelers to attend to the importance of deforestation, summed up the situation in the early 1990s: “The special insight of the 1980s is that forests globally are much more important in determining the composition of the atmosphere on a year-to-year basis than climatologists, oceanographers, and others involved in anticipating climatic changes have recognized.”¹⁵¹ This way of seeing tropical forests as a key component of the global carbon budget represented a crucial conceptual advance in the effort to make deforestation into a particular kind of problem—one of global climate governance—illustrating the powerful influence of systems thinking in the post-World War II earth sciences.¹⁵²

Based on this understanding and in light of the high “carbon density” of tropical forests relative to other forms of land cover (forests contain twenty to one hundred times more carbon per unit area than agricultural

148. See, e.g., Bert Bolin, *Changes of Land Biota and Their Importance for the Carbon Cycle*, 196 *SCIENCE* 613, 613 (1977) (“Deforestation and the cultivation of land for agricultural purposes are examples of major changes in the land biota that may well have had significant implications for the global carbon cycle.”); Eberhard F. Brunig, *The Tropical Rain Forest—A Wasted Asset or an Essential Biospheric Resource?*, 6 *AMBIO* 187, 190 (1977) (“If forest is converted to vegetation cover types with lower biomass accumulation, large amounts of carbon dioxide will be released into the atmosphere and part of it will stay there.”); G.M. Woodwell et al., *The Biota and the World Carbon Budget*, 199 *SCIENCE* 141, 141 (1978) (concluding on the basis of convergent lines of evidence that the terrestrial biota operate as a significant source of CO₂ emissions to the atmosphere).

149. See G.M. Woodwell et al., *Global Deforestation: Contribution to Atmospheric Carbon Dioxide*, 222 *SCIENCE* 1081, 1085 (1983) (concluding that “[t]he biotic release of carbon dioxide to the atmosphere is large . . . [such that] its management will affect the CO₂ content of the atmosphere appreciably”).

150. See John Hobbie et al., *Role of Biota in Global CO₂ Balance: The Controversy*, 34 *BIOSCIENCE* 492 (1984) (discussing controversy between geochemists and ecologists regarding the role of terrestrial biota in the global carbon cycle and the contributions of deforestation to global carbon emissions).

151. George M. Woodwell, *Forests in a Warming World: A Time for New Policies*, 19 *CLIMATIC CHANGE* 245, 245 (1991).

152. See, e.g., Sheila Jasanoff, *Heaven and Earth: The Politics of Environmental Images*, in *EARTHLY POLITICS* 31, 44–45 (Sheila Jasanoff & Marybeth Long Martello eds., 2004) [hereinafter Jasanoff, *Heaven and Earth*] (discussing post-World War II developments in earth systems science and the resulting effort to develop a new kind of legibility capable of generating “facts on a planetary scale”); Peter J. Taylor, *Technocratic Optimism, H.T. Odum, and the Partial Transformation of the Ecological Metaphor after World War II*, 21 *J. HIST. BIOLOGY* 213, 214 (1988) (discussing early work on biogeochemical cycles in development of systems approach within ecology and the earth sciences).

lands),¹⁵³ it was clear that the ongoing conversion of tropical forests to agriculture and pasture was releasing significant amounts of carbon to the atmosphere, either rapidly through burning or more slowly through decay.¹⁵⁴ Under one "business-as-usual" scenario from 1990, tropical forests were projected to be "virtually eliminated from the earth in the next 50 to 100 years," releasing vast amounts of carbon to the atmosphere.¹⁵⁵ From the perspective of the global carbon cycle, this meant that policies intended to stabilize the concentration of CO₂ in the atmosphere would have to account for emissions from deforestation.¹⁵⁶ Such lessons were not lost on the newly formed Intergovernmental Panel on Climate Change (IPCC), which released its first set of assessments in 1990.¹⁵⁷ These reports recognized the importance of tropical deforestation as a source of global anthropogenic GHG emissions (perhaps as much as 20–25 percent) and identified a World Forest Conservation Protocol to a climate treaty as a possible policy response.¹⁵⁸ Subsequent IPCC assessments have elaborated on the role of forests in the carbon cycle, confirming the overall contribution of deforestation to global climate change, with the most recent assessment estimating the emissions from tropical deforestation in the 1990s at 1.6 gigatonnes of carbon per year, accounting for roughly 20 percent of total anthropogenic emissions during that time period.¹⁵⁹ Given the vast amount of carbon stored in

153. See Valentin Bellassen et al., *Reducing Emissions from Deforestation and Degradation: What Contribution from Carbon Markets?*, 6 IOP CONF. SERIES 252020, 252026 (2009).

154. See Richard A. Houghton, *The Future Role of Tropical Forests in Affecting the Carbon Dioxide Concentration of the Atmosphere*, 19 AMBIO 204, 204 (1990) (noting that carbon emissions from deforestation in the 1980s were on the order of 35 percent to 50 percent of global emissions from combustion of fossil fuels).

155. *Id.* at 209.

156. *Id.* ("Policies to stabilize the concentration of CO₂ in the atmosphere, if the stabilization is to last into the indefinite future, must include three measures: a reduction of fossil-fuel use, a cessation of deforestation, and an initiation of reforestation.").

157. See IPCC, SCIENTIFIC ASSESSMENT OF CLIMATE CHANGE: REPORT OF WORKING GROUP I (1990); IPCC, IMPACTS ASSESSMENT OF CLIMATE CHANGE: REPORT OF WORKING GROUP II (1990); IPCC, THE IPCC RESPONSE STRATEGIES: REPORT OF WORKING GROUP III (1990).

158. See R.T. Watson et al., *Greenhouse Gases and Aerosols*, in CLIMATE CHANGE: THE IPCC SCIENTIFIC ASSESSMENT: WORKING GROUP I CONTRIBUTION TO THE FIRST ASSESSMENT REPORT OF THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE 1, 13 (J.T. Houghton, G.J. Jenkins & J.J. Ephraums eds., 1990) [hereinafter *Greenhouse Gases and Aerosols*, 1990 IPCC REPORT] (estimating emissions from deforestation and land use during the 1980s at 1.6 ± 1.0 GtC/yr and emissions from fossil fuels at 5.4 ± 0.5 GtC/yr, with the result that deforestation and land use accounted for some 22 percent of global anthropogenic carbon emissions); see also IPCC, THE IPCC RESPONSE STRATEGIES: REPORT OF WORKING GROUP III 94 (1990) ("Deforestation may be responsible for one-quarter to one-fifth of global anthropogenic carbon dioxide emissions . . ."); *id.* at 103–04 (identifying a World Forest Conservation Protocol to a climate convention as a possible response option).

159. K.L. DENMAN ET AL., CLIMATE CHANGE 2007: THE PHYSICAL SCIENCE BASIS: WORKING GROUP I CONTRIBUTION TO THE FOURTH ASSESSMENT REPORT OF THE INTERGOVERNMENTAL PANEL OF CLIMATE CHANGE 518 tbl.7.2 (2007) [hereinafter IPCC WG I

tropical forests—between 212 and 340 billion metric tons in above-ground biomass, which is equivalent to more than 20–30 times total global anthropogenic CO₂ emissions in 2008¹⁶⁰—finding ways to maintain that carbon in the terrestrial biosphere and keep it from leaking into the atmosphere has emerged as an obvious and urgent part of the climate challenge.

To be sure, there are still considerable uncertainties associated with the actual role of tropical forests in the global carbon budget,¹⁶¹ a reflection of the fact that this is still very much an object “under construction,” with scientific and technical work proceeding to further refine and stabilize the basic understanding and render it comprehensible for climate governance. Such uncertainties stem from the heterogeneity of aboveground biomass,¹⁶² the complex biology underlying carbon storage in soils,¹⁶³ varying rates of deforestation,¹⁶⁴ difficulties in accounting for vegetation re-growth and/or re-clearing,¹⁶⁵ the fate of carbon that is removed from the land,¹⁶⁶ effects of past land-use change,¹⁶⁷

REPORT]. This estimate was the same as that provided in the first IPCC report in 1990. *Greenhouse Gases and Aerosols*, 1990 IPCC REPORT, *supra* note 158, at 13. The range of uncertainty reported in the 2007 report was also comparable to that from the first report. *Id.* at 13 (reporting its range of uncertainty as ± 1.1 , while the 2007 IPCC WG I REPORT, *supra*, stated its range of uncertainty as ± 1.0).

160. 2001 IPCC REPORT, *supra* note 86, at 192 tbl.3.2. Global anthropogenic CO₂ emissions for 2008 are estimated at 9.9 billion metric tons of carbon. See Le Quéré et al., *supra* note 4, at 832.

161. R.A. Houghton, *Balancing the Global Carbon Budget*, 35 ANN. REV. EARTH & PLANETARY SCI. 313, 314 (2007) [hereinafter Houghton, *Balancing the Global Carbon Budget*] (“The global carbon cycle is critical to [climate stabilization] because its processes define how emissions of carbon dioxide (CO₂) from anthropogenic activities translate into concentrations in the atmosphere.”); Navin Ramankutty et al., *Challenges to Estimating Carbon Emissions from Tropical Deforestation*, 13 GLOBAL CHANGE BIOLOGY 51, 51 (2007) (“Emissions from land-use and land-cover change are perhaps the most uncertain component of the global carbon cycle, with enormous implications for balancing the present-day carbon budget and predicting the future evolution of climate change.”); IPCC WG I REPORT, *supra* note 159, at 518 (“The land use carbon source has the largest uncertainties in the global carbon budget.”).

162. D. Schimel et al., *CO₂ and the Carbon Cycle*, in CLIMATE CHANGE 1994: RADIATIVE FORCING OF CLIMATE CHANGE 51 (R.A. Houghton et al. eds., 1995); R.A. Houghton, *Aboveground Forest Biomass and the Global Carbon Balance*, 11 GLOBAL CHANGE BIOLOGY 945, 945 (2005); see also R.A. Houghton et al., *The Spatial Distribution of Forest Biomass in the Brazilian Amazon: A Comparison of Estimates*, 7 GLOBAL CHANGE BIOLOGY 731, 731 (2001) (“The lack of agreement among estimates confirms the need for reliable determination of aboveground biomass over large areas.”); Ramankutty et al., *supra* note 161, at 55 (“[U]ncertainty in biomass estimates has been a key source of disagreement regarding estimates of carbon emissions from tropical deforestation.”).

163. See Ramankutty et al., *supra* note 161, at 55, 57; see also IPCC WG III REPORT, *supra* note 4, at 544 (“There is still limited insight regarding impacts [of climate change] on soils”).

164. Ramankutty et al., *supra* note 161, at 51, 53–54; R.A. Houghton, *Aboveground Forest Biomass and the Global Carbon Balance*, 11 GLOBAL CHANGE BIOLOGY 945, 945 (2005).

165. Ramankutty et al., *supra* note 161, at 55.

166. *Id.* at 56.

167. *Id.* at 58.

and potential feedback effects from rising temperatures and increasing atmospheric CO₂ concentrations¹⁶⁸—all of which raise the question of whether terrestrial carbon can be understood and rendered calculable with sufficient accuracy for climate policy and emerging GHG compliance regimes.

Notwithstanding such challenges, however, there is little question that carbon cycle research, as part of the broader agenda of earth systems science that has come of age during the post-World War II period, has proved instrumental in re-framing forests as components of the global carbon cycle. This new way of seeing necessarily resulted in a radical simplification of diverse tropical forest ecosystems to their functional, aggregated role in carbon cycling (forests collectively became a box or sub-unit in the larger terrestrial carbon budget, which was itself a box or sub-unit in the larger global carbon budget)¹⁶⁹ and laid the groundwork for making forest carbon a new object of environmental governance, illustrating the fundamental role of “kind-making” in environmental law. As the most recent IPCC report summed up the matter: “Forest clearing (mainly in the tropics) is a large contributor to the land use change component of the current atmospheric CO₂ budget, accounting for up to one-third of total anthropogenic emissions The future evolution of this term in the CO₂ budget is therefore of critical importance.”¹⁷⁰ Although such a statement may seem obvious today, at least to some, it rests on a distinctive way of seeing that took years, even decades, to cultivate and one that has profound implications for climate governance.

B. Remote Sensing and the Synoptic Gaze

If carbon cycle research provided the conceptual foundation for reframing tropical deforestation as an object of climate governance, remote sensing has provided the ability to view and assess changes in forest cover on a global scale, offering a previously unavailable synoptic view of tropical deforestation.¹⁷¹ This move toward a truly global

168. See IPCC WG I REPORT, *supra* note 159, at 604–05; IPCC WG III REPORT, *supra* note 4, at 564; Christopher B. Field et al., *Feedbacks of Terrestrial Ecosystems to Climate Change*, 32 ANN. REV. ENV'T & RES. 1 (2007); Christian Körner, *Through Enhanced Tree Dynamics Carbon Dioxide Enrichment May Cause Tropical Forests to Lose Carbon*, 359 PHIL. TRANSACTIONS ROYAL SOC'Y LONDON B 493 (2004).

169. See e.g., Houghton, *Balancing the Global Carbon Budget*, *supra* note 161, at 316 fig.1 (illustrating role of vegetation and land use change in global carbon cycle).

170. IPCC WG I REPORT, *supra* note 159, at 527.

171. See, e.g., Ruth DeFries, *Terrestrial Vegetation in the Coupled Human-Earth System: Contributions of Remote Sensing*, 33 ANN. REV. ENV'T & RES. 369, 383 (2008) [hereinafter DeFries, *Terrestrial Vegetation in the Coupled Human-Earth System*] (discussing the role of remote sensing in transforming understandings of terrestrial vegetation in the earth system); Eli Kintisch, *Improved Monitoring of Rainforests Helps Pierce Haze of Deforestation*, 316 SCIENCE 536 (2007); Carlos M. Souza, Jr., *Mapping Land Use of Tropical Regions from Space*, 103 PROC.

perspective resonates in very direct ways with earlier forest inventory practices that sought to develop a quantitative or statistical “picturing” of forest resources over large geographic areas.¹⁷² As such, it represents a new round in the effort to reformat the forest as an object of *calculation*—a new way of seeing that promises to serve as a foundational tool for the emerging agenda of earth systems governance.

The goal of such a synoptic view, of course, had long been apparent to those concerned with the scientific management of forests and land use. Starting in the 1930s, the U.S. Department of Agriculture deployed aerial photography to monitor agricultural lands for purposes of administering farm programs, and by the late 1940s, aerial photography was providing the basis for forest and rangeland inventories in the United States.¹⁷³ During the early 1960s, the development of multi-spectral sensing capabilities and digitalization, which allowed for computer-based processing of remote sensing data, provided more accurate and timely information regarding the state of forests.¹⁷⁴ By 1972, with the launch of the first Landsat satellite (Landsat 1), the modern era of remote sensing had arrived.¹⁷⁵ Application of these new satellite-based capabilities to forest assessments soon followed, providing levels of accuracy that matched field measurements, but at far lower cost.¹⁷⁶

During the early 1980s, researchers began using satellite data to assess the state of tropical forests.¹⁷⁷ Given the enormous and largely inaccessible areas covered by these forests, satellite-based remote sensing provided the only realistic tool for doing such assessments, offering “simple, objective techniques of measurement that can be applied over large areas.”¹⁷⁸ By the 1990s, remote sensing capabilities were being

NAT'L ACAD. SCI. 14261 (2006); Ruth DeFries et al., *Carbon Emissions from Tropical Deforestation and Regrowth Based on Satellite Observations for the 1980s and 1990s*, 99 PROC. NAT'L ACAD. SCI. 14256 (2002).

172. See Demeritt, *supra* note 44, at 433.

173. See Daniel B. Botkin et al., *Studying the Earth's Vegetation from Space*, 34 BIOSCIENCE 508, 510 (1984).

174. See *id.*

175. See NAT'L RESEARCH COUNCIL, EARTH OBSERVATIONS FROM SPACE: HISTORY, PROMISE, AND REALITY 16 (1995); NAT'L RESEARCH COUNCIL, EARTH SCIENCE AND APPLICATIONS FROM SPACE: URGENT NEEDS AND OPPORTUNITIES TO SERVE THE NATION 21 (2005); Botkin et al., *supra* note 173, at 510.

176. Botkin et al., *supra* note 173, at 510–11. In 1990, Finland became the first country to use Landsat imagery as the basis for country-wide mapping of forest variables in its National Forest Inventory. See Heather Reese et al., *Countrywide Estimates of Forest Variables Using Satellite Data and Field Data from the National Forest Inventory*, 32 AMBIO 542, 542 (2003).

177. See G.M. Woodwell et al., *Measurement of Changes in the Vegetation of the Earth by Satellite Imagery*, in THE ROLE OF TERRESTRIAL VEGETATION IN THE GLOBAL CARBON CYCLE: MEASUREMENT BY REMOTE SENSING 221 (G.M. Woodwell ed., 1984).

178. See, e.g., G.M. Woodwell et al., *Deforestation in the Tropics: New Measurements in the Amazon Basin Using Landsat and NOAA Advanced Very High Resolution Radiometer Imagery*,

widely deployed to monitor deforestation and land cover change in the tropics, with the first comprehensive global and pan-tropical maps based on remote sensing data released in the late 1990s and early 2000s.¹⁷⁹ From the start, these efforts to map tropical deforestation were directed at developing an improved understanding of the role of tropical deforestation (and terrestrial vegetation in general) in the global carbon cycle,¹⁸⁰ reinforcing the view of many ecologists that land use and deforestation were important sources of global GHG emissions.

As part of the broader trend toward satellite-based earth observation that began in the post-World War II period (in part as a product of Cold War rivalries) and has emerged in recent decades as a key component of earth systems science, the deployment of these capabilities to monitor the terrestrial biosphere is underwriting the effort to develop global institutions capable of managing various aspects of earth's biogeochemical cycles—what might be called earth systems governance.¹⁸¹ By creating “facts on a planetary scale,” remote sensing

92 J. GEOPHYSICAL RES. 2157, 2159–62 (1987) (discussing results of efforts to use satellite imagery to assess deforestation in the Amazon).

179. See William Booth, *Monitoring the Fate of Forests from Space*, 243 SCIENCE 1428, 1428 (1989) (reporting on calls from ecologists and remote sensing experts to develop and apply worldwide, “wall-to-wall” systematic assessment of deforestation); Philippe Mayaux et al., *Tropical Forest Cover Change in the 1990s and Options for Future Monitoring*, 360 PHIL. TRANSACTIONS ROYAL SOC'Y B 373, 374–75 (2005) (discussing remote sensing initiatives in the early 1990s to establish a reliable baseline inventory of tropical forest resources and cataloguing main global land-cover maps derived from remote sensing data).

180. See, e.g., NAT'L RESEARCH COUNCIL, EARTH OBSERVATIONS FROM SPACE: THE FIRST 50 YEARS OF SCIENTIFIC ACHIEVEMENTS 73 (2008) [hereinafter EARTH OBSERVATIONS FROM SPACE] (“For the first time, remote sensing made direct global observations of photosynthesis, plant growth, and ecosystem phenology possible, leading to the evolution of a global perspective on ecology.”); THE ROLE OF TERRESTRIAL VEGETATION IN THE GLOBAL CARBON CYCLE: MEASUREMENT BY REMOTE SENSING, *supra* note 177, at 7–8.

181. See, e.g., EARTH OBSERVATIONS FROM SPACE, *supra* note 180, at 1 (discussing the launch of Sputnik in 1957 as a transformative moment for earth systems science, ushering in an era of space-based observations “that have fundamentally altered our understanding of the planet”); HAROLD A. MOONEY, THE GLOBALIZATION OF ECOLOGICAL THOUGHT 49 (1998) (characterizing remote sensing as “[o]ne of the foremost technological advances in recent decades” in terms of “the amount and quality of information on Earth System processes, at frequent intervals, and at many scales of resolution”); see also William C. Clark et al., *Evaluating the Influence of Global Environmental Assessments*, in GLOBAL ENVIRONMENTAL ASSESSMENTS: INFORMATION AND INFLUENCE 2–6 (Ronald B. Mitchell et al. eds., 2006) (discussing growth and influence of large scale “global environmental assessments” over the last several decades as important components of international environmental governance); William C. Clark et al., *Acid Rain, Ozone Depletion, and Climate Change: An Historical Overview*, in 1 LEARNING TO MANAGE GLOBAL ENVIRONMENTAL RISKS: A COMPARATIVE HISTORY OF SOCIAL RESPONSES TO CLIMATE CHANGE, OZONE DEPLETION, AND ACID RAIN 22–26 (Social Learning Group eds., 2001) (describing evolution of knowledge of the earth system during the twentieth century and the related efforts to “manage” global environmental problems). On the concept of “earth systems governance,” see *supra* note 7. See also NAT'L RESEARCH COUNCIL, TOWARD AN UNDERSTANDING OF GLOBAL CHANGE: INITIAL PRIORITIES FOR U.S. CONTRIBUTIONS TO THE INTERNATIONAL GEOSPHERE-BIOSPHERE PROGRAM 2 (1988) (“[T]he

allows particular environmental problems to be understood and approached in ways (and at scales) that differ significantly from previous approaches.¹⁸² This fundamentally new way of seeing has profoundly altered our ability to visualize tropical deforestation and land cover change, providing the basis for a comprehensive, global mapping of forest carbon stocks—a new round in the simplification of forest ecosystems to calculable objects on a global scale.¹⁸³

Of course, the accurate assessment of emissions from deforestation requires more than space-based observation of changes in forest cover; it also requires quantification of the forest carbon stocks associated with changes in forest cover.¹⁸⁴ Because carbon density¹⁸⁵ varies among different forest types and conditions, field measurements are needed to calibrate or “ground truth” satellite images and translate them into an overall map of forest carbon stocks.¹⁸⁶ In the absence of extensive field-based forest inventories, which do not exist in many tropical countries, the IPCC has published guidelines for forest carbon accounting based on a default forest classification system that can be refined and elaborated as countries develop additional capabilities.¹⁸⁷ At the same time, new active remote sensing applications, based on laser technology known as

prediction and ultimate management of environmental problems inescapably require development of a new earth *system* science aimed to improve understanding of the earth as an integrated whole.”).

182. See Jasanoff, *Heaven and Earth*, *supra* note 152, at 44–45.

183. See, e.g., EARTH OBSERVATIONS FROM SPACE, *supra* note 180, at 84 (“The advent of satellite data has revolutionized our ability to characterize global land cover and monitor land-use patterns. Satellite sensors offer a synoptic view of Earth, as well as the objectivity associated with a consistent measurement and methodology for mapping the entire planet.”).

184. See IPCC, GOOD PRACTICE GUIDANCE FOR LAND USE, LAND-USE CHANGE, AND FORESTRY 3.15 (Jim Penman et al. eds., 2003) [hereinafter IPCC GOOD PRACTICE GUIDANCE]; GOF-C-GOLD, REDUCING GREENHOUSE GAS EMISSIONS FROM DEFORESTATION AND DEGRADATION IN DEVELOPING COUNTRIES: A SOURCEBOOK OF METHODS AND PROCEDURES FOR MONITORING, MEASURING, AND REPORTING, GOF-C-GOLD Report Version COP14-2, 1-11 to -13 (2009) [hereinafter GOF-C-GOLD SOURCEBOOK] (summarizing general methodologies for estimating CO₂ emissions from deforestation and discussing the IPCC approach).

185. Carbon density refers to the amount of carbon per unit area, often expressed in tons of carbon per hectare.

186. See Asner, *supra* note 142, at 2 (“Satellites thus provide an opportunity to measure changes in forest carbon caused by deforestation and forest degradation but only if carbon densities have been assessed. Traditionally, carbon densities have been assessed using field-based inventory plots, which are valuable but also expensive, time-consuming and inherently limited in geographic representativeness. . . . New approaches are needed to extend field plot networks, and to bridge the gap between field measurements and satellite observations.”).

187. See IPCC GOOD PRACTICE GUIDANCE, *supra* note 184; IPCC, 2006 IPCC GUIDELINES FOR NATIONAL GREENHOUSE GAS INVENTORIES (Simon Eggleston et al. eds., 2006) [hereinafter 2006 IPCC GUIDELINES FOR NATIONAL GREENHOUSE GAS INVENTORIES]; see also Ruth DeFries et al., *Earth Observations for Estimating Greenhouse Gas Emissions from Deforestation in Developing Countries*, 10 ENVTL. SCI. & POL’Y 385, 390 (2007) [hereinafter DeFries et al., *Earth Observations for Estimating Greenhouse Gas Emissions*].

LIDAR,¹⁸⁸ provide a basis for three-dimensional inventories of forest biomass and a possible technique for sampling across large, inaccessible areas in tropical forest countries that lack traditional forest inventory systems.¹⁸⁹

Given their many advantages, remote sensing capabilities are now being actively deployed in a number of countries for the express purpose of quantifying changes in forest cover (and forest carbon).¹⁹⁰ A majority of Annex I industrialized countries, for example, are using remote sensing techniques as a basis for their terrestrial carbon accounting in their national GHG inventory reports under the UNFCCC and, in some cases, as a basis for their own GHG compliance systems.¹⁹¹ Australia, in particular, has developed what is widely viewed as the most advanced terrestrial carbon accounting system in the world, the National Carbon Accounting System (NCAS), based on extensive use of remote sensing and geo-referenced mapping capabilities.¹⁹² Among non-Annex I countries, Brazil has developed some of the most sophisticated capabilities in the world for monitoring changes in forest cover. The Brazilian National Space Agency (INPE), for example, released its first report on deforestation in 1978 and has been producing comprehensive annual reports on the extent and rate of deforestation in the Amazon using a consistent methodology since 1988.¹⁹³ Results of the analysis of satellite imagery are published every year and made available to the public on the INPE website.¹⁹⁴ Brazil has also developed a satellite-based

188. Light Detection and Ranging ("LIDAR") sensors use lasers to measure the three-dimensional distribution of vegetation, allowing for characterization of forest structure, which can be used as a basis for estimating forest biomass (carbon) over large areas. *See* GOFC-GOLD SOURCEBOOK, *supra* note 184, at 2-107 to -108.

189. *See id.* at 2-107 to -110 (discussing advances in LIDAR applications to forest monitoring and its potential deployment as an alternative method of field measurements to assess forest biomass); *see also* Asner, *supra* note 142, at 1-10 (discussing use of LIDAR mapping techniques that, when combined with field calibration plots, can be used to generate aboveground carbon maps over very large areas, at relatively low cost and at high levels of accuracy). As discussed above, these capabilities are now being integrated into an online, transparent, publicly available platform that will use the Google "cloud" to "enable global-scale observation and measurement of changes in the earth's forests." *See* Google, *supra* note 142.

190. *See, e.g.*, FRÉDÉRIC ACHARD ET AL., GOFC-GOLD REPORT NO. 33, USE OF REMOTE SENSING IN LULUCF SECTOR, at 7 (May 2008) (reporting that 60 percent of Annex I countries reported the use of remote sensing techniques in compiling their GHG inventories).

191. *See id.*

192. *See* Australian Gov't, Dep't of Climate Change, Nat'l Carbon Accounting Sys., <http://www.climatechange.gov.au/ncas/> (last visited Sept. 2, 2009); GOFC-GOLD SOURCEBOOK, *supra* note 184, at 3-130 to -131 (describing the Australian NCAS).

193. *See* ACHARD ET AL., *supra* note 190, at 18 (quoting Brazilian official on the importance of space-based monitoring of land use change: "a task which could never be conducted without the use of space technology").

194. *See id.* INPE has also adopted a policy of open access to all remote sensing data, resulting maps, and software. *See* Hilcéa Santos Ferreira & Gilberto Câmara, *Current Status and Recent Developments in Brazilian Remote Sensing Law*, 34 J. SPACE L. 11, 15 (2008) (describing

early warning system, DETER, which provides almost real-time information on significant deforestation events.¹⁹⁵ Taken together, these various national-level activities can be seen as elements of an emerging socio-technical infrastructure for bringing forest cover under continuous observation, with the express aim of rendering forests calculable for emerging GHG compliance systems.

Building on these important national activities, a concerted international effort has emerged over the last decade to coordinate and facilitate the application of remote sensing to deforestation, with the express purpose of informing climate policy. The Global Observation of Forest and Land Cover Dynamics (GOFC-GOLD) initiative, which was established in the late 1990s as a network of international organizations, national space agencies, forestry experts, remote sensing scientists, and NGOs convened under the auspices of the FAO's Global Terrestrial Observing System (GTOS),¹⁹⁶ is "coordinat[ing] international efforts . . . to provide ongoing space-based and in-situ observations of forests and other vegetation cover, for the sustainable management of terrestrial resources and to obtain an accurate, reliable, quantitative understanding of the terrestrial carbon budget."¹⁹⁷ These efforts are feeding directly into the ongoing United Nations climate discussions on REDD, with particular attention to the technical tools, methodologies, and related institutions needed to operationalize a national accounting approach to emissions from deforestation that comports with existing emissions inventory practices in other sectors.¹⁹⁸ The overall goal is to provide the infrastructure for integrating these emissions into the post-2012 climate regime,¹⁹⁹ illustrating the importance of emerging transnational networks

INPE's de facto data policy of providing free access on the internet to "all remote sensing data received by INPE, the resulting maps, and the software for image processing and GIS").

195. See Coordenação-Geral de Observação da Terra, Sistema DETER, <http://www.obt.inpe.br/deter/> (last visited Aug. 12, 2009).

196. See GOFC-GOLD, <http://www.fao.org/gtos/gofc-gold/> (last visited Sept. 2, 2009).

197. See GOFC-GOLD, Overview, <http://www.fao.org/GTOS/gofc-gold/overview.html> (last visited Sept. 2, 2009).

198. See MARTIN HEROLD ET AL., GOFC-GOLD REPORT NO. 30, REPORT OF THE 2ND GOFC-GOLD WORKSHOP ON TROPICAL DEFORESTATION iii (2007) ("The GOFC-GOLD network has emerged as an important expert forum to provide information and technical guidance on how remote sensing tools and methods, coupled with ground-based inventories, can support policies to monitor and reduce . . . emissions [from deforestation].").

199. See GOFC-GOLD, Working Group on Earth Observations for Reducing Emissions from Deforestation, <http://www.gofc-gold.uni-jena.de/sites/deforest.php> (last visited Sept. 3, 2009); see generally GTOS/GOFC-GOLD, SUBMISSION TO UNFCCC ON THE ISSUE FOR REDUCING EMISSIONS FROM DEFORESTATION IN DEVELOPING COUNTRIES (RED-DC) (2007); RUTH DEFRIES ET AL., GOFC-GOLD REPORT NO. 26, REPORT OF THE GLOBAL TERRESTRIAL OBSERVING SYSTEM [GTOS] NO. 46, REDUCING GREENHOUSE GAS EMISSIONS FROM DEFORESTATION IN DEVELOPING COUNTRIES: CONSIDERATIONS FOR MONITORING AND MEASURING (2006).

of expertise in constituting global environmental governance regimes.²⁰⁰ To that effect, the GOFC-GOLD network recently released a “consensus” statement from the earth observation community concluding that “[a]nalysis of remotely sensed data . . . is the only practical approach to measure changes in forest area in developing countries at national scales . . . [and] [s]ince the early 1990s, changes in forest cover can be measured from space with confidence.”²⁰¹ When combined with existing IPCC guidelines for forest carbon classification and enhanced capabilities for carbon density assessment, this effort provides a possible platform for bringing deforestation into the climate regime in a manner that was not possible during the Kyoto negotiations a decade ago.²⁰²

At the same time, new image processing techniques have been developed that allow for better quantification of emissions from forest *degradation*, a phenomenon that is much harder to measure than deforestation but that contributes significantly to GHG emissions from the sector.²⁰³ Likewise, a number of new “active” remote sensing applications are emerging that hold great promise for further reducing uncertainties associated with efforts to measure and monitor forest loss and forest carbon from space. In 2006, the Japanese Space Agency launched a radar-based earth-observing satellite, the Advanced Land Observing Satellite, which deploys advanced imaging radar sensors capable of providing “wall-to-wall” high resolution cloud-free image data day or night.²⁰⁴ Similarly, new laser-based systems are being deployed on a trial basis in several countries, holding considerable promise for improved sampling of forest carbon inventories over large areas.²⁰⁵ The

200. See, e.g., Anne-Marie Slaughter & David Zaring, *Networking Goes International: An Update*, 2 ANN. REV. L. & SOC. SCI. 211 (2006) (discussing the role of transnational regulatory networks in global governance).

201. GTOS/GOFC-GOLD, SUBMISSION TO UNFCCC ON THE ISSUE FOR REDUCING EMISSIONS FROM DEVELOPING COUNTRIES (RED-DC) (2007); see also DeFries et al., *supra* note 187, at 386.

202. See *supra* Part III.B.

203. See Lisa M. Curran & Simon N. Trigg, *Sustainability Science from Space: Quantifying Forest Disturbance and Land-Use Dynamics in the Amazon*, 103 PROC. NAT'L ACAD. SCI. 12663, 12663–64 (2006) (describing Carnegie Land Analysis System (CLAS) for assessing forest degradation as a “tremendous breakthrough” offering “enhanced governance capabilities, refined regional carbon emissions estimates, and better understanding of the complex drivers of deforestation from logging and road access”); see also Gregory P. Asner et al., *Condition and Fate of Logged Forests in the Brazilian Amazon*, 103 PROC. NAT'L ACAD. SCI. 12947, 12947 (2006) (describing the CLAS approach and applying it to selective logging in the Brazilian Amazon).

204. See Woods Hole Research Center, Presentation at the UNFCCC COP-13 in Bali, Indonesia: New Eyes in the Sky: Cloud-Free Tropical Forest Monitoring for REDD with the Japanese Advanced Land Observing Satellite (ALOS) (Dec. 2007).

205. GOFC-GOLD SOURCEBOOK, *supra* note 184, at 2-107 to -110 (discussing LIDAR applications for forest carbon assessment needs); Asner, *supra* note 142 (discussing integration

ultimate goal is to develop a technology platform capable of monitoring changes in forest carbon stocks on a continuous basis over continental scales at low cost.

Like the “statistical picturing” efforts that drove forest inventories during the late nineteenth and early twentieth centuries,²⁰⁶ these new visualization capabilities allow for a new form of calculability that reduces tropical forests to their embodied carbon and their functional role in the global carbon cycle. By providing previously unavailable national, “wall-to-wall” views of deforestation since the mid-1990s, remote sensing allows deforestation, and its accompanying emissions, to be monitored at national scales in a manner that was simply not possible a decade ago.²⁰⁷ As one remote sensing expert put it: “The synoptic view from remote sensing has transformed the perceived role of terrestrial vegetation in the [Earth] system. Rather than a site-specific characteristic studied at the plot level, the global role of vegetation in carbon, water, and energy exchanges is now the norm in Earth system models.”²⁰⁸ In sum, this emerging remote sensing infrastructure has “fundamentally altered the capacity to observe and monitor land change,”²⁰⁹ providing a basis for constructing new regulatory and management strategies to integrate terrestrial carbon into global climate governance.²¹⁰

C. Translating Forest Carbon into Compliance Carbon

Conceptual advances in global carbon cycle research and an increasingly sophisticated ability to monitor forest and land cover change from space have provided the intellectual and technical tools necessary to see forests both as an important reservoir of carbon and as a large source of carbon emissions, as well as an unprecedented ability to grasp

of LIDAR mapping techniques with satellite-based remote sensing to provide a platform for tropical forest carbon assessment).

206. See Demeritt, *supra* note 44, at 433.

207. DeFries et al., *Earth Observations for Estimating Greenhouse Gas Emissions*, *supra* note 187, at 389 (“High resolution data with nearly complete global coverage are available at low or no cost for early 1990s and early 2000s These data serve a key role in establishing historical deforestation rates.”).

208. DeFries, *Terrestrial Vegetation in the Coupled Human-Earth System*, *supra* note 171, at 383.

209. B.L. Turner et al., *The Emergence of Land Change Science for Global Environmental Change and Sustainability*, 104 PROC. NAT’L ACAD. SCI. 20666, 20666 (2007).

210. To date, only a few environmental law scholars have focused on the role of remote sensing in environmental governance. See, e.g., Daniel C. Esty, *Environmental Protection in the Information Age*, 79 N.Y.U. L. REV. 115, 156–57 (2004) (discussing the role of remote sensing in environmental monitoring); Kenneth J. Markowitz, *Legal Challenges and Market Rewards to the Use and Acceptance of Remote Sensing and Digital Information as Evidence*, 12 DUKE ENVTL. L. & POL’Y F. 219, 219–20 (2002) (“Satellite remote sensing and digital systems, including geographic information systems (GIS), provide powerful tools for visualizing and solving complex legal and environmental problems.”).

changing patterns of forest cover on a global scale. These developments have provided much of the foundation for efforts to make deforestation into a coherent object of climate governance. But such efforts also depend on the ability to translate forest carbon into compliance carbon. That is, they depend on the ability to construct an *equivalence* between reduced emissions from deforestation and other emissions reductions that comports with larger carbon accounting frameworks in emerging GHG compliance regimes.²¹¹ This sort of exercise is endemic to climate policy, from the construction of GHG inventories and registries to the development of specific protocols, standards, and criteria that allow emissions of different greenhouse gases from different sectors and activities to be reduced to a common unit. As Professors Jim Salzman and J.B. Ruhl point out, the effort to develop an appropriate “currency” for ensuring fungibility is also deeply embedded in efforts to construct environmental trading markets in a whole host of areas, as well as in other “non-market” areas of environmental law such as comparative risk assessment.²¹²

The problem of equivalence is particularly challenging in the effort to assimilate forest carbon into GHG compliance systems. Indeed, efforts to bring forests into climate policy under the Kyoto Protocol have long struggled with the challenges of translating forest carbon into compliance carbon.²¹³ From the development of elaborate accounting rules for GHG inventory reporting in the land use and forest sector for the Annex I parties²¹⁴ to a whole new class of temporary emissions credits for forest sector projects under the CDM,²¹⁵ forest carbon has never fit comfortably within the Kyoto regime.

211. This notion of equivalence borrows from DESROSIÈRES, *supra* note 143, at 324 (discussing the instrumental role of “the construction of equivalence spaces” in creating and elaborating statistical systems).

212. See Salzman & Ruhl, *supra* note 30, at 611–13, 625 (emphasizing the importance of currency selection for the “structure and effectiveness” of environmental trading markets); see also Carol M. Rose, *From H₂O to CO₂: Lessons of Water Rights for Carbon Trading*, 50 ARIZ. L. REV. 91, 105 (2008) (“[E]fforts to improve the precision of property rights limit their alienability. Imprecise proxies may be more easily traded, but they fail to account for the externalities that will occur if the right is exercised in some new way or at some new location or some different time.”). Salzman and Ruhl also point out that the challenges associated with the effort to account for “trades of nonfungible commodities . . . seem remarkably similar to those faced by practitioners of cost-benefit analysis and comparative risk assessment.” See Salzman & Ruhl, *supra* note 30, at 632.

213. See *supra* Part III.B for a discussion of some of the technical challenges associated with the effort to bring forests into the Kyoto Protocol.

214. See IPCC, GOOD PRACTICE GUIDANCE, *supra* note 184; IPCC, 2006 IPCC GUIDELINES FOR NATIONAL GREENHOUSE GAS INVENTORIES, *supra* note 187.

215. UNFCCC, *Decision 19/CP.9: Modalities and Procedures for Afforestation and Reforestation Project Activities under the Clean Development Mechanism in the First Commitment Period of the Kyoto Protocol*, § K, U.N. Doc. FCCC/CP/2003/6/Add.2 (Mar. 30, 2004).

The effort to bring REDD into climate policy faces similar challenges, requiring among other things a set of common standards for defining what constitutes a forest and what counts as deforestation; accepted procedures and protocols for monitoring, measuring, and verifying changes in land cover and associated carbon stocks; and a set of conversion factors for translating changes in forest carbon and/or avoided emissions to compliance-grade emissions reductions.²¹⁶ Although this may seem a purely technical exercise, such practices play a fundamental role in many areas of climate policy and environmental regulation more generally. In particular, the success of various markets for environmental services or benefits often depends upon these basic questions of equivalence.²¹⁷ Even though these markets all *assume* fungibility, such an assumption is “more problematic than it first appears,” and efforts to extend market instruments into new areas often face significant challenges in developing currencies that facilitate trading while serving as good overall proxies for environmental quality.²¹⁸

In the effort to bring forest carbon into GHG compliance systems, the currency is well established: GHG emissions, most often quantified in units of CO₂-equivalent based on the so-called global warming potential (GWP) of the different gases relative to CO₂.²¹⁹ The challenge lies in

216. See, e.g., M. Skutsch et al., *Clearing the Way for Reducing Emissions from Tropical Deforestation*, 10 ENVTL. SCI. & POL’Y 322, 327 (2007) (discussing accounting challenges associated with bringing deforestation into climate policy); Ian Noble et al., *Implications of Different Definitions and Generic Issues*, in LAND USE, LAND-USE CHANGE, AND FORESTRY 53–126 (Robert T. Watson et al. eds., 2000) (providing detailed discussion of major definitional, accounting, and methodological issues associated with efforts to include land use and forestry in climate policy).

217. See, e.g., Donald MacKenzie, *Making Things the Same: Gases, Emission Rights and the Politics of Carbon Markets*, 34 ACCT., ORGS. & SOC’Y 440, 440 (2009) (analyzing how commensurability is established between emissions reductions activities and the role of such commensurability in providing “conditions of possibility” for emerging carbon markets); Michel Callon, *Civilizing Markets: Carbon Trading Between in vitro and in vivo Experiments*, 34 ACCT., ORGS. & SOC’Y 535, 540 (2009) (discussing the establishment and stabilization of “equivalences” between different greenhouse gases as a critical prerequisite for economic valuation and the functioning of carbon markets); Peter Levin & Wendy Nelson Espeland, *Pollution Futures: Commensuration, Commodification, and the Market for Air*, in ORGANIZATIONS, POLICY, AND THE NATURAL ENVIRONMENT: INSTITUTIONAL AND STRATEGIC PERSPECTIVES (Andrew J. Hoffman & Marc J. Ventresca eds., 2002) (examining the role of “commensuration” in creating tradable pollution permits and sustaining market-based approaches to air pollution control).

218. See Salzman & Ruhl, *supra* note 30, at 609–15.

219. The GWP concept, which was first articulated in the late 1980s as an analogue to the “[o]zone-depletion potential” concept used to assess the impacts of different ozone-depleting substances, was promoted as a tool for comparing the global warming impact of CO₂ with non-CO₂ greenhouse gases. The IPCC First Assessment Report offered a tentative embrace of the concept, which soon became the “metric of choice” for comparing the climate impact of GHGs and provided a key part of the technical foundation for the Kyoto Protocol’s embrace of a multi-gas approach. See Keith P. Shine, *The Global Warming Potential: The Need for an Interdisciplinary Retrial*, 96 CLIMATIC CHANGE 467, 467 (2009) [hereinafter Shine, GWP]. The IPCC First Assessment Report defined the GWP of a particular GHG as “the time integrated

developing and standardizing the measurement and accounting practices needed to bring emissions from deforestation into an equivalence with emissions and removals from other sources and sectors, such that the avoided emissions from forest protection efforts can be compared to and ultimately traded with emissions reductions or sequestrations in other sectors. Notwithstanding the difficulties involved in comparing the climate impacts of different GHGs,²²⁰ the primary concerns that must be addressed by such an effort are those of leakage, additionality, and non-permanence.²²¹ These concerns are particularly challenging in the effort to bring avoided deforestation into the climate regime, because the activity that is being credited rests on a counter-factual—emissions avoided relative to a particular emissions baseline or reference scenario (the additionality problem)—and because of the difficulties of ensuring the integrity of such avoided emissions over space (the leakage problem) and time (the permanence problem).²²²

In the Kyoto discussions, these concerns provided the technical grounds for much of the opposition to crediting avoided deforestation projects under the CDM.²²³ Simply put, under the CDM's project-based accounting, it proved especially difficult to ensure that forest protection efforts within the project boundary would not simply displace emissions to areas outside the project boundary, with no net reduction in emissions.²²⁴ Appropriate discounting for such emissions leakage on a

commitment to climate forcing from the instantaneous release of 1 kg of a trace gas expressed relative to that from 1 kg of carbon dioxide." The report then identified three different time horizons for evaluating GWPs (twenty, one hundred, and five hundred years). See K.P. Shine et al., *Radiative Forcing of Climate*, in CLIMATE CHANGE: THE IPCC SCIENTIFIC ASSESSMENT: WORKING GROUP I CONTRIBUTION TO THE FIRST ASSESSMENT REPORT OF THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE 58, 60 (J.T. Houghton, G.J. Jenkins & J.J. Ephraums eds., 1990) [hereinafter *Radiative Forcing*, 1990 IPCC REPORT]. The 100-year time horizon was selected, "without any clear scientific argumentation," as the basis for the GWP calculations for the six greenhouse gases regulated under the Kyoto Protocol. Katsumasa Tanaka et al., *Evaluating Global Warming Potentials with Historical Temperature*, 96 CLIMATIC CHANGE 443, 444 (2009) (discussing the GWP concept and the "arbitrariness" of the time horizon chosen for the GWP as a "fundamental shortcoming"). Obviously, different choices on time horizons would have generated different equivalences between the different GHGs.

220. See Shine, *GWP*, *supra* note 219 (discussing problems of using GWPs as a basis for comparing the climate impacts of different GHGs); see also Tanaka et al., *supra* note 219, at 444–47.

221. See definitions of these terms *supra* notes 102, 103, and 104.

222. See Noble et al., *supra* note 102, at 83–89 (discussing challenges of leakage and permanence in context of land use, land-use change, and forestry activities); Brown et al., *supra* note 102, at 304–16 (discussing issues of additionality, leakage, and permanence associated with forest carbon project activities).

223. See *supra* Part III.B.

224. See Noble et al., *supra* note 102, at 83–85 (discussing carbon leakage issues associated with forestry projects); Sandra Brown et al., *Issues and Challenges for Forest-Based Carbon-Offset Projects: A Case Study of the Noel Kempff Climate Action Project in Bolivia*, 5

project-by-project basis would have imposed massive monitoring and transactions costs, with no clear methodology to account for direct or indirect emissions leakage.²²⁵ Likewise, non-permanence proved particularly problematic in the avoided deforestation context because of the obvious difficulties of ensuring that forest stocks protected under a particular project would not be deforested in future years.²²⁶ And it appeared to be extremely difficult to ensure that any particular forest protection project was truly additional.²²⁷

The move to REDD since the mid-2000s, however, has been marked by a concerted effort to develop a new approach to accounting for forest sector emissions that resolves some of these technical challenges.²²⁸ Specifically, the shift toward jurisdiction-wide accounting (primarily at the national level), which has been made possible by advances in remote sensing and the ability to map forest cover change over large areas, combined with a focus on reducing forest sector emissions rather than the protection of carbon sinks, has placed REDD within (or closer to) an equivalence space that works for other fossil fuel related emissions, based on national caps or baselines.²²⁹ In contrast to the project-level accounting advocated in the past under the CDM and currently used in the voluntary carbon markets, national- and state-level accounting

MITIGATION & ADAPTATION STRATEGIES FOR GLOBAL CHANGE 99, 106–10 (2000) (discussing challenges of mitigating leakage associated with one of the first avoided deforestation projects).

225. See Brown et al., *supra* note 102, at 316–26 (discussing monitoring, accounting, and verification challenges associated with land use change and forestry projects).

226. See Noble et al., *supra* note 102, at 85–86 (discussing permanence challenges associated with avoided deforestation activities); Ebeling & Yasué, *supra* note 106, at 1919 (“Permanence of emission reductions was a major controversial issue during earlier climate negotiations regarding the inclusion of forests as carbon sinks in the Kyoto Protocol. The concern was that if a newly created sink is burnt or logged, the sequestered carbon will be released back into the atmosphere and there will be no net emission reduction.”).

227. See, e.g., Brown et al., *supra* note 102, at 304–08 (discussing issues associated with establishing baselines and assessing additionality for forest carbon project activities); Fearnside, *supra* note 107, at 178–79 (discussing challenges of establishing baselines for avoided deforestation projects under CDM).

228. See *supra* Part III.C.

229. Efforts within the UNFCCC to expand the scope of REDD to include other forest carbon activities, such as enhancement and sustainable management of forest carbon stocks, under the broader umbrella of REDD+, depends upon the development of accounting frameworks capable of viewing the forest sector as a whole, across the relevant jurisdiction, and providing an accurate accounting of overall emissions and removals for the different sets of eligible activities. See, e.g., UNFCCC, *Draft Decision -/CP.15, Methodological Guidance for Activities Relating to Reducing Emissions from Deforestation and Forest Degradation and the Role of Conservation, Sustainable Management of Forests and Enhancement of Forest Carbon Stocks in Developing Countries*, ¶ 1(d) (2009) (requesting developing country parties to establish “national forest monitoring systems” using forest carbon inventory approaches “for estimating, as appropriate, anthropogenic forest-related greenhouse gas emissions by sources and removals by sinks, forest carbon stocks and forest area changes”) (footnote omitted).

frameworks appear to hold a number of advantages and have received considerable support in REDD policy discussions.²³⁰

Most importantly, these jurisdictional accounting frameworks solve, or greatly reduce, some of the environmental integrity problems associated with project-based approaches. Thus, under a national accounting approach, there would be no need to demonstrate additionality for individual projects given that any reduction in the rate of deforestation relative to the national baseline or reference scenario would be deemed additional and, accordingly, eligible for crediting. Likewise, concerns about project-scale leakage are irrelevant under an approach that measures reductions in deforestation at a national scale. It does not matter, in other words, where the emissions reductions come from under the jurisdictional bubble, as long as the overall rate of deforestation and the associated emissions decline.

And because REDD is about *reducing* or *avoiding* emissions from the forest sector, it matches up much more directly with efforts to reduce or avoid emissions in other sectors (such as the combustion of fossil hydrocarbons to generate electricity or power automobiles), making the permanence challenge more tractable.²³¹ Simply put, a ton of avoided emissions from reduced deforestation is conceptually identical to a ton of avoided emissions from reduced fossil fuel use, with the same permanence issues applying (in theory) in both cases. In the former case, live carbon is left in the forest reservoir and prevented from leaking into the atmosphere. In the latter case, dead carbon is left in the geological reservoir and prevented from leaking into the atmosphere. In both cases, the permanence of the reduction is tied to the ability to maintain carbon in the respective biological or geological reservoir over some time horizon.²³²

230. See, e.g., UNFCCC, *Views on the Range of Topics and Other Relevant Information Relating to Reducing Emissions from Deforestation in Developing Countries*, 11–16, U.N. Doc. FCCC/SBSTA/2007/MISC.2 (May 2007), available at <http://unfccc.int/resource/docs/2007/sbsta/eng/misc02.pdf> (advocating national baseline approach as basis for REDD accounting); Waxman-Markey Bill, *supra* note 125, § 743(e) (identifying national and state level reductions of deforestation relative to national- or state-level baselines as eligible for international offsets); CAL. AIR RES. BD., *supra* note 127, at 38 (discussing possibility of accepting offsets from reduced emissions from deforestation “in accordance with appropriate national or sub-national accounting frameworks”).

231. See Michael Dutschke, *Fractions of Permanence—Squaring the Cycle of Sink Carbon Accounting*, 7 MITIGATION & ADAPTATION STRATEGIES FOR GLOBAL CHANGE 381, 385–94 (2002) (discussing technical approaches to dealing with the permanence issue in afforestation and reforestation projects under the CDM); Gregg Marland et al., *Accounting for Sequestered Carbon: The Question of Permanence*, 4 ENVTL. SCI. & POL’Y 259, 260 (2001) (identifying “permanence” as the “fundamental issue that is unique to sequestration projects” when compared to emissions reductions efforts and discussing various proposals to account for permanence of forest sequestration projects).

232. Noble et al. provide a technical discussion of permanence in the avoided emissions and sequestration context and note that “the effect of delaying for 1 year a given amount of fossil

To be sure, the unique biological vulnerabilities of forests²³³ relative to the long-term stability of geological reservoirs of fossil hydrocarbons suggest a greater vulnerability to future release in the case of forest carbon. But there are many economic pressures on fossil hydrocarbons, and a massive techno-economic infrastructure dedicated to extracting these resources, raising questions about the long-term permanence of avoided emissions from reductions in fossil fuel burning.²³⁴ All of which is simply another way of saying that the widely accepted view that avoided emissions are necessarily permanent is incorrect.²³⁵ The key point is that permanence in the avoided emissions context (as opposed to the sequestration context, whether biological or geological) is an artifact of the larger emissions policy, that is, whether there is an absolute quantity constraint on emissions over the relevant time horizon or some other mechanism(s) for ensuring that avoided carbon emissions stay out of the atmosphere.²³⁶ In other words, when the accounting for reduced emissions from avoided deforestation is done at the national level, permanence becomes an issue of country performance over time, akin to performance of any country relative to an emissions cap or baseline in any other sector or sectors. In this context, the permanence of any particular stand of forest stocks is not relevant. What matters is that overall forest sector emissions are under the baseline or cap over the relevant time period and, if not, that there are effective measures (such as

fuel burning or a given amount of deforestation will be to delay the release of carbon from the barrels of oil that would be burned or hectares of forest that would be deforested in subsequent years. To the extent that the emission displacement propagates forward until the end of the time horizon, the result is a 'permanent' saving." Noble et al., *supra* note 216, at 85; see also Philip M. Fearnside et al., *Accounting for Time in Mitigating Global Warming Through Land-Use Change and Forestry*, 5 MITIGATION & ADAPTATION STRATEGIES FOR GLOBAL CHANGE 239, 240 (2000) (noting that "[c]onfusion has often resulted from lumping all LUCF [Land Use Change and Forestry] activities in a single category as biotic sinks" and asserting that "in the case of avoiding deforestation in low-latitude regions, the result is more like reducing fossil fuel C [Carbon] emissions than it is like C sequestration in plantations").

233. See, e.g., Phillips et al., *supra* note 88, at 1344 (documenting significant carbon release from the Amazon rainforest during the intense drought of 2005).

234. See Howard Herzog et al., *An Issue of Permanence: Assessing the Effectiveness of Temporary Carbon Storage*, 59 CLIMATIC CHANGE 293, 294 (2003) ("[E]conomic considerations lead one to conclude that a ton of avoided [fossil fuel] emissions today will, absent an absolute quantity constraint on emissions in all regions through time, mean higher emissions in the future.").

235. See *id.* ("[T]he idea that a ton of fossil emissions avoided today is avoided forever is not necessarily an accurate characterization of the problem because that unburned fossil fuel may still be mined and burned later.").

236. See *id.* at 306 ("Permanence or lack thereof of different mitigation options is a function of the policy regime If the emissions cap is not global or cannot be maintained in perpetuity, then emissions reductions today will be subject to temporal leakage"); see also Fearnside et al., *supra* note 232, at 244 ("The cascading effect of displaced emissions depends heavily on the assumption that the C [Carbon] reserve (either forest or fossil) will last beyond the end of the time horizon.").

liability rules, insurance, or credit reserves) in place to compensate for any reversals and ensure that the atmosphere is made whole.²³⁷

Thus, in moving away from a focus on protecting sinks and crediting sequestrations at the project level (the Kyoto approach to forests) toward a policy that credits avoided emissions from reduced deforestation relative to a national baseline or cap, REDD effectively brings the forest sector into a much more robust equivalence space with other emissions reduction efforts. Viewed in this way, the challenge of translating forest carbon into compliance carbon is fundamentally about finding the right legal technologies and accounting rules to ensure equivalence with other emissions reduction efforts over time. By situating forest carbon within a particular accounting infrastructure, and by bundling reduced emissions from deforestation with a specific set of legal instruments or technologies (insurance, liability rules, credit reserves, etc.), things of a different order (compliance-grade assets) are created, opening up new spaces of equivalence and new possibilities for regulation. As will be discussed in Part V, this sort of exercise is endemic to environmental law and operates as a key knowledge practice aimed at fashioning particular objects of governance and inserting them into larger regulatory systems.

V. WAYS OF SEEING IN ENVIRONMENTAL LAW

The story of how tropical deforestation has become an object of climate governance illustrates the powerful role that scientific and technical ways of seeing play in objectifying and framing particular problems, thereby shaping the possibilities for particular legal and policy responses. Building on this study, this Part explores some of the broader implications of such an approach for environmental law, asking at a more abstract level how the formatting of particular problems shapes the content of our responses. The discussion is organized around the three mutually constitutive sets of knowledge practices, or three ways of seeing, that were instrumental in making tropical deforestation an object of climate governance: (1) kind-making, (2) calculability, and (3) equivalence.

A. *Kind-Making*

The enormous amount of scientific, technical, and institutional work that has gone into rendering the problem of deforestation comprehensible for climate governance can be seen as an exercise in

237. See Michael Dutschke & Arild Angelsen, *How Do We Ensure Permanence and Assign Liability?*, in *MOVING AHEAD WITH REDD: ISSUES, OPTIONS, AND IMPLICATIONS* 77 (Arild Angelsen ed., 2008) (discussing various approaches to permanence in context of REDD).

global “kind-making”²³⁸; that is, an exercise aimed at formatting deforestation as a particular type of problem, that of carbon management, amenable to solutions at a particular scale, that of the planet as a whole, in the context of a particular policy instrument, that of emissions reductions and trading. This practice of global kind-making, of course, is evident across a whole range of global problems (environmental and otherwise).²³⁹

In the environmental field, such global understandings derive fundamentally from the powerful influence of systems thinking and other conceptual advances in the post-World War II earth sciences; from new capabilities of measurement, visualization, modeling, and simulation (what will be discussed collectively in the next section as new forms and

238. Clark A. Miller, *Democratization, International Knowledge Institutions, and Global Governance*, 20 GOVERNANCE 325, 339 (2007) (arguing “that kind-making is a key element in the emerging authority of international institutions to order global spaces”). Miller borrows the notion of “kind-making” from philosophers and historians of science, who employ it in an effort to capture the historical construction and normalization of distinct objects and categories. See, e.g., IAN HACKING, *THE SOCIAL CONSTRUCTION OF WHAT?* 125–62 (1999) (discussing kind-making and its role in creating “child abuse” as a new domain for medical inquiry and regulation); John Dupré, *Metaphysical Disorder and Scientific Disunity*, in *THE DISUNITY OF SCIENCE: BOUNDARIES, CONTEXTS AND POWER* 101, 104–06 (Peter Galison & David J. Stump eds., 1996) (discussing philosophical debates over “natural kinds”).

239. See Miller, *supra* note 238, at 339 (noting that “[r]ecognition of the existence of new global kinds, such as the *ozone layer*, the *Earth’s climate system*, or *global financial markets*, is an essential feature of globalism and underpins the authority of claims that the management, regulation, or preservation of these systems requires worldwide cooperation”). Other examples from the environmental area where new categories or kinds have been constructed at the intersection of science and law include persistent organic pollutants (POPs) and genetically modified organisms (GMOs). See Henrik Selin & Noelle Eckley, *Science, Politics, and Persistent Organic Pollutants: The Role of Scientific Assessments in International Environmental Cooperation*, 3 INT’L ENVTL. AGREEMENTS: POL., L. & ECON. 17, 22–26 (2003) (discussing how the POPs problem was framed as a specific global kind starting in the late 1980s and the subsequent traction that the concept has gained in contemporary policy debates); Javier Lezaun, *Creating a New Object of Government: Making Genetically Modified Organisms Traceable*, 36 SOC. STUD. SCI. 499, 501–503 (2006) (discussing ways in which specific technical and administrative practices have allowed GMOs to be rendered “traceable” and, as a result, amenable to governance across global agro-food systems). Timothy Mitchell’s work analyzing how “the economy” was made into an object that could be investigated and governed is similar to the notion of “kind-making” advanced here. See, e.g., Timothy Mitchell, *The Work of Economics: How a Discipline Makes Its World*, 46 EUR. J. OF SOCIOLOGY 297, 298 (2005) (describing how “the economy” in its modern sense emerged in the mid-twentieth century as a result of socio-technical practices which “brought into being a world that for the first time could be measured and calculated as though it were a free-standing object”); TIMOTHY MITCHELL, *RULE OF EXPERTS: EGYPT, TECHNO-POLITICS, MODERNITY* 5 (2002) (“The economy did not come about as a new name for the processes of exchange that economists had always studied. It occurred as the reorganization and transformation of those and other processes, into an object that had not previously existed. The crises and forces that brought about this transformation lay partly in actions economists had always studied, but for the most part were far wider and more diverse. These ‘extraeconomic’ origins of the economy made possible new forms of value, new kinds of equivalence, new practices of calculation, new relations between human agency and the nonhuman, and new distinctions between what was real and the forms of its representation.”).

practices of calculability); and from the development of extensive social, technical, and institutional infrastructures capable of sustaining such perspectives.²⁴⁰ Think, for example, of the many ways in which climate science and its infrastructure of “worldwide data collection networks, computer models, and satellite images” have been instrumental in constructing the global climate system as “a natural object to be understood, investigated, and managed on planetary scales.”²⁴¹ None of which is to say that global climate change is somehow not real or that it is merely a social construction; rather, it is to say that our understanding of climate and climate change “has gone from . . . an aggregation of local weather patterns to . . . an ontologically unitary whole capable of being understood and managed on scales no smaller than the global itself,”²⁴² and that such an understanding has important implications for law and governance.

Understanding tropical deforestation as a problem of global carbon management thus depends upon a conceptual understanding of the earth’s forests as a single, aggregated component of the global carbon budget, as well as new synoptic infrastructures for coordinating the

240. See Paul N. Edwards, *Meteorology as Infrastructural Globalism*, 21 OSIRIS 229 (2006) [hereinafter Edwards, *Meteorology as Infrastructural Globalism*] (analyzing the development of global infrastructures for weather observation and meteorology). Edwards also emphasizes the role of standards in building and maintaining these infrastructures or networks for global monitoring and assessment. See Paul N. Edwards, “A Vast Machine”: *Standards as Social Technology*, 304 SCIENCE 827, 827 (2004) (“Behind the emerging consensus on climate change lie more than 150 years of slow, painful negotiations over global standards for measuring, recording, and communicating about the weather.”).

241. Clark A. Miller & Paul N. Edwards, *Introduction: The Globalization of Climate Science and Climate Politics*, in CHANGING THE ATMOSPHERE: EXPERT KNOWLEDGE AND ENVIRONMENTAL GOVERNANCE 1, 7 (Clark A. Miller & Paul N. Edwards eds., 2001) (emphasis omitted). The environmental historian Richard White makes a similar point: “the very ability to formulate the scales of an environmental issue, either historically or in the present, is a social product. The current focus on global scale, for example, is not just the result of a correspondence between actual global environmental problems and scholarly efforts that correctly recognize them as such Without a *social* infrastructure—an international scientific community, incredibly sensitive measuring instruments, computer modeling, an international popular media willing and able both to reduce complicated problems to simple slogans and then to repeat them across the globe, and the ability of humans to move information and themselves quickly around the planet—global warming or the loss of biodiversity, to cite only two examples, would neither be recognized as global problems nor have the same potential for spurring historical change.” Richard White, *The Nationalization of Nature*, 86 J. AM. HIST. 976, 979 (1999).

242. Clark Miller, *Climate Science and the Making of a Global Political Order*, in STATES OF KNOWLEDGE: THE CO-PRODUCTION OF SCIENCE AND SOCIAL ORDER 54 (Sheila Jasanoff ed., 2004). Miller discusses the transformative role played by General Circulation Models (GCM) of the atmosphere between the mid-1960s and the late 1980s in re-conceptualizing the climate as “an integrated global system” and in establishing the foundation for the view that “it was the entire system that was . . . at risk from human emissions of greenhouse gases.” *Id.* at 53–54; see also Mike Hulme et al., *Unstable Climates: Exploring the Statistical and Social Constructions of ‘Normal’ Climate*, 40 GEOFORUM 197, 198 (2009) (“The climatologists and meteorologists of the 19th century using standardized instruments and a series of formal statistical rules . . . turned the idea of climate into something that could be measured and quantified.”).

observation of tropical forests on a planetary scale. This new way of seeing constitutes an immensely powerful technology of simplification and legibility “dedicated to specific forms of globalist information”²⁴³ (creating new “facts on a planetary scale”²⁴⁴) that are in turn shaping the content of specific regulatory responses. The effort to construct and elaborate this way of seeing, which generates a particular understanding of the world as a whole, underwrites emerging forms of earth systems governance with significant implications for existing legal regimes governing forests, land use, and carbon rights.

Of course, the practice of kind-making in environmental law goes far beyond the global framing of particular problems. Indeed, kind-making is intimately bound up with basic practices of classification in environmental law.²⁴⁵ The categories of hazardous wastes, toxic substances, particular types of air and water pollution, threatened or endangered species, land cover classifications, and risks of various degrees of significance, to name only a few obvious examples, all depend upon elaborate taxonomic work that is rooted in historically situated scientific and technical ways of seeing. As with all classifications, some of these efforts are deeply contested and inflected with elaborate political compromise, while others are rendered invisible, seemingly natural.²⁴⁶

Beneath these basic regulatory categories, there are many additional practices of kind-making that sustain the knowledge infrastructure of environmental law. From the classification of particular diseases to the elaboration of risk factors for specific populations,²⁴⁷ from the concept of

243. Edwards, *Meteorology as Infrastructural Globalism*, *supra* note 240, at 239.

244. Jasanoff, *supra* note 152, at 45.

245. Obviously, these practices have relevance beyond the field of environmental law.

246. See GEOFFREY C. BOWKER & SUSAN LEIGH STARR, SORTING THINGS OUT: CLASSIFICATION AND ITS CONSEQUENCES 319 (1999) (“Classifications are powerful technologies. Embedded in working infrastructures they become relatively invisible without losing any of that power.”); DESROSIÈRES, *supra* note 143, at 236 (“Taxonomy is, in a way, the obscure side of both scientific and political work.”). Of course, “forms of classification,” to use the original phrase employed by Durkheim and Mauss, have received considerable attention in social theory and the sociology of knowledge since the early twentieth century. See ÉMILE DURKHEIM AND MARCEL MAUSS, PRIMITIVE CLASSIFICATION (Rodney Needham trans., Univ. of Chicago Press 1963) (1903) (providing first sociological investigation into certain “primitive forms of classification”). This Article is particularly interested in how particular forms and practices of classification shape regulation and governance. See, e.g., Pierre Bourdieu, *Rethinking the State: Genesis and Structure of the Bureaucratic Field*, 12 SOC. THEORY 1, 12–13 (1994) (analyzing “structuring structures,” which he compares to Durkheim’s “forms of classification,” as “historically constituted forms” by which “social agents construct the social world” and emphasizing the central role of the state in the contemporary era in generating and consolidating particular forms of classification).

247. For a discussion of the history of efforts to develop classification systems for diseases, including the International Classification of Diseases (ICD), see BOWKER & STARR, *supra* note 246, at 53–133. See also DESROSIÈRES, *supra* note 143, at 272–73 (discussing the origins of efforts to link certain occupations with particular diseases in order to develop “risk factors” as part of the larger effort to develop and refine the International Classification of Disease); Charles E.

threshold dose to the definition of average exposure,²⁴⁸ from the idea of biodiversity to the framework of ecosystem services,²⁴⁹ kind-making and classification perform enormously important work in environmental law, establishing the basis for organizing facts and valorizing certain normative framings that favor particular kinds of approaches. Focusing on the practice of kind-making and taxonomy generally as an object of study and investigation, rather than simply accepting them as pre-established grids or neutral tools, trains attention to the work that goes into making these classifications and how this shapes the nature and practice of environmental law.

Discounting these practices as merely “technical” activities that are somehow subordinate to law and governance misses a great deal. If we enlarge our field of vision to include the ways in which classification practices make and remake the world as an object of governance, we can work toward an understanding of environmental law and governance that recognizes the deep articulation between seemingly “technical” forms and practices, on the one hand, and “institutional” practices on the other. Kind-making matters, and more robust and stable kinds are more amenable to coherent regulatory solutions.

B. Calculability

If kind-making goes to the ways in which problems are defined as particular objects of governance, calculability goes to the practices involved in making them hold together, allowing new problems to be

Rosenberg, *Framing Disease: Illness, Society, and History*, in FRAMING DISEASE: STUDIES IN CULTURAL HISTORY xxi (Charles E. Rosenberg & Janet Golden eds., 1992) (“[D]isease classifications serve to rationalize, mediate, and legitimate relationships between individuals and institutions in a bureaucratic society.”).

248. See, e.g., JOHN WARGO, OUR CHILDREN’S TOXIC LEGACY: HOW SCIENCE AND LAW FAIL TO PROTECT US FROM PESTICIDES 172 (1998) (“[A]t what dose does a substance change from harmless, or even health-promoting, to damaging? This deceptively simple question has become the Achilles’ heel of modern U.S. environmental law.”). Wargo also discusses the “simplification of exposure and risk” embedded in the concept of average exposure and its problematic use in the regulatory sphere. See *id.* at 219–34.

249. See Takacs, *supra* note 67, at 74–75 (“Use of the term *biodiversity* represents greater sophistication both in how we conceive of conservation and in how we promote broader conservation goals It is the label for a new, synthetic discipline devoted to conservation. The word represents a new approach, but not necessarily a new entity: the terms *biological diversity*, *natural variety*, and *nature* have been around for quite a while. Under the rubric of biodiversity, these terms are repackaged to unite amorphous, diverse endeavors in a streamlined, do-or-die conservation effort with biologists at the helm.”); Richard Norgaard, *Ecosystem Services: From Eye-Opening Metaphor to Complexity Blinder*, 69 ECOLOGICAL ECON. 1219, 1219 (2010) (discussing reductionist “stock-flow” framework that underlies the concept of ecosystem services and the implications for policy); Erik Gómez-Baggethun et al., *The History of Ecosystem Services in Economic Theory and Practice: From Early Notions to Markets and Payment Schemes*, 69 ECOLOGICAL ECON. 1209 (2010) (discussing the history of the ecosystem services concept and its increasing use as a policy tool).

seen, understood, and governed—often over vast expanses of space and time.²⁵⁰ In the case of deforestation, the effort to make forests an object of calculation on a global scale has deep historical roots.²⁵¹ The quantification of tropical forests as carbon stocks and as components of the global carbon cycle represents a new round in the ongoing rationalization and simplification of forest ecosystems. In the context of REDD, the deployment of remote sensing capabilities and carbon accounting practices have provided the foundation for visualizing forest carbon stocks on a global scale—an example of how new mapping and accounting practices are opening up new possibilities for the quantification and management of terrestrial carbon.²⁵² In the process, these techniques are paving the way for the application of specific legal technologies and the creation of new carbon entitlements that work to de-couple forest carbon from its ecological context and insert it into new, increasingly global carbon value chains.²⁵³

250. There is an extensive social science and historical literature on the role of quantification and its use (and abuse) in government and public policy. This Article finds inspiration in two different, though not mutually exclusive, approaches to quantification: quantification as what Theodore Porter calls a “technology of distance” directed primarily at problems of solving trust and accountability for public officials; and quantification as a “technology of visibility”—a way of seeing and organizing particular phenomena for investigation and governance. Compare, e.g., PORTER, *supra* note 9, at ix (describing quantification as a “technology of distance” given its capacity to act as a strategy for communication “that goes beyond the boundaries of locality and community” and that seeks to “produce knowledge independent of the particular people who make it”) with Clark Miller, *New Civic Epistemologies of Quantification*, 30 SCI., TECH. & HUM. VALUES 403, 425–26 (2005) (describing quantification as a “technology of visibility” and discussing how new technologies of visualization “have helped to transform the environment into an entity to be understood, managed, and governed on scales no smaller than the globe itself”). For a specific discussion of the role of quantification and its links to accountability in law that draws upon Porter’s work, see Wendy Nelson Espeland & Berit Irene Vannebo, *Accountability, Quantification, and Law*, 3 ANN. REV. LAW & SOC. SCI. 21 (2007). Scholars working in the fields of science and technology studies have also taken measurement and quantification as important objects of inquiry. See, e.g., Andrew Barry & Don Slater, *Introduction: The Technological Economy*, 31 ECON. & SOC’Y 175, 181 (2002) (discussing the importance of “metrology and calculation” in creating “new calculable objects”); Alexandre Mallard, *Compare, Standardize and Settle Agreement: On Some Usual Metrological Problems*, 28 SOC. STUD. SCI. 571, 572 (1998) (discussing the “increasing importance of measurement and precision for society as a whole, not only for scientific practices but for a society enlightened by the quantifying spirit”). Mallard focuses specifically on what she refers to as “legal metrology,” based on the example of automobile emissions monitoring systems, as “a special way of coordinating and articulating metrological operations: of purifying them, making them visible and ‘traceable’, distributing them to different actors, embodying them in specific objects and organizations, and tying them up with procedures.” *Id.* at 574.

251. See discussion *supra* Part II.A.

252. See *supra* Part IV.B.

253. Recent studies documenting the emergence of new carbon property rights, particularly in the forest sector, include Samantha Hepburn, *Carbon Rights as New Property: The Benefits of Statutory Verification*, 31 SYDNEY L. REV. 239 (2009); Takacs, *supra* note 128; IUCN, *supra* note 128. See also Levin & Espeland, *supra* note 217, at 124, 132–33 (analyzing the role of measurement and calculability—what they refer to as “measurement regimes”—in creating new

Of course, there are many other examples of how particular practices of calculation have shaped, and are shaping, environmental law and governance. The development of standardized measures for various kinds of pollution, the deployment of new analytical techniques for monitoring the fate and transport of substances in the environment, probabilistic risk assessment, biomonitoring, the modeling and simulation of global climate change, satellite observations of earth system dynamics, and many other examples all demonstrate how the past, present, and future of environmental law are deeply bound up with calculative practices of various kinds—practices that, each in their own way, can be understood as “technologies of visibility.”²⁵⁴ Their role in environmental law and governance would be difficult to overestimate.

Yet, the standard narrative of environmental law appears to take such knowledge practices for granted, assuming that they are simply part of the technical infrastructure that supports, and thus operates largely prior to, the making of environmental law. As with kind-making and classification, however, such a view is misplaced. Calculative practices and the objects that they create and sustain are enormously important in the making of environmental law and are worthy subjects of investigation on their own terms. A few examples serve to illustrate.

In their study of water pollution control efforts on the Delaware River during the late 1960s and early 1970s, Bruce Ackerman and his colleagues demonstrated how the “pollution problem” was defined and framed in a manner “susceptible to quantification” by focusing on dissolved oxygen (DO) as a proxy for water quality.²⁵⁵ Even though DO is not a particularly useful proxy for overall water quality, it came to dominate ways of seeing the water pollution problem, contributing to the resulting policy failures.²⁵⁶ As Ackerman and his colleagues argued, “the use of DO as an index for water quality facilitates a way of thinking about the pollution problem that is fraught with danger. Once a simple number is provided as a ‘proxy’ for water quality, it may take on a life of its own, tempting all concerned to evaluate alternative programs solely in terms of the number, without asking more fundamental questions.”²⁵⁷ From this, they drew a cautionary lesson regarding how “facts” get defined and filtered in environmental policy:

For it was during the process of defining what is to count as a “fact” that the technocratic effort to chart future policy took the wrong

commodities and providing the technical infrastructure for new environmental markets) (quote is at 124).

254. Clark Miller, *New Civic Epistemologies of Quantification*, 30 SCI., TECH. & HUM. VALUES 403, 425–26 (2005).

255. See ACKERMAN ET AL., *supra* note 12, at 18–19.

256. See *id.*

257. *Id.* at 28.

course. While the technocratic intelligence seems to promise to the lay decision maker a comprehensive assay of the problem to be confronted, the fact of the matter is that, both because resources are finite and knowledge imperfect, only certain aspects of the problem can be approached with suitably “scientific” rigor and decisiveness. Thus one part of the problem is explored with intensity while other aspects—of equal or greater importance—are left in limbo. Of course, a truly comprehensive analysis of the facts is impossible in a necessarily limited period of time. All this means, however, is that the most vigorous efforts must be made to insure that the array of “facts” now *known* is not confused with the range and kinds of “facts” which *are important* for intelligent policy making.²⁵⁸

One could come up with many other examples of how a particular proxy—chosen because of its “susceptibility to quantification”—has driven a particular way of seeing in the context of environmental policy choices.²⁵⁹ And yet, this aspect of the work of Ackerman and his colleagues stands largely as a road not taken in environmental law scholarship.

Or take the many examples of how particular analytical techniques have shaped basic approaches to the understanding and regulation of toxic substances in the environment. From early efforts to trace the spread of radionuclides and synthetic organic compounds such as PCBs and DDT in the environment,²⁶⁰ to the refinement and widespread

258. *Id.* at 30.

259. Think, for example, of the use of ambient concentrations of certain air pollutants as a proxy for human health impacts under the National Ambient Air Quality Standards (NAAQS) program; the use of “excess cancer deaths” as a shorthand way of determining acceptable risk at hazardous waste sites; or the many ways that risk assessments and cost-benefit analyses of various kinds employ proxies susceptible to quantification and monetization. Numerous examples also come to mind from the conservation and natural resources fields, from the use of specific ecological indicators of various types as proxies for ecosystem integrity to the use of acreage as a “surrogate” for the environmental services provided by wetlands in wetlands mitigation. *See, e.g.,* Virginia H. Dale & Suzanne C. Beyeler, *Challenges in the Development and Use of Ecological Indicators*, 1 *ECOLOGICAL INDICATORS* 3, 5 (2001) (discussing problems associated with use of ecological indicators in facilitating narrow, oversimplified management programs); Vincent Carignan & Marc-André Villard, *Selecting Indicator Species to Monitor Ecological Integrity: A Review*, 78 *ENVTL. MONITORING & ASSESSMENT* 45, 50–52 (2002) (reviewing problems associated with the use of indicator species to monitor ecological integrity); Royal C. Gardner, *Mitigation, in WETLANDS LAW AND POLICY: UNDERSTANDING SECTION 404*, at 263 (Kim Diana Connolly et al. eds., 2005) (noting that “[w]here site-specific data are lacking, the Corps may use acreage ‘as a reasonable surrogate for no net loss of functions and values’”) (citation omitted).

260. *See, e.g.,* George M. Woodwell, *Toxic Substances and Ecological Cycles*, 216 *SCI. AM.* 24, 24 (1967) (discussing contributions of radioactive fallout studies to understanding “global, long-term ecological processes that concentrate toxic substances” in the environment); David B. Peakall & Jeffrey L. Lincer, *Polychlorinated Biphenyls: Another Long-Life Widespread Chemical in the Environment*, 20 *BIOSCIENCE* 958 (1970) (describing techniques for measuring presence of PCBs in various environmental media and animal tissues); S. Jensen et al., *DDT and PCB in Marine Animals from Swedish Waters*, 224 *NATURE* 247 (1969) (discussing early efforts

deployment of gas chromatography-mass spectrometry in the 1970s as a tool for assessing the presence of contaminants in various environmental media,²⁶¹ specific analytical techniques have made it possible to approach toxics in the environment as an object of regulation. More recently, the dramatic increase in detection limits made possible by new sampling techniques (down to the parts per trillion level and beyond), combined with increased use of biomonitoring, has made visible trace amounts of chemicals in human tissues and the environment, often challenging prevailing assumptions—whether dioxin contamination discovered in the effluent of pulp and paper mills in the mid-1980s,²⁶² perchlorate contamination of groundwater from rocket fuel facilities in the late 1990s,²⁶³ or the recently discovered presence in human and animal tissues of perfluorinated compounds used in various stain-resistant products, brominated compounds used as flame retardants, and bisphenol-A used in a variety of plastics, resins, and sealants.²⁶⁴ Such techniques, which have provided radically enhanced ways of visualizing the fate and transport of chemicals in the environment and their presence in human populations, often exceed basic understandings of the possible harms of

to identify presence of PCBs in animal tissues); George M. Woodwell et al., *DDT in the Biosphere: Where Does it Go?*, 174 SCIENCE 1101 (1971) (describing how global modeling permits appraisal of the hazards of DDT residues in the biosphere); H.L. Harrison et al., *Systems Studies of DDT Transport*, 170 SCIENCE 503 (1970) (discussing development and application of systems model for understanding long-term impacts of DDT in ecosystems).

261. See WILLIAM L. BUDDE, ANALYTICAL MASS SPECTROMETRY: STRATEGIES FOR ENVIRONMENTAL AND RELATED APPLICATIONS 5–11 (2001) (describing deployment of the first gas chromatography-mass spectrometry machines in the late 1960s and early 1970s, which underwrote substantial increases in capabilities for identifying the presence of organic contaminants in various environmental media, leading to new regulatory approaches).

262. See William Boyd, *Controlling Toxic Harms: The Struggle Over Dioxin Contamination in the Pulp and Paper Industry*, 21 STAN. ENVTL. L.J. 345, 359–61 (2002) (describing development of new analytical techniques in mid-1980s that revealed relatively high dioxin concentrations in waters previously identified as “background” streams).

263. See William E. Motzer, *Perchlorate: Problems, Detection, and Solutions*, 2 ENVTL. FORENSICS 301, 302 (2001) (describing development of new analytical techniques by the California Department of Health Services during the late 1990s that improved perchlorate detection limits by some two orders of magnitude, revealing perchlorate “in water sources not previously suspected of being contaminated”).

264. See, e.g., John L. Butenhoff et al., *The Applicability of Biomonitoring Data for Perfluorooctanesulfonate to the Environmental Public Health Continuum*, 114 ENVTL. HEALTH PERSP. 1776, 1777 (2006) (discussing development of biomonitoring techniques since late 1990s that have uncovered widespread distribution of perfluorinated compounds in humans and wildlife); Linda S. Birnbaum & Elaine A. Cohen Hubal, *Polybrominated Diphenyl Ethers: A Case Study for Using Biomonitoring to Address Risk Assessment Questions*, 114 ENVTL. HEALTH PERSP. 1770, 1771 (2006) (discussing use of biomarkers for assessing exposure to polybrominated diphenyl ethers, or PBDEs); Antonia M. Calafat et al., *Urinary Concentrations of Bisphenol A and 4-Nonylphenol in a Human Reference Population*, 113 ENVTL. HEALTH PERSP. 391, 393 (2005) (finding widespread human exposure to bisphenol-A).

exposure.²⁶⁵ At the same time, however, they have prepared the ground for and called forth new *ecological* understandings of toxic substances that emphasize interconnections and persistence, opening up new spaces for regulation.²⁶⁶

The construction and elaboration of monitoring and surveillance systems also demonstrate how practices of calculability and the creation of specific infrastructures organize and stabilize particular objects of environmental governance. Efforts to control acid rain, for example, depended fundamentally upon the development of standardized monitoring techniques and the construction of acid rain monitoring networks in Europe and the United States that allowed the problem to be defined as one of regional rather than local concern.²⁶⁷ Likewise, the development of continuous emissions monitoring systems (CEMS) provided the basis for the particular policy response of emissions trading

265. See JOSEPH V. RODRICKS, *CALCULATED RISKS: THE TOXICITY AND HUMAN HEALTH RISKS OF CHEMICALS IN OUR ENVIRONMENT* 208 (1992) ("Our ability to detect chemicals in the environment bears no relationship whatsoever to the degree of risk they pose.").

266. See, e.g., Arthur Daemmrich, *Risk Frameworks and Biomonitoring: Distributed Regulation of Synthetic Chemicals in Humans*, 13 ENVTL. HIST. 684, 685 (2008) (arguing that biomonitoring capabilities are driving changes in conceptions of risk and basic norms governing chemicals regulation); Richard Albertini et al., *The Use of Biomonitoring Data in Exposure and Human Health Risk Assessments*, 114 ENVTL. HEALTH PERSP. 1755, 1756 (2006) ("Improved analytical capabilities make possible the accurate and precise measurement of many environmental chemicals at very low levels in the tissues of the general population, thus demonstrating human exposure to and absorption of chemicals, and often their distribution, metabolism, storage, and elimination."). George Woodwell provided an early (and prescient) analysis of how new capabilities for monitoring and assessing the fate and transport of toxic substances in ecological systems altered our ways of seeing the environment. See Woodwell, *supra* note 260, at 24 ("Over the past decade detailed studies of the distribution of both radioactive debris and pesticides have revealed patterns that have surprised even biologists long familiar with the unpredictability of nature."); see also Daniel C. Esty, *Environmental Protection in the Information Age*, 79 N.Y.U. L. REV. 115, 156–57 (2004) ("Breakthroughs in nanotechnologies and small-scale sensors, however, have begun to provide a vastly improved ability to detect and measure pollutants at a fine-grained level. Similarly, remote sensing from satellites in space and other new macroscale sensor technologies appear poised to provide on-the-ground monitoring of environmental conditions from anywhere, at any time, at increasingly low cost. We thus are approaching the day when virtually all emissions will be susceptible to tagging, tracking, and measurement at relatively low cost.").

267. See William C. Clark et al., *Acid Rain, Ozone Depletion, and Climate Change: An Historical Overview*, in 1 LEARNING TO MANAGE GLOBAL ENVIRONMENTAL RISKS: A COMPARATIVE HISTORY OF SOCIAL RESPONSES TO CLIMATE CHANGE, OZONE DEPLETION, AND ACID RAIN 30–31 (Social Learning Group eds., 2001) (discussing development of European Air Chemistry Network in mid-1940s and its role in providing the foundation for efforts to understand and approach acid rain as a large-scale, regional phenomenon); Stephen Zehr, *Method, Scale, and Socio-Technical Networks: Problems of Standardization in Acid Rain, Ozone Depletion, and Global Warming Research*, 7 SCI. STUD. 47, 47–49 (1994) (discussing development of an acid rain monitoring network in the United States and its implications for policy approaches to the problem). Advances in air pollution modeling were also important in conceptualizing acid rain as a specific object of governance. See David W. Cash et al., *Knowledge Systems for Sustainable Development*, 100 PROC. NAT. ACAD. SCI. 8086, 8089 (2003) (discussing role of RAINS model in framing problem of acid rain as an object of governance).

by ensuring a degree of accuracy and standardization in measuring sulfur dioxide (SO₂) emissions needed for the SO₂ trading market.²⁶⁸ In the case of stratospheric ozone depletion, the move from a ground-based monitoring network to satellite-based observation in the late 1960s and 1970s provided a previously unavailable synoptic view of ozone depletion and atmospheric dynamics, allowing the problem to be framed as one of global scope and concern.²⁶⁹ And, of course, in the case of global climate change, the massive and continually growing network of ground- and space-based monitoring capabilities, some of which have been built up over more than a century, are instrumental in creating our basic understanding of global climate conditions and in establishing the key proxies, such as global average surface temperature, that we use to assess and calibrate such understandings.²⁷⁰

Of the many ways that practices of calculation have shaped environmental law by creating and sustaining new objects of governance, however, few are as important in the current period as modeling and simulation. From basic applications in the various scientific disciplines that support environmental law (whether in ecology, environmental engineering, epidemiology, or the earth sciences) to specific policy-oriented applications (such as the behavior of geological repositories

268. See Levin & Espeland, *supra* note 217, at 132 (“Trading emissions requires that buyers and sellers see pollution as standardized units of some scarce resource. The shift in units of analysis from rates to aggregate pollution, which was crucial for creating this conception of pollution, was accomplished largely through the development of a rigorous emissions monitoring system. The EPA was primarily responsible for designing and implementing this ‘continuous emissions monitoring system’ (CEMS).”); Paul D. Brown, *Lofty Goals, Questioned Motives, and Proffered Justifications: Regional Transport of Ground-Level Ozone and the EPA’s NO_x SIP Call*, 60 U. PITT. L. REV. 923, 967 (1999) (“CEMS [continuous emissions monitoring systems] provide a degree of certainty that the commodity sought actually exists. It protects the would-be purchaser from transacting for ‘phantom’ allowances.”).

269. See EARTH OBSERVATIONS FROM SPACE, *supra* note 180, at 38–39 (noting “rudimentary view” of stratospheric ozone distribution provided by ground-based instruments in the “pre-satellite era” compared to the “revolutionized” understanding of atmospheric dynamics, and stratospheric ozone in particular, made possible by satellite instruments); STEPHEN O. ANDERSEN & K. MADHAVA SARMA, PROTECTING THE OZONE LAYER: THE UNITED NATIONS HISTORY 5–19 (2002); Zehr, *supra* note 267, at 48; SETH CAGIN & PHILIP DRAY, BETWEEN EARTH AND SKY: HOW CFCs CHANGED OUR WORLD AND ENDANGERED THE OZONE LAYER 262–76 (1993).

270. A moment’s reflection on the concept of average global surface temperature makes apparent the tremendous challenges involved in constructing such a measure, requiring the development, elaboration, and calibration of extensive observation networks across the planet and through time and the synthesis of enormous amounts of data. See IPCC WG I REPORT, *supra* note 159, at 102 (“Despite the fact that many recent observations are automatic, the vast majority of data that go into global surface temperature calculations—over 400 million individual readings of thermometers at land stations and over 140 million individual *in situ* SST [sea surface temperature] observations—have depended on the dedication of tens of thousands of individuals for well over a century [C]entury-scale global temperature time series would not have been possible without the conscientious work of individuals and organizations worldwide dedicated to quantifying and documenting their local environment.”).

targeted for long-term storage of radioactive waste, the spread of air pollution from industrial facilities, or the response of the global climate to various emissions scenarios, to name only a few), modeling and simulation provide access to previously invisible phenomena (and to the future) in ways that are simply not possible with traditional techniques of experimentation and observation. Within earth systems science, simulation models, such as the increasingly powerful General Circulation Models (GCMs) used to model global climate change,²⁷¹ provide a new way of seeing “systems that are too large, too complex, or too far away to study by other means.”²⁷² In many respects, modeling and simulation, together with satellite-based remote sensing and other forms of global observation, represent the triumph of systems theory in the earth sciences during the post-World War II period, allowing for the creation of new objects of knowledge such as global climate change, and underwriting new forms of global environmental governance.²⁷³

271. See PAUL N. EDWARDS, *A VAST MACHINE: COMPUTER MODELS, CLIMATE DATA, AND THE POLITICS OF GLOBAL WARMING* 139–86, 337–55 (2010) (discussing historical development of GCMs and their implications for knowledge about the climate system); Leo J. Donner & William G. Large, *Climate Modeling*, 33 ANN. REV. ENV'T & RES. 1 (2008) (reviewing current state of climate modeling); HERVÉ LE TREUT ET AL., *CLIMATE CHANGE 2007: HISTORICAL OVERVIEW OF CLIMATE CHANGE SCIENCE: WORKING GROUP I CONTRIBUTION TO THE FOURTH ASSESSMENT REPORT OF THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE* 112–18 (S. Solomon et al. eds., 2007) (providing overview of the development of climate modeling and the increased complexity and resolution made possible by advances in computational capacity).

272. Oreskes, *supra* note 9, at 70–71; see also Amy Dahan Dalmedico, *History and Epistemology of Models: Meteorology (1946-1963) as a Case Study*, 55 ARCH. HIST. EXACT SCI. 395 (2001) (tracing the rise of innovative modeling practices in post-World War II meteorology to the deployment of increasingly powerful computational technologies—marking a broader shift in the study of earth systems from mathematization to modeling). On simulations, see Peter J. Galison, *Computer Simulations and the Trading Zone*, in *THE DISUNITY OF SCIENCE: BOUNDARIES, CONTEXT, AND POWER* 118 (Peter Galison & Donald J. Stump eds., 1996) (discussing history of the Monte Carlo simulation and its epistemic implications); Eric Winsberg, *Sanctioning Models: The Epistemology of Simulation*, 12 SCI. IN CONTEXT 275, 276 (1999) (describing simulation as “a form of calculation,” but with its own unique epistemology). On the use of Monte Carlo simulations in environmental risk assessment, see Susan R. Poulter, *Monte Carlo Simulation in Environmental Risk Assessment—Science, Policy, and Legal Issues*, 9 RISK: HEALTH, SAFETY, AND ENV'T 7 (1998).

273. The fundamental importance of models in environmental law and governance has not escaped environmental law scholars, although few have sought to place these practices within their historical context and understand, with reference to the vast literature on modeling, the kinds of knowledge claims made possible by such practices and the concomitant implications for governance. See, e.g., Daniel A. Farber, *Modeling Climate Change and its Impacts: Law, Policy, and Science*, 86 TEX. L. REV. 1655, 1698 (2008) (providing a general overview of climate models and noting the importance of understanding the uncertainties and limits associated with such models); James D. Fine & Dave Owen, *Technocracy and Democracy: Conflicts between Models and Participation in Environmental Law and Planning*, 56 HASTINGS L.J. 901, 912–13 (2005) (“Models can organize, manipulate, and process vast quantities of data and can simulate complex multivariable processes, and these capacities allow them to predict the future, compare alternative possible futures, test the ramifications of assumptions, and contribute to improved

But there are limits embedded within all of these calculative practices. Predictive models, for example, operate as “a surrogate for access to the future,” but it is very difficult to evaluate “how good a surrogate they are.”²⁷⁴ These models, in other words, provide a tool for rendering certain futures visible, establishing a basis for policy choices, but we have no way of knowing how partial this visibility is. Likewise, there are problems of false precision attending any effort to quantify particular phenomena.²⁷⁵ And there are fundamental issues that go to the manner in which these practices of calculation and the resulting ways of seeing render certain aspects of a problem less visible. To take one example, in the case of the “ozone hole” discovered over Antarctica in the mid-1980s, the prior move to satellite-based observations and the corresponding *global* view of stratospheric ozone depletion led directly to the practice of discarding certain satellite data suggesting severe depletion over Antarctica for several years based on erroneous assumptions of “instrument failure,” because the readings were outside the expected “normal” range and did not comport with the prevailing understanding of ozone depletion as a uniform, global process.²⁷⁶ The understanding of stratospheric ozone depletion as a global problem, in other words, made it *more* difficult to see a particularly vital aspect of the problem.

Finally, as numerous scholars have emphasized in multiple contexts, the very act of rendering something objective and calculable is a way of making it technical, thereby taking it out of the world of politics and social institutions.²⁷⁷ In the effort to make deforestation a unitary object of climate governance, the act of reducing the forest to its embodied carbon and its functional role in the global carbon cycle takes

understanding of system interactions.”); Thomas O. McGarity & Wendy E. Wagner, *Legal Aspects of Regulatory Use of Environmental Modeling*, 33 ENVTL. L. REP. 10751 (2003) (providing an overview of key issues arising in substantive judicial review of EPA modeling and discussing key challenges to the use of models in regulatory decision making); Charles D. Case, *Problems in Judicial Review Arising from the Use of Computer Models and Other Quantitative Methodologies in Environmental Decision Making*, 10 B.C. ENVTL. AFF. L. REV. 251 (1982) (reviewing increasing use of quantitative models in environmental decision making and the implications for judicial review).

274. See, e.g., Oreskes, *supra* note 9, at 79 (discussing the inability to evaluate and confirm model predictions regarding behavior thousands of years in the future, such as that of high-level nuclear waste repositories).

275. See *id.* at 81 (“Modeling may lead to greater rigor in the evaluation of earth processes, but it may also propagate the illusion that things are better known than they really are.”); Sheila Jasanoff & Brian Wynne, *Science and Decision Making*, in 1 HUM. CHOICE & CLIMATE CHANGE 62 (pointing out that although models are often seen as “tools and heuristics” by the modeling community, they are often perceived and presented as “truth machines” in the policy community).

276. See CAGIN & DRAY, *supra* note 269, at 270; Jasanoff & Wynne, *supra* note 275, at 32–33.

277. See ROSE, *supra* note 11; FERGUSON, *supra* note 11; SCOTT, *supra* note 11.

deforestation out of its many social, political, and institutional contexts and inserts it into a project of global environmental governance. A set of phenomena deeply embedded within particular circumstances is re-formatted as a singular problem of global carbon management. But unless this global project can somehow be re-inserted into these different contexts in a workable fashion, through the elaboration of specific legal and institutional forms in particular places, it will almost certainly fail, regardless of how accurately one can calculate the carbon embodied in tropical forests.

C. *Equivalence*

Equivalence is about making things of a different order, creating a basis for common measurement and evaluation. It is a form of technical and regulatory alchemy aimed at establishing commensurability—a practice that is similar to but broader than that of choosing a “currency” to ensure fungibility in environmental trading markets.²⁷⁸ As a way of seeing oriented toward organizing and standardizing practices of calculation and kind-making, equivalence provides the basis for inserting these practices into larger regulatory architectures. This notion of equivalence borrows from recent work in social and economic theory directed at the construction of particular conventions of equivalence as a basis for statistical reasoning²⁷⁹ and at the use of particular forms of equivalence in solving coordination problems in the context of economic activities and the construction of markets.²⁸⁰ By taking coordination as problematic, these perspectives direct attention to the general modes, devices, and technologies used to create common frameworks for action. Understood in this way, technologies of equivalence are endemic in environmental law and governance, as well as other fields, and merit investigation on their own terms as important knowledge practices that

278. Cf. Salzman & Ruhl, *supra* note 30.

279. See DESROSIÈRES, *supra* note 143, at 104–05 (discussing the importance of conventions of equivalence in the development of national statistical traditions and the role of these conventions in “creating contexts of common measurement”).

280. See, e.g., Laurent Thévenot, *Organized Complexity: Conventions of Coordination and the Composition of Economic Arrangements*, 4 EUR. J. SOC. THEORY 405, 407 (2001) (exploring different ways of creating equivalence between people or things in order to resolve economic coordination problems). The challenge of establishing equivalence is particularly apparent in the effort to construct markets for emissions and other environmental commodities. See, e.g., Levin & Espeland, *supra* note 217, at 133–34 (“The fungibility of pollutants as commodities hinged on people’s faith that one ton of SO₂ in Chicago was really equal to a ton of SO₂ in New York. Standardized measures help produce these equivalencies and help reassure traders and regulators alike of the legitimacy of this equivalency. The technical commensuration accomplished in this synchronization of software, hardware, and bureaucratic rule-making transformed smoke from smokestacks into a meticulously tracked quantity.”); MacKenzie, *supra* note 217, at 440 (analyzing the “conditions of possibility of these [carbon markets], by examining . . . what it takes to make the entities traded in these markets ‘the same’”).

shape the field by bringing various phenomena and practices into common evaluative schemes.

Thus, the standardization of particular measures and protocols for environmental monitoring and control provides one obvious example of the role that equivalence technologies play in environmental regulation.²⁸¹ But there are many other examples, some less obvious, that play equally fundamental coordinative roles in the construction of ever more elaborate systems of environmental regulation. In the climate change context, for example, the development of the GWP concept, together with accounting standards, registries, and emissions inventories, operates as a powerful equivalence machine, allowing different emissions reduction and sequestration activities across different sectors, and involving different gases with different climate impacts, to be compared, standardized, and tracked in a manner that, at least in theory, creates the possibility for a comprehensive multi-sector, multi-gas compliance system.²⁸² With respect to the effort to bring deforestation into climate policy, the move to jurisdiction-wide accounting practices and the application of particular legal tools and standards to deal with leakage, permanence, and additionality have all worked to create an equivalence space for translating forest carbon into compliance carbon.²⁸³

In other areas of environmental law, equivalence practices of various kinds provide a basis for placing different activities and phenomena within a common regulatory framework. Thus, the creation of particular "currencies" provides a means for dealing with fungibility problems in

281. See PORTER, *supra* note 11, at 27–28 (discussing development of standards for measuring pollutants in the environment, a process that "means disciplining people as well as standardizing instruments and processes" and developing "specifications [that] must be put into effect at millions of diverse locations, by calibrating millions of instruments and millions of people to the same standard").

282. On the GWP concept, see the discussion *supra* note 219. The IPCC First Assessment Report, which introduced the GWP concept as a possible tool for dealing with different greenhouse gases in climate policy, noted the difficulties of using this tool as an equivalence technique. See *Radiative Forcing*, 1990 IPCC REPORT, *supra* note 219, at 58 ("In considering the policy options for dealing with greenhouse gases, it is necessary to have a simple means of describing the relative abilities of emissions of each greenhouse gas to affect radiative forcing and hence climate It must be stressed that there is no universally accepted methodology for combining all the relevant factors into a single global warming potential for greenhouse gas emissions. In fact there may be no single approach which will represent all the needs of policymakers."). And yet, the climate policy process has established the GWP as the basis for making greenhouse gases commensurable in existing and emerging compliance systems, illustrating the strong regulatory push for equivalence and the durability of particular conventions of equivalence. For technical assessments of the GWP concept, including its shortcomings, see Shine, *supra* note 219; Tanaka et al., *supra* note 219. See also MacKenzie, *supra* note 217, at 445–46 (describing the development of the GWP concept and its "inscription" into the Kyoto Protocol as a "black-box" for making greenhouse gases "commensurable"). MacKenzie also notes the importance of accounting standards and practices in "mak[ing] carbon 'fungible'" and, thus, amenable to trading. *Id.* at 447.

283. See *supra* Part IV.C.

environmental trading markets.²⁸⁴ The use of dose-response curves and model organisms to extrapolate from high-dose to low-dose exposures and from animals to humans provide an equivalence space for setting regulatory standards and comparing toxic substances.²⁸⁵ The concepts of emissions bubbles and offsets represent, in an almost literal sense, the very embodiment of equivalence. More generally, the practices of comparative risk assessment and cost-benefit analysis are founded on the drive toward a common metric, most often that of human lives and/or money, for comparing and evaluating tradeoffs among different activities.²⁸⁶

284. See Salzman & Ruhl, *supra* note 30, at 613–14; Levin & Espeland, *supra* note 217, at 133–34.

285. See DONALD G. CROSBY, ENVIRONMENTAL TOXICOLOGY AND CHEMISTRY 143–53 (1998) (discussing use of dose-response relationship and animal bioassays in toxicology).

286. See, e.g., John D. Graham & Jonathan Baert Wiener, *Confronting Risk Tradeoffs*, in RISK VERSUS RISK: TRADEOFFS IN PROTECTING HEALTH AND THE ENVIRONMENT 33 (John D. Graham & Jonathan Baert Wiener eds., 1995) (discussing challenges of comparing certain kinds of risks, but noting that “it is chiefly our lack of methods of comparison—of ways of seeing commonality among these risks—that makes these risks seem ‘dissimilar’ or noncomparable, not an inherent incommensurability”); SUNSTEIN, *supra* note 25, at 6–7 (discussing rise of cost-benefit analysis in U.S. environmental regulation and its “cognitive” virtues in providing a basis for comparing alternative courses of action); PORTER, *supra* note 9, at 186–89 (discussing the historical transformation of cost-benefit analysis from a tool used by engineers to evaluate public works projects into a “universal standard of rationality” for evaluating a whole host of government expenditures and regulatory activities). Echoing Marx’s famous observations on the role of money as the universal equivalent, Michel Callon describes the central role of money in constructing equivalences and ensuring commensurability in these sorts of exercises. See Michel Callon, *Introduction: The Embeddedness of Economic Markets in Economics*, in THE LAWS OF THE MARKETS 21–22 (Michel Callon ed., 1998) (“[Money] makes commensurable that which was not so before. The case of negative externalities, for example the effects of pollution produced by a chemical plant, clearly illustrates this point. Once identified and acknowledged, [the externality], if it is to be framed and thus internalized, has to be measured This measuring involves the establishment of a metrology, anchored in techno-scientific instruments, which enables the agents concerned to establish quantitative correspondences between a cause (eg, the discharge of dioxin) and an injury (eg, a probability of cancer). This correlation between a risk of death and the activity of a factory, established by means of laboratory experiments and epidemiological research, creates a link between two distinct series of events. But if the relationship (between a discharge and deaths) becomes calculable by the agents, it is not enough merely to prove its existence; it has to be expressed in the same units. This is where money comes in. It provides the currency, the standard, the common language which enables us to reduce heterogeneity, to construct an equivalence and to create a translation between a few molecules of a chemical substance and human lives. Money comes in last in a process of quantification and production of figures, measurements and correlations of all kinds. It is the final piece, the keystone in a metrological system that is already in place and of which it merely guarantees the unity and coherence. Alone it can do nothing; combined with all the measurements preceding it, it facilitates a calculation which makes commensurable that which was not so before: grams of dioxin and a human life. Thanks to it the agents can measure the investments required to reduce the risk of death below a certain threshold. Money establishes an ultimate equivalence between the value of a human life and that of investment in pollution abatement.”).

In each of these cases, it is important to understand how specific technologies of equivalence have evolved within the larger framework of environmental law and the nature of the work they do. To be sure, there is a certain violence associated with the simplifications—quite radical in some cases—entailed by these different technologies of equivalence, a fact that has sometimes provoked a strong normative reaction against their application in areas affecting human health and the environment.²⁸⁷ And there is little question that particular conventions of equivalence have a certain durability or permanence (what some might call path dependence) that may have less to do with their overall efficacy or validity from a particular technical or normative standpoint than with the substantial political, economic, and cognitive investments that have gone into establishing and holding them together.²⁸⁸ By taking conventions of equivalence as objects of investigation on their own terms, by exploring how they work to construct things of a different order, and by seeking to generalize about the different forms and modes of equivalence at work in environmental law, the intent is not to discount the importance of normative debates regarding their use or abuse, but rather to develop our understanding of the capabilities and limits of particular conventions of equivalence in particular contexts. As we develop more expansive environmental regulatory systems, some with truly global reach, equivalence becomes much more challenging, though no less important, in the effort to facilitate interoperability between different systems and across jurisdictions. By taking the problem of coordination head on and focusing on the role of different equivalence practices in structuring the way we see and approach environmental problems, we open up a whole new range of questions regarding how these ways of seeing shape and define the conditions of possibility for particular strategies of

287. See, e.g., FRANK ACKERMAN & LISA HEINZERLING, *PRICELESS: ON KNOWING THE PRICE OF EVERYTHING AND THE VALUE OF NOTHING* (2004) (criticizing widespread application of cost-benefit analysis in evaluating environmental, health, and safety regulations); Kysar, *Climate Change, Cultural Transformation, and Comprehensive Rationality*, *supra* note 29, at 562–89 (discussing key limitations of cost-benefit analysis in the climate change context).

288. In his fascinating history of statistical reasoning, Alain Desrosières discusses the “extremely expensive political, social, and technical investments” necessary to produce “the conventions of equivalence and permanence of the objects on which statistical practice is based.” See DESROSIÈRES, *supra* note 143, at 337. Desrosières rejects what he refers to as the “dead-ended epistemological opposition” between realism and relativism, asserting that statistical objects, such as poverty or unemployment, are both real and constructed. See *id.* History thus provides the means for understanding how these objects came to be, how they were made to hold together, and how they are severed from their contexts, naturalized, and allowed to circulate as objective facts in public debate. Viewing statistics in this manner serves to reveal the relationship between statistics and the public sphere, helping to “clarify and analyze these spaces of durably solidified forms, which must simultaneously remain undebated so that life may follow its course, and debatable, so that life can change its course.” See *id.*

environmental law and governance across multiple geographies and publics.

CONCLUSION

In a 1998 policy editorial in *Science*, the Terrestrial Carbon Working Group of the International Geosphere Biosphere Program offered an assessment of the effort to account for terrestrial carbon under the recently adopted Kyoto Protocol.²⁸⁹ After reviewing the complex treatment of carbon sinks under Kyoto and the ongoing efforts to develop carbon accounting methodologies, the group concluded that “[e]ventually, all terrestrial ecosystems, both managed and unmanaged, should be included [in carbon accounting systems] to recognize and potentially increase all terrestrial sinks, to minimize sources, and to avoid the surprise of large unanticipated releases of carbon from unmanaged systems.”²⁹⁰ In many ways, the editorial summed up the vision of an emerging program aimed at earth systems governance and built around the idea that the entire global terrestrial carbon cycle could be made into a viable object of climate governance.²⁹¹

The emergence of REDD since 2005 can be seen as the first tangible effort to bring a major component of the terrestrial carbon cycle, tropical deforestation, into a global environmental governance regime. But the story of how deforestation became (and is becoming) an object of climate governance cannot be understood without attending to the manner in which scientific and technological ways of seeing have formatted the problem in a manner amenable to climate policy. Based on advances in post-World War II carbon cycle research, the deployment of increasingly powerful remote sensing capabilities, and the development of legal and accounting techniques for rendering forest carbon equivalent to other forms of compliance carbon, a set of phenomena previously viewed through the lens of biodiversity loss, North-South linkages, macro-economic imbalances, and governance failures of various kinds has been (and continues to be) reduced, simplified, and reformatted in a manner that is comprehensible for climate mitigation efforts in general and emerging GHG compliance systems in particular.

Viewing this as simply another step toward a more fundamental understanding of the “underlying” problem of deforestation misses the fact that this is a problem that has no single essence or identity waiting to

289. See Int’l Geosphere-Biosphere Program Terrestrial Carbon Working Group, *The Terrestrial Carbon Cycle: Implications for the Kyoto Protocol*, 280 SCIENCE 1393 (1998).

290. *Id.* at 1394.

291. See *id.*

be discovered, but rather a diverse range of phenomena that have to be organized into a coherent object of investigation and governance. It also misses the important normative observation that these new ways of seeing represent a radical simplification of complex social and biological systems, providing the basis for a new abstraction—forest carbon—that, in turn, prepares the way for the application of particular legal technologies and new forms of property that are pulling tropical forests, and the many people who depend on them, into a regulatory regime that is global in scope and premised on the possibility of de-coupling forest carbon from forest ecosystems. Ways of seeing are, in this way and others, intimately bound up with particular ways of acting on the world.

By asking how scientific and technological ways of seeing shape the subject matter of environmental law, we gain a new and deeper understanding of the nature and limits—the conditions of possibility—of governance as well as the durability, or stickiness, of particular forms of governance. Few areas of law are as deeply implicated with science and technology as environmental law, and yet we have no theory of how the knowledge practices of science and technology shape the field. Exploring the specific knowledge practices of kind-making, calculability, and equivalence provides a first step toward a possible larger effort to investigate how objects of governance are made and, in the process, how particular dimensions or aspects of the underlying phenomena are foregrounded, backgrounded, or left out altogether in the elaboration of specific regulatory regimes. A mature environmental law, together with a mature environmental law scholarship, needs to look closely (and critically) at how we see and at how ways of seeing shape and inform the substance of environmental law.