Mapping Ecosystem Benefit Flows To Normalize Equity

Keith H. Hirokawa[*], Cinnamon P. Carlarne[**], Karrigan S. Börk[***], and Sonya Ziaja[****]

INTRODUCTION

Although the needs of the public health, safety, and welfare vary across time and space, human survival requires functioning natural systems.[1] It is no exaggeration to say that, either cumulatively or individually at a relevant scale, interruptions to ecosystems, atmospheric systems, the geosystem, or the hydrological cycle cause major disruptions in the ability of such systems to maintain the planet as a habitable place.[2] Ensuring that natural systems are functional, limiting actions that disturb those systems, and maintaining important aspects of ecosystems as they respond to climate change, all seem appropriate targets for regulation and community empowerment. At this point in time, "[h]uman society has never had a more pressing need to understand

* Keith Hirokawa is Distinguished Professor of Law and Associate Dean of Research and Scholarship at Albany Law School.

** Cinnamon Carlarne is the Robert J. Lynn Chair in Law & Associate Dean for Faculty and Intellectual Life at the Ohio State University College of Law.

*** Karrigan Börk is an Acting Professor of Law at the UC Davis School of law and an Associate Director of the UC Davis Center for Watershed Sciences.

**** Sonya Ziaja is an Assistant Professor at the University of Baltimore School of Law. The authors wish to thank the editors of Arizona State Law Journal for their excellent work on this article, as well as the organizers of the *SRP Sustainability Conference of American Legal Educators* for the opportunity to refine our collective ideas.

1. Brendan Fisher et al., *Defining and Classifying Ecosystem Services for Decision Making*, 68 ECOLOGICAL ECON. 643, 644 (2009) ("Humanity's reliance upon nature for welfare and survival is complete. The history of civilization is, at its most basic, a story of people trying to access resources and seek protection from the elements.").

2. Johan Rockström et al., *A Safe Operating Space for Humanity*, 461 NATURE 472, 472 (2009).

its dependence on nature"[3] and maintain the conditions under which ecosystems can continue to function.[4]

In the recent 25 years, scholars and practitioners from across many disciplines have contributed to the explosion of interest and research in ecosystem services.[5] Ecosystem services embodies the idea that functioning ecosystems are critical to both human resiliency and economic wealth.[6] Ecosystem services research explores how ecosystems provide "basic life support for human and animal populations and are the source of spiritual, aesthetic, and other human experiences that are valued in many ways by many people,"[7] as well as how those services have substantial economic worth. Research on ecosystem services has produced a substantial body of literature on ways to understand the value provided by these services in economic terms, the policies that might be used to guide ecosystem services legal tools, and even regulatory mechanisms that might effectively capture the value of ecosystems as we continue to build on the land.[8] In short, ecosystem service research attempts to make the value of ecosystems visible, in part by translating that value into monetary terms.

---

3. John Peterson Myers & Joshua S. Reichert, *Perspectives on Nature's Services*, *in* NATURE'S SERVICES: SOCIETAL DEPENDENCE ON NATURAL ECOSYSTEMS xvii, xviii (Gretchen C. Daily ed., 1997).

4. *See, e.g.*, Mary Christina Wood, *Advancing the Sovereign Trust of Government to Safeguard the Environment for Present and Future Generations (pt. 2): Instilling a Fiduciary Obligation in Governance*, 39 ENV'T L. 91, 102 (2009) (arguing that a natural capital accounting "is a necessary tool to prevent the government from bankrupting the natural wealth of this country"); *cf.* Daniel W. O'Neill et al.,
A Good Life for All Within Planetary Boundaries, 1 NATURE SUSTAINABILITY 88 (2018).

5. Robert Costanza et al., *Twenty Years of Ecosystem Services: How Far Have We Come and How Far Do We Still Need to Go?*, 28 ECOSYSTEM SERVS. 1, 2 (2017); J.B. Ruhl et al., *Connecting Ecosystem Services Science and Policy in the Field*, 19 FRONTIERS ECOLOGY & ENV'T 519, 519 (2021).

6. Gretchen C. Daily et al., *Ecosystem Services: Benefits Supplied to Human Societies by Natural Ecosystems*, 2 ISSUES ECOLOGY 1, 2 (1977); Robert Costanza et al., *The Value of the World's Ecosystem Services and Natural Capital*, 387 NATURE 253, 253 (1997); CARLOS CORVALAN ET. AL., ECOSYSTEMS AND HUMAN WELL-BEING: HEALTH SYNTHESIS: A REPORT OF THE MILLENNIUM ECOSYSTEM ASSESSMENT 2 (2005).

7. EPA SCIENCE ADVISORY BOARD, VALUING THE PROTECTION OF ECOLOGICAL SYSTEMS AND SERVICES 8 (2009).

8. Critiques of ecosystem service analysis tend to focus on this quantification or commodification, arguing that quantification obscures, rather than brings to light, values in ecosystems (for example, religious or cultural values) that should not be compared in the same terms as quarterly profits. *See, e.g.*, Erik Gomez-Baggethun & Manuel Ruiz-Perez, *Economic Valuation and the Commodification of Ecosystem Services*, 35 PROGRESS PHYSICAL GEOGRAPHY 613, 613 (2011); Tracey Osborne & Elizabeth Shapiro-Garza, *Embedding Carbon Markets: Complicating Commodification of Ecosystem Services in Mexico's Forests*, 108 ANNALS AM. ASS'N GEOGRAPHERS 88, 91 (2018).

Ecosystem services research has been used as a communication tool,[9] and as a basis for creating markets or payments for the benefits ecosystems provide.[10] Yet, the research has produced fewer insights on the social dimensions of ecosystem services, hampering efforts to understand and address the distribution of power and resources in an ecosystem services context.[11] Moreover, ecosystem services research has suffered the fairly typical scientific research problem of being difficult to understand by all stakeholders: those who control the flow of ecosystem services, those who need to receive ecosystem benefits, and those who govern.[12]

Mapping the flows of ecosystem benefits between and among geographically distinct communities incorporates social dimensions into ecosystem services while also making the research more accessible.[13] Mapping ecosystem benefit flows identifies the supply and demand of ecosystem services and provides critical information about resource access and control that allows us to understand existing forms of ecosystem services dominance.[14] Moreover, benefit flows mapping takes the technical languages of ecology and economics and makes them more visually accessible.[15]

In this paper, we explore how mapping benefit flows fosters an understanding of the power relationships among ecosystem stakeholders, distinguishing between those with the opportunity to control the flow of ecosystem services and those whose well-being depends on them. Benefit flows mapping enables stakeholders to engage in more informed conversations about needs, priorities, and trade-offs in ecosystem management and empowers more specific and effective communication within and among power relationships, ensuring a more equitable allocation of resources. We then discuss how to operationalize mapping benefit flows using existing environmental law tools, like planning, environmental justice

---

9. *See, e.g.*, S.A. Bekessy et al., *Ask Not What Nature Can Do for You: A Critique of Ecosystem Services as a Communication Strategy*, 224 BIOLOGICAL CONSERVATION 71, 71 (2018).

10. *See* Sarah Schomers & Bettina Matzdorf, *Payments for Ecosystem Services: A Review and Comparison of Developing and Industrialized Countries*, 6 ECOSYSTEM SERVS. 16, 16 (2013).

11. *See* Fisher et. al, *supra* note 1, at 645 ("[T]he social value of the benefits that ecosystems provide could potentially be enumerated so that society can make more informed policy and management decisions.") (citation omitted).

12. *See id.* at 652. ("There is an obvious need for scientists to more clearly communicate findings to the public and decision makers.").

13. *See* Jennifer Hauck et al., "*Maps Have an Air of Authority": Potential Benefits and Challenges of Ecosystem Service Maps at Different Levels of Decision Making*, 4 ECOSYSTEM SERVS. 25, 27 (2013).

14. *See id.* at 29; *see also* Keith H. Hirokawa & Cinnamon P. Carlarne, *Climate Dominance*, GEO. ENV'T L. REV. (forthcoming 2023) (discussing existing systems of dominance in the context of climate change and climate adaptation).

15. *See* Hirokawa & Carlarne, *supra* note 14, at 27.

screening tools, and environmental impact assessments, as well as through more cutting-edge approaches, like exactions that consider ecosystem services impacts. This analysis illustrates how mapping ecosystem benefit flows is an act of community empowerment.

I. ECOSYSTEM SERVICES AND MAPPING SERVICE FLOWS

A. Ecosystem Services

Ecosystem services research illustrates the ways in which humans benefit from functioning ecosystems, exposing how access to ecosystem services is a form of wealth. "Ecosystem services" refers to "the ecological characteristics, functions, or processes that *directly or indirectly* contribute to human wellbeing: that is, the benefits that people derive from functioning ecosystems."[16] Humans rely on (and value) ecosystems in ways that are not reflected in the marketplace.[17] The ecosystem services approach to ecological economics quantifies and reflects the human dependence on and value in functioning ecosystems.[18] As J.B. Ruhl notes, in the absence of functioning ecosystems, humans lose: "[W]ithout ecosystem services, we all die."[19]

Traditionally, ecosystem services have been ignored or otherwise undervalued.[20] Most ecosystem services "have no market value for the simple reason that no markets exist in which they can be exchanged."[21] In contrast to the *products* that nature provides (such as building materials and food), most ecosystem *services* are not traded in the marketplace: people seldom (if ever) pay a premium for land because of its critical contribution to sediment cycling, provision of pollinators, or for flood regulation, particularly where those services benefit other properties. Indeed, "[m]any of the critical ecosystem services generated by natural capital (such as pollination services,

16. Costanza et al., *supra* note 5, at 3. The term has also been defined as the "wide range of conditions and processes through which natural ecosystems, and the species that are part of them, help sustain and fulfill human life." Daily et al., *supra* note 6, at 2.

17. James Salzman et al., *Protecting Ecosystem Services: Science, Economics, and Law*, 20 STAN. ENV'T L.J. 309, 311–12 (2001).

18. *See* Costanza et al., *supra* note 6, at 253.

19. J.B. Ruhl, The Law and Policy of Ecosystem Services 52 (June 23, 2006) (Ph.D. dissertation, Southern Illinois University Carbondale) (ResearchGate) https://www.researchgate.net/publication/40777463_The_Law_and_Policy_of_Ecosystem_Services [https://perma.cc/CW9G-UED4].

20. *See* Salzman et al., *supra* note 17, at 311.

21. *Id.* at 312; *see also* Ruhl, *supra* note 19, at 52 ("One does not have to purchase photosynthesis or the radiation screening effects of the ozone layer, and therefore no market price data are available for them.").

flood control, water filtration, and provision of habitat for biodiversity) are externalities—they are not given a price in markets."[22] Without the benefit of conventional valuation,[23] ecosystem services have been difficult to value[24] and often go unnoticed until some landscape change results in ecosystem degradation, which interrupts the ability of the environment to provide such services, which in turn impacts communities and people who rely on those services.[25]

Ecosystem services analysis responds to this need by facilitating an understanding of ecosystem services values to people and their well-being—information that is critical for purposes of maintaining a community's natural wealth.[26] Baseline information on ecosystem structures and processes, together with an understanding of the ways that human society benefits from those processes, illustrates the dependencies and expectations we have for functioning ecosystems both in everyday life and in cases of environmental hazards and disasters. In this way, ecosystem services research describes the

---

22. Lawrence H. Goulder & Donald Kennedy, *Interpreting and Estimating the Value of Ecosystem Services*, *in* NATURAL CAPITAL: THEORY AND PRACTICE OF MAPPING ECOSYSTEM SERVICES 15, 15 (Peter Kareiva et al. eds., 2011).

23. *See* Costanza et al., *supra* note 6, at 257 ("A large part of the contributions to human welfare by ecosystem services are of a purely public goods nature. They accrue directly to humans without passing through the money economy at all.").

24. *See* Ida Kubiszewski et al., *The Production and Allocation of Information as a Good That Is Enhanced with Increased Use*, 69 ECOLOGICAL ECON. 1344, 1347 (2010) (observing that conventional markets must rely on private property rights, as such markets reveal demand only for privately-owned goods and services). *But cf.* M. Robertson, *Ecosystem Services*, *in* ENCYCLOPEDIA OF ENVIRONMENTAL HEALTH 225, 229 (Jerome O. Nriagu ed., 2011) ("[T]he entirety of a given service or set of services present in ecosystems is far more difficult, if not impossible, to price using conventional valuation methods.").

25. In the absence of programs that facilitate the valuation of ecosystem services, "[E]cosystems in all parts of the world are being degraded to a suboptimal extent, causing loss of [ecosystem services] supply." Jan Phillip Schägner et al., *Mapping Ecosystem Services' Values: Current Practice and Future Prospects*, 4 ECOSYSTEM SERVS. 33, 35 (2013); *see also* Charles H. Peterson & Jane Lubchenco, *Marine Ecosystem Services*, *in* NATURE'S SERVICES: SOCIETAL DEPENDENCE ON NATURAL ECOSYSTEMS 177, 190 (Gretchen C. Daily ed., 1997) ("Although the scope and application of future scientific discoveries are impossible to predict, it is clear that failure to preserve this information bank that is the natural ecosystem represents irretrievable loss of natural capital that would generate tangible future economic value."); C. Max Finlayson et al., *Inland Water Systems*, *in* 1 ECOSYSTEMS AND HUMAN WELL-BEING: CURRENT STATE AND TRENDS ASSESSMENT 551, 573 (Rashid Hassan et al. eds., 2005) ("[D]ecisions that have not considered the trade-offs between services provided by inland waters . . . have often resulted in the degradation of inland waters, and the loss or decline in the multiple services they provide, in favor of a smaller number of services, such as the supply of fresh water for drinking or irrigation or the supply of hydroelectricity or transport routes."); Goulder & Kennedy, *supra* note 22 ("[U]nfettered markets often lead to the compromising or collapse of ecosystems, much to the detriment of human welfare.").

26. *See* Ken J. Wallace, *Classification of Ecosystem Services: Problems and Solutions*, 139 BIOLOGICAL CONSERVATION 235, 242–43 (2007).

value of nature to humans, or alternatively, the value of the continuing receipt of ecosystem benefits.[27]

The ecosystem services framework is not, in a sense, new: humans have always depended on natural processes, such as flowing water, natural production of food and other goods, climate regulation, and so on.[28] However, ecosystem services research recasts how we look at nature: "In a real sense, the natural ecosystem is a repository of information, a capital resource that when tapped in the future will create economic wealth and improve the welfare of human society."[29] By identifying the ways that functioning ecosystems provide benefits to humans, ecosystem services research also accounts for the potential costs associated with changes in land uses and landscapes, particularly where such changes interfere with or interrupt ecosystem structures or processes.[30] For instance, ecosystem services assessment might calculate the costs (in terms of lost services) from levelling a forest or filling a wetland. Such an analysis might take on several forms, focusing on a particular impact or multiple impacts that result from the change. For instance, loss of tree canopy cover might lead to the local loss of natural stormwater or flood control capacity, the costs of which might be calculated as the expense of constructing artificial control structures; the analysis might focus on habitat loss and wildlife and pollinator displacement; it might involve cascading impacts on the regional loss and relocation of recreational opportunities and associated off-site impacts; or the analysis might account for the tradeoffs and temporal loss of the above services by exploiting the ecosystem through harvesting timber. Likewise, ecosystem services analysis reveals those moments where a loss of services is irretrievable.[31] Across many disciplines, ecosystem services research has forced us to rethink what is valued in nature, as well as how to view the

27. "Changes in quality or quantity of ecosystem services have value insofar as they either change the benefits associated with human activities or change the costs of those activities." Costanza et al., *supra* note 6, at 255. Much of nature's value lies outside of the ecosystem service framework, but ecosystem service analysis is nonetheless useful for assigning value to some of the utilitarian values of ecosystems.

28. *See* Fisher et al., *supra* note 1, at 644–45.

29. Peterson & Lubchenco, *supra* note 25, at 190.

30. *See generally* Giulia Wegner & Unai Pascual, *Cost-Benefit Analysis in the Context of Ecosystem Services for Human Well-Being: A Multidisciplinary Critique*, 21 GLOBAL ENV'T CHANGE 492, 492 (2011).

31. *See id.* at 502 ("[T]he notion of economic value is of little use when an ecosystem approaches a critical ecological threshold and ecosystem services become non-substitutable and absolutely scarce.").

relationship between public goods and private preferences in natural resource valuation.[32]

Ecosystem services fall into four primary classes that illustrate a wide range of services: provisioning services, regulating services, cultural services, and supporting services.[33] Provisioning services, which dominate traditional market valuations of the environment's economic worth, refer to the production of goods from ecosystems, like wood or fish.[34] But ecosystems serve other valuable functions as well. Regulatory services include the regulation[35] of natural hazards, air and water quality, waste treatment, pests, and pollination.[36] Cultural services include intangible benefits, such as opportunities for spiritual fulfillment, inspiration, recreation, cultural heritage, and sense of place.[37] Supporting services,[38] which provide the basis for all other ecosystem services, provide indirect and sustained benefits such as soil formation, photosynthesis, nutrient cycling, and water cycling.[39] Considering the range and importance of these services to human well-being, it seems fair to say that ecosystem services analysis provides better information than what is otherwise available in the marketplace.[40]

---

32. *See* J.B. Ruhl et al., *Proposal for a Model State Watershed Management Act*, 33 ENV'T L. 929, 931 (2003) (examining the relationship between the physical and political dynamics of watersheds); Salzman et al., *supra* note 17, at 310–11; Costanza et al., *supra* note 6, at 253; Geoffrey Heal et al., *Protecting Natural Capital Through Ecosystem Service Districts*, 20 STAN. ENV'T L.J. 333, 334 (2001).

33. MILLENNIUM ECOSYSTEM ASSESSMENT, ECOSYSTEMS AND HUMAN WELL-BEING: SYNTHESIS, at v–vi (2005); *see also* Chundi Chen et al., *Ecosystem Services Mapping in Practice: A Pasteur's Quadrant Perspective*, 40 ECOSYSTEM SERVS. 1, 3 (2019) (grouping ecosystem services into provisioning services, regulating/supporting services, and cultural services).

34. *See* MILLENNIUM ECOSYSTEM ASSESSMENT, *supra* note 33, at 49, 56 figs.3.2, 88 &100.

35. "Regulation" is used here in its ecological sense, not in the legal sense of what administrative agencies do.

36. MILLENNIUM ECOSYSTEM ASSESSMENT, *supra* note 33, at 40.

37. *Id.*

38. Some classifications combine regulating and supporting services. *See, e.g.*, Chen et al., *supra* note 33, at 3.

39. MILLENNIUM ECOSYSTEM ASSESSMENT, *supra* note 33, at 40.

40. Keith H. Hirokawa & Elizabeth J. Porter, *Aligning Regulation with the Informational Need: Ecosystem Services and the Next Generation of Environmental Law*, 46 AKRON L. REV. 963, 987 (2013) ("The ecosystem services perspective not only recognizes that natural resources are producers of goods and services, but also that the goods and services produced by ecosystems might represent a greater economic, social, and environmental value than the goods and services acquired from the conversion of those natural resources over time.").

B. Connecting from Both Ends: Mapping the Flows of Ecosystem Service Benefits

There appears to be general consensus on the idea that "ecosystem services must be explicitly and systematically integrated into decision making by individuals, corporations, and governments."[41] However, although ecosystem services have generated an astounding amount of interest, a persistent challenge has been to bridge the gap between the theoretical understanding of the services nature provides and the implementation of that understanding on the ground in a way that is accessible and understandable to stakeholders and decision makers.[42] To meet this need, an increasingly popular application of ecosystem services research involves mapping ecosystem services benefit flows.[43] Specifically, mapping provides practical, grounded information about control of and dependencies on ecosystem services in a particular location.[44]

As Gretchen Daily has observed, "[T]he safeguarding of critical ecosystem services requires that they first be identified."[45] Benefit flows mapping, or ecosystem services mapping, recognizes that capturing ecosystem value is primarily an exercise in communicating information about ecosystem value:

> Maps are a powerful way to convey information to users. Maps provide intuitive and simple methods for communicating information amongst stakeholders (scientists, policy makers, resource managers, and citizens) about the complex interactions between ecosystem services at a range of spatial and temporal scales. Maps can be used to visualize trade-offs and synergies among ecosystem services; they may help identify spatial congruence or mismatches between supply, flow, and demand of

41. Gretchen C. Daily et al., *Ecosystem Services in Decision Making: Time to Deliver*, 7 FRONTIERS ECOLOGY & ENV'T 21, 22 (2009) (citations omitted).

42. *See* Kenneth J. Bagstad et al., *From Theoretical to Actual Ecosystem Services: Mapping Beneficiaries and Special Flows in Ecosystem Service Assessments*, ECOLOGY & SOC'Y, June 2014, at 1, 11.

43. *See generally* Chen et al., *supra* note 33, at 1 (2019) (discussing the "exponential growth" in ecosystem services mapping literature); Sarah Wolff et al., *Mapping Ecosystem Services Demand: A Review of Current Research and Future Perspectives*, 55 ECOLOGICAL INDICATORS 159, 160 (2015).

44. *See, e.g.*, Brendan Fisher et al., *Measuring, Modeling and Mapping Ecosystem Services in the Eastern Arc Mountains of Tanzania*, 35 PROGRESS PHYSICAL GEOGRAPHY 595, 596 (2011).

45. Gretchen C. Daily, *Valuing and Safeguarding Earth's Life-Support Systems*, *in* NATURE'S SERVICES: SOCIETAL DEPENDENCE ON NATURAL ECOSYSTEMS 365, 369 (Gretchen C. Daily ed., 1997).

> ecosystem services or between ecosystems providing services and beneficiaries receiving services.[46]

Mapping benefit flows secures access to this information by depicting the local and regional connections between the supply and demand of ecosystem services.[47] Beyond the conceptual notion that ecosystem processes provide benefits, mapping benefit flows grounds ecosystem values by connecting the spaces where ecosystem services are generated (supply) to those places the benefits are needed, relied upon, or enjoyed (demand).[48]

Mapping ecosystem benefit flows begins with cataloging where ecosystem services are generated and/or where the services are required.[49] Depicting ecosystem services information spatially "provides baseline data to measure new future gains or losses,"[50] that is specific to particular communities, properties, and ecosystems.[51] Mapping ecosystem services where they are found can help account for spatial variations in supply, such as dominant ecosystem features across regions or levels of productivity in ecosystem processes. The same is true when of variations in demand, which might include varying beneficiary characteristics such as factors relating to vulnerability, population density, and land-use need.[52] In addition, mapping supply and demand illustrates the direction of ecosystem service flows, which might occur directionally (such as services that follow water flows in a watershed), omni-directionally (such as pollination or carbon sequestration services that do not follow a particular path), or in situ services (such as shade from vegetation, which exists in place).[53]

---

46. Joachim Maes et al., *Mapping Ecosystem Services*, *in* ROUTLEDGE HANDBOOK OF ECOSYSTEM SERVICES 188, 188 (Marion Potschin et al. eds., 2016) (citations omitted).

47. *Cf.* Melanie Feurer et al., *Regional Scale Mapping of Ecosystem Services Supply, Demand, Flow and Mismatches in Southern Myanmar*, ECOSYSTEM SERVS., Dec. 2021, at 1, 1 (2021) (explaining how mapping ecosystem services (ES) across Myanmar's Tanintharyi Region for local stakeholders yielded "results show[ing] that while there is a high supply of multiple ES at regional level, demand for ES in urban and rapidly developing agricultural areas is not fully covered").

48. *See* Joachim Maes et al., *Mapping Ecosystem Services for Policy Support and Decision Making in the European Union*, 1 ECOSYSTEM SERVS. 31, 33 (2012) (identifying several rationales for ecosystem services mapping: "evaluation of spatial congruence with biodiversity, analyzing synergies and trade-offs between different ES, analyzing trends in ES, estimating costs and benefits, comparing ES supply with demand, monetary valuation on biophysical quantities, or the prioritization of areas in spatial planning and management") (citations omitted).

49. *See id.*

50. *Id.* at 32.

51. Schägner et al., *supra* note 25, at 36 (clarifying that an ecosystem services inventory for mapping purposes includes two components: "(1) a biophysical assessment of ESS supply and (2) a socioeconomic assessment of the value per unit of ESS").

52. *Id.*

53. *See id.*

Importantly, by tracing the flows of ecosystem services across geography, benefit flows mapping helps to identify and illustrate the relationships between ecosystem processes and the numerous stakeholders who depend on ecosystem benefits.[54] In particular, mapping provides locally tailored information about "which regions are critical to maintaining the supply and flow of benefits for specific beneficiary groups,"[55] as it identifies the needs of relevant beneficiaries and their specific ecosystem service needs–information that might be obscured in a generalized view of ecosystem services.[56] Likewise, mapping helps to understand which services have more value in a particular place by identifying actual beneficiaries and an actual benefit.[57]

Finally, mapping ecosystem service flows helps us understand the risks that often come with development or other anthropogenic transformations of the environment.[58] Benefit flow mapping is critical for recognizing ecosystem benefit disruption, especially how land use changes will disrupt ecosystem dependencies and increase vulnerabilities.[59] Assessing demands for ecosystem services requires an interdisciplinary examination of socio-economic needs and preferences that might include land use choices, economic wealth, ecosystem capacity, and geographical and climatic conditions.[60] From a risk perspective, ecosystem services demand assessments should include geographically situated service dependencies and vulnerabilities to change, which "can give valuable insight into social needs

---

54. *See* Lydia P. Olander et al., *Benefit Relevant Indicators: Ecosystem Services Measures that Link Ecological and Social Outcomes*, *in* 85 ECOLOGICAL INDICATORS 1262, 1271 (2018) (discussing an approach that focuses on "benefit-relevant indicators," which are defined as "measurable descriptors of ecosystem services of all types, whether market goods or non-market, including those that support existence values for species and ecosystems . . . . BRIs make explicit the connections between ecological conditions and human use and enjoyment using causal chains, which can be implemented as mental models or as formal predictive models, along with service sheds that clarify the areas and beneficiaries affected").

55. Bagstad et al., *supra* note 42, at 10.

56. Katja Malmborg et al., *Mapping Regional Livelihood Benefits from Local Ecosystem Services Assessments in Rural Sahel*, PLOS ONE, Feb. 1, 2018, at 1.

57. Wolff et al., *supra* note 43, at 162 ("Understanding of ES flows is essential for understanding ES demand as they allow people to actually benefit from a good or service.").

58. *Cf.* Bagstad et al., *supra* note 42, at 1, 10.

59. Olander et al., *supra* note 54, at 1271 ("Incorporating ecosystem services into decision-making can change the way a problem is perceived and the way solutions are formulated because decision makers consider not only changes to ecological conditions but also how these changes can affect people.").

60. Chen et al., *supra* note 33, at 8 (emphasizing the importance of using mapping indicators that "will be directly relevant to people's values, needs and demands, instead of purely ecological biophysical measures or general socio-economic data").

and reliance on the service (e.g. for safety, subsistence) capturing both socio-economic and environmental conditions."[61]

As we explore in the next section, mapping the flows of ecosystem benefits improves ecosystem services assessments by making it easier to understand the power and equity dynamics of ecosystem services access and management.

II. ECOSYSTEM BENEFIT FLOW MAPPING NORMALIZES EQUITY

Ecosystem services research advances our understanding of the many "ways humans need healthy and productive ecosystems."[62] However, even as our frameworks for integrating ecosystem services into decision-making processes have become more sophisticated over the past two decades, it has been challenging to adapt the research to identify the important linkages between ecosystem services and equity.[63] It is clear that access to and control of ecosystem services is a form of power, and that not all stakeholders benefit equally from ecosystem services.[64] Likewise, it is clear that control of ecosystem processes, the destruction of which can interrupt the flow of ecosystem benefits, is not distributed equally.[65] Understanding who holds that power and how power relationships shape access to resources is key to uncovering asymmetries in the distribution of ecosystem services wealth.[66] Mapping benefit flows from ecosystem services illustrates patterns of supply and demand and provides *accessible* information about resource access and control that allows us to understand existing forms of ecosystem services dominance.[67]

In the sections that follow, we explore how mapping benefit flows exposes differences in the distribution of access to ecosystem services and creates usable information to address questions of fairness in the distribution of burdens and benefits in future ecosystem management decisions, in other words, ecosystem equity. We start by briefly discussing what equity means

---

61. Wolff et al., *supra* note 43, at 163.

62. Keith H. Hirokawa, *The World Is My Oyster and Other Tales of Domination: The Critique from Ecosystem Services*, 49 ECOLOGY L. CURRENTS 1, 2 (2022).

63. *Cf.* Cecile Barnaud et al., *Ecosystem Services, Social Interdependencies, and Collective Action: A Conceptual Framework*, *in* 23 ECOLOGY & SOC'Y 15 (2018) (proposing a participatory research approach to incorporate social dimensions of ecosystem services).

64. *See, e.g.*, Erik Swyngedouw, *The Political Economy and Political Ecology of the Hydro-Social Cycle*, 142 J. CONTEMP. WATER RSCH. & EDUC. 56, 57, 59 (2009) (describing the power dynamics of access to water, one example of many of how access to resources implicates power).

65. María R. Felipe-Lucia et al., *Ecosystem Services Flows: Why Stakeholders' Power Relationships Matter*, PLOS ONE, July 22, 2015, at 2.

66. *Id.*

67. *See infra* Section III.B.

and how equity considerations arise in the ecosystem services context. We then explore the ways in which mapping helps us understand who controls resources and who will benefit (or suffer) from ecosystem investments. This lays the framework for interrogating existing power dynamics and demonstrating how mapping provides a tool for work in communities to achieve more equitable management outcomes. Moreover, this work helps fill a gap between growing recognition of ecosystem services and the important project of developing policies "that account for interactions and trade-offs among environmental, economic, and social values."[68]

A. Ecosystem Services & Equity

Equity is a contested and malleable concept.[69] The term has been the subject of extensive thought and inquiry across disciplines, with scholars from the fields of moral philosophy, political theory, and jurisprudence paying particular attention to the ways in which the principle is used.[70] Inevitably, the meaning of the term is highly contextual, and the concept is deployed in distinct ways in different settings, including within the field of environmental law.[71] Here we use the term to refer to the fair distribution of burdens and benefits in the context of ecosystem services, across geography,

---

68. Heather Tallis et al., *Poverty and the Distribution of Ecosystem Services*, *in* NATURAL CAPITAL: THEORY AND PRACTICE OF MAPPING ECOSYSTEM SERVICES 278, 278 (Peter Kareiva et al. eds., 2011).

69. *See generally* Cinnamon P. Carlarne & JD Colavecchio, *Balancing Equity and Effectiveness: The Paris Agreement and the Future of International Climate Change Law*, 27 N.Y.U. ENV'T. L.J. 107, 116–18, 124–29 (2019). Inequity and inequality in environmental law scholarship are at times used interchangeably, further complicating the definition of each. For example, Salzman et al. use "inequality" to refer to the distribution of disproportionate burdens: "[e]nvironmental inequality occurs when certain population sectors—predominantly low-income and minority populations—either bear a disproportionate burden from industrial pollution sources or receive fewer benefits from environmentally beneficial projects." James Salzman et al., *The Most Important Current Research Questions in Urban Ecosystem Services*, 25 DUKE ENV'T. L. & POL'Y F. 1, 15 (2014). Compare with the EPA's initial definition of environmental equity, from Robert Kuehn, *A Taxonomy of Environmental Justice*, 30 ENV'T L. REP. 10681, 10682 (2000), meaning the "equitable distribution of environmental risks across population groups.".

70. Jekwu Ikeme, *Equity, Environmental Justice and Sustainability: Incomplete Approaches in Climate Change Politics*, 13 GLOB. ENV'T. CHANGE 195, 195–96 (2003) (clarifying equity via various moral philosophy perspectives); Jerret Yan, *Rousing the Sleeping Giant: Administrative Enforcement of Title VI and New Routes to Equity in Transit Planning*, CAL. L. REV. 1131, 1157–58 (2013) (proposing a new definition of equity for judicial interpretation of Title VI claims); Anna Livia Brand, *The Politics of Defining and Building Equity in the Twenty-First Century*, 35 J. PLAN. EDUC. & RSCH. 249, 260–61 (2015) (defining equity in the political context).

71. *See* Sonya Ziaja, *How Algorithm Assisted Decision-Making Is Influencing Environmental Law and Climate Adaptation*, 48 ECOLOGY L. Q. 899, 916–917 (2021).

jurisdictions, and communities. More importantly, we emphasize that equity analyses cannot be done in the abstract, which is one of the pressing reasons we need benefit flows mapping that provides local, contextual information about how relevant stakeholders need ecosystem services and the degree to which different stakeholder receive varying levels of benefits and burdens of ecosystem services.[72] To advance ecosystem services equity, "there is a need to better understand the broader political economy of decision making and the distributional consequences of particular policy choices, underpinned by the latest biophysical understanding of trade-offs and synergies between ecosystem services."[73]

Ecosystem services generally benefit society, but "not everybody benefits equally."[74] Ecosystem services research has long recognized linkages between poverty and ecosystem services and has sought ways to advance the "twin goals of environmental improvement and poverty reduction."[75] Yet despite more than two decades of efforts to understand the relationship between ecosystem services and poverty, broader questions of equity have been poorly integrated into decision-making processes: "[D]ecisions made today based on costs and benefits to society leave out many of the public goods and services provided to the poor by the environment . . . ."[76] As a result, many of our ecosystem management decisions continue to reflect built-in biases that ignore ecosystem services disparities and their determinative impacts, in many cases, on natural wealth and opportunity.

Also missing from most ecosystem management decision making is a framework for thinking about the role of power and the power relationships that exist among ecosystem services stakeholders. Existing "power asymmetries among stakeholders mean that some stakeholders may use a

---

72. *See, e.g.*, Charity Nyelele & Charles N. Kroll, *The Equity of Urban Forest Ecosystem Services and Benefits in the Bronx, NY*, URB. FORESTRY & URB. GREENING, Aug. 2020, at 1, 2 ("Equity, a term used synonymously with fairness or justice, refers to the fair distribution of resources, especially the absence of systematic disparities between more and less advantaged social groups . . . equity is a multi-dimensional concept of ethical concerns and social justice with distributive, procedural and contextual dimensions.").

73. Bhaskar Vira et al., *Negotiating Trade-Offs: Choices About Ecosystem Services for Poverty Alleviation*, 47 ECON. & POL. WKLY. 67, 73 (2012).

74. Felipe-Lucia et al., *supra* note 65, at 2.

75. Vira et al., *supra* note 73, at 67; *see also* Fisher et al., *Strengthening Conceptual Foundations: Analysing Frameworks for Ecosystem Services and Poverty Alleviation Research*, 23 GLOB. ENV'T CHANGE 1098, 1107, 1110 (2013) ("Interest is growing in the potential for ecosystem services to be managed to contribute to poverty alleviation."); Tallis et al., *supra* note 68, at 279 (noting that poverty is not only an "agent" of ecosystem degradation but also a "victim" of ecosystem services degradation and allocation).

76. Tallis et al., *supra* note 68, at 278.

particular ecosystem service or a set of ecosystem services while other stakeholders might be excluded."[77] Uncovering such asymmetries

> [e]xposes the gap between the production of services by an ecosystem and the actual benefits stakeholders receive. Such gaps can reveal those stakeholders dependent on certain ecosystem services for their well-being that are at risk of being excluded from accessing ecosystem services. Power relationships, including the beneficiaries of ecosystem services. . . . [T]he contributors to services production, and those who are excluded (i.e., the losers) have not yet been integrated into ecosystem services management. Integrating power relationships into ecosystem services research explicitly provides an opportunity to assess how power mediates ecosystem services flows that may be crucial information to design more sustainable management policies.[78]

Despite growing recognition of the pivotal role that power relationships play in shaping the distribution of ecosystem wealth, there is little research exploring how asymmetries in access to ecosystem services reflect and imbed larger patterns of social inequality.[79] If we do not account for existing inequities, future management decisions will replicate these patterns.[80] However, if we take inequality into account, ecosystem services can be an effective tool to support efforts to identify and address existing inequities.[81] As a result, as we improve our ability to use ecosystem services as a tool to express the real value of those services to humans, we should also be working to improve our assessment of how ecosystem services can be used as a tool to advance equity.[82]

Here we seek to advance the conversation around the use of ecosystem services in law and policy-making decisions by asking not only how we value these services as a form of wealth, but also: which services should we be focused on protecting, why, and for whom? The background questions for this include: who already has access to natural wealth? Why? How do decisions we make now affect existing forms of wealth distribution moving forward, particularly in a climate stressed world? This is where benefit flows

---

77. Felipe-Lucia et al., *supra* note 65, at 2.
78. *Id.*
79. *See id.* at 15.
80. *See id.* at 17.
81. *See id.* at 15.
82. Felipe-Lucia et al. describes: "in order to delineate sustainable management practices that foster equal access to ecosystem services, it is necessary to contribute detailed information on: (i) ecosystem services' interactions, (ii) the governance for each ecosystem service, (iii) the role of stakeholders regarding each ecosystem service, and (iv) the power relationships established among stakeholders." *Id.* at 17.

mapping makes a significant contribution. Mapping benefit flows allows us to see how patterns of power shape access to natural resource decision making[83] and provides this information in a usable format that is conducive to more inclusive community conversations.[84]

B. Benefit Flows Mapping as an Equity Tool

Ecosystem services allow us to value a resource to better communicate the important roles that natural resources provide to society.[85] By valuing functioning ecosystems, we hope to encourage better ecosystem management decisions. But ecosystem services analysis does not necessarily account for equity. Ecosystem services analyses are not designed to provide information about why management systems look the way they do. Equally, ecosystem services are not designed as a tool for accounting for "the ways in which different stakeholders benefit from [ecosystem services] flows over space and time,"[86] or determining what the implications of these systems are for communities who lack control over natural resources but are dependent upon those resources.[87] Yet ecosystem services analyses provide valuable information that can be used to understand these relationships. Benefit flows mapping adds to the effective use of ecosystem services information by showing who controls and who benefits from ecosystem services.[88] Mapping visually depicts how natural wealth is being distributed in an accessible way.[89]

---

83. When the power structures and trade-offs of ecosystem services management decisions are not acknowledged, future conflict and inequitable outcomes are likely to follow. Yet this is how most ecosystem services management decisions are made. *See* Vira et al., *supra* note 73, at 68.

84. As Opdam et al. suggests:

> The significance of landscape information to enhance collaboration is that, in addition to a planning process that maximizes social learning, building collaborative relationships result in strengthened social networks, which accommodate knowledge diffusion and deliberation. Such a feed-back mechanism may improve the capacity for collective management and social learning in a social-ecological system.

Paul Opdam et al., *Does Information on Landscape Benefits Influence Collective Action in Landscape Governance?*, 18 CURRENT OP. ENV'T SUSTAINABILITY 107, 112 (2016).

85. *See* Ken J. Wallace, *Classification of Ecosystem Services: Problems and Solutions*, 139 BIOLOGICAL CONSERVATION 235, 242–43.

86. *See* Vira et al., *supra* note 73, at 70.

87. *See id.*

88. *See* Karrigan Börk et al., *Adapting to a 4˚C World*, 52 ENV'T L. REP. 10211, 10227 (2022).

89. *Id.*

Access to information is a form of power relating to procedural equity.[90] Benefit flows mapping provides communities with access to usable information.[91] As an ecosystem equity tool, ecosystem services maps allow us to account for the distribution of ecosystem services benefits more easily, while identifying the connections between ecosystem service beneficiaries and those areas where ecosystem structure and function is critical to the continuation of those benefits.[92] As Olander et al. suggest, "[a]ll services do not flow to all people equally, and some decision contexts present a requirement to consider those differences."[93] Mapping exposes power relationships among ecosystem service providers and beneficiaries by showing how "those stakeholders able to manage . . . keystone ecological properties and ecosystem services can affect the well-being of other stakeholder groups by determining the ecosystem's capacity to provide services and/or by controlling access to them."[94]

Benefit flows mapping offers access to information about the ways that geographically distinct communities are related and connected, transforming natural resource competition between and among communities into opportunities for communication and collaboration.[95] Such information, which is ineffective in the abstract, operationalizes ecosystem services information to empower communities.[96] By creating visual depictions of who controls and accesses ecosystem services as well as who needs access to ecosystem services, benefit flows mapping can help communities understand how power influences control over natural wealth (such as through the exercise of property rights) and how future resource management decisions will impact a wide variety of stakeholders.[97] In these contexts, using information from benefit flows mapping "can help decision makers consider where a change in provision of a service may have a large impact on

---

90. *See* Urcil Papito Kenfack Essougong et al., *Addressing Equity in Community Forestry: Lessons from 20 Years of Implementation in Cameroon*, ECOLOGY & SOCIETY, Mar. 2019, at 6.

91. *See* Börk et al., *supra* note 88, at 10227.

92. *See id.*

93. Olander et al., *supra* note 54, at 1267.

94. Felipe-Lucia et al., *supra* note 65, at 17.

95. *See* Opdam et al., *supra* note 84, at 111 ("Spatial dependencies may also cause competitive relationships within a landscape area, for example if there is a shortage of resources. Magombeyi et al. used a river basin game to share knowledge on the spatial interdependence of different water users in the Olifants river basin in South Africa. By demonstrating the relationship between the functioning of the catchment and the user value, the tool facilitated negotiations between upstream and downstream water users. This resulted in a shared understanding about which areas and families were affected and led to collective water management by elected committees.") (citation omitted).

96. *See id.* at 111–12.

97. *See id.* at 107, 111.

particular populations, including social groups of special concern, such as the elderly, young, or disabled or those who are part of tribal communities or are economically disadvantaged."[98] Benefit flows mapping thus adds to our understanding of ecosystem services by making hidden forms of resource dominance visible, providing visual tools for interrogating past practices, and deepening community conversations about social values and future practices.[99] As Vira et al. suggest, mapping allows us to "enhance our understanding about the relationships between ecosystems and human wellbeing in specific contexts and develop associated methods to measure, map, and monitor the impacts of change in both the ecological and socio-economic domains."[100]

Mapping ecosystem benefit flows helps bridge the gap between ecosystem services and efforts to engage in more informed policymaking.[101] It provides access to information about the present and future distribution of costs and benefits associated with ecosystem services and it provides opportunities for "achieving the 'win-win' solution of both restoring ecosystems and improving access . . . to ecosystem services" for those who have been historically excluded or underrepresented in decision making processes.[102] It provides a necessary first step for advancing ecosystem services equity.

In the section that follows, we use the example of flood control services provided in a watershed as they might exist in a hypothetical watershed in upstate New York. This example will help to illustrate how ecosystem services operate in practice and to imagine how mapping of ecosystem benefit flows could be used to normalize equity in watershed management decision making.

---

98. Olander et al., *supra* note 54, at 1267; *see also id.* at 1269–70 (noting further "[i]nformation or assumptions about social preferences or values are essential for decision makers to draw conclusions about how changes in the provision of ecosystem services will affect social benefits. Even 'more is better' conclusions require decision makers to assume a positive relationship between services and social welfare.").

99. *See* Opdam et al., *supra* note 84, at 111.

100. Vira et al., *supra* note 73, at 70 (Mapping does not "provide clear guidance on how to reconcile competing objectives."). Mapping benefit flows provides information to make informed choices, but it does not provide policy prescriptions about how to resolve competing interests and objectives. *Id.* at 70–71.

101. *Id.* at 68, 73.

102. *Id.* at 67–68.

III. ECOSYSTEM SERVICES MAPPING IN ACTION: MAPPING FLOOD CONTROL SERVICES

The absence of empirical data makes it difficult to highlight how systems of dominance over ecosystem services often operate to imbed existing systems of power and privilege at the expense of those who have been historically excluded from accessing and managing ecosystem services.[103] These gaps limit communities' ability to understand and assess the trade-offs that are constantly being made and the equity implications of ecosystem services management decisions.[104] As Vira et al. note, "Programmes based on ecosystem services can be more explicit about losses, costs and the hard choices associated with alternatives so that they can be openly discussed and honestly negotiated. By not doing so, such interventions may lead to unrealistic expectations and perverse outcomes, and ultimately to unresolved conflict."[105]

Here, we offer a case study to aid in efforts to advance thinking around the ways that ecosystem mapping can enhance the implementation of ecosystem policy and law and normalize equity as part of this process.

Flood control services provided in watersheds illustrate the equity opportunities that stem from understanding ecosystem benefit flows. Creeks and rivers provide various ecosystem services and disservices to those who live alongside them and depend upon them.[106] Watersheds, of course, are complex in terms of the number of ecosystem services they provide and the vast range of stakeholders that have interests in those ecosystem services.[107] As Bhaskar Vira et al. describe:

> hydrological relationships cover a larger scale and many projects with their multiple objectives have often faced trade-offs among the interests of different stakeholders. Some of the key challenges have

103. *See id.* at 68 ("[W]atershed projects often as the poorest, most vulnerable people to provide valuable environmental services to much wealthy landowners.").

104. *See id.* (discussing the "complex trade-offs that exist between conservation goals and other economic, political and social agendas across multiple scales"); *see also* Nyelele & Kroll, *supra* note 72, at 10 ("Results reveal that ecosystem services in the Bronx are related to a variety of socio-demographic and socio-economic characteristics of the census block groups and therefore support the conclusion that ecosystem services from urban trees are inequitably distributed in the Bronx, and that this inequity is associated with traditional socio-economic and socio-demographic divisions.").

105. Vira et al., *supra* note 73, at 68.

106. *See, e.g.*, Stoyan Nedkov & Benjamin Burkhard, *Flood Regulating Ecosystem Services— Mapping Supply and Demand, in the Etropole Municipality, Bulgaria*, 21 ECOLOGICAL INDICATORS 67, 67–68 (2012) (characterizing floods as an ecosystem disservice).

107. Vira et al., *supra* note 73, at 73.

> been uneven distribution of benefits and costs of technical interventions, multiple and conflicting uses of natural resources, multiple and overlapping property rights regimes and the difficulty of encouraging social groups to organise around a spatial unit defined by hydrology.[108]

On the other hand, for mapping purposes, watersheds are simple in the sense that the flow of flood control services is largely unidirectional and can be tracked from the upstream stakeholders linearly to the downstream stakeholders.[109] Moreover, watersheds have been the focus of early thinking about mapping ecosystem service benefit flows.[110] This work provides a foundation for understanding the complexity of power relationships and trade-offs that must be considered along the way to normalizing equity as part of the ecosystem services management process.

In the case study, we explore the ecosystem services that the watershed provides—focusing on flood control services—and the power that different stakeholders exercise over these services. The goal of this case study is to consider stakeholders at the very end of the power hierarchy; those who do not control or influence how ecosystem services are managed, but who will experience disproportionate harms because of management decisions made elsewhere. These stakeholders, which here include a racially and socio-economically diverse urban community that is situated at the most downstream point of the watershed, and who experience extreme ecosystem disservice in the form of flooding. Their ability to control and respond to the flooding in their community is limited. Their ability to control upstream ecosystem decision making, which could prevent or exacerbate flooding, is equally limited. They are among the most powerless of the stakeholders in the watershed. To return to our definition of ecosystem inequity, in this scenario, the community exercises the least amount of control over upstream ecosystem services decisions, while bearing a disproportionate burden of ecosystem disservices (e.g., floods), because of how and where the ecosystem services in the watershed are managed. In this case study, ecosystem services reveal the value of the resources the watershed provides and the ways in which stakeholders in the watershed benefit from a functioning ecosystem. Benefit flows mapping builds on our understanding of ecosystem services by helping us understand how stakeholders in the watershed benefit or suffer as

---

108. *Id.*

109. *See, e.g.*, Opdam et al., *supra* note 84, at 111 (discussing the relationship between upstream and downstream water users of a river basin game).

110. *See, e.g.*, Kenneth J. Bagstad et al., *Spatial Dynamics of Ecosystem Service Flows: A Comprehensive Approach to Quantifying Actual Services*, 4 ECOSYSTEM SERVICES 117 (2013); Nedkov & Burkhard, *supra* note 106.

a result of resource management control and decision making.[111] Mapping these flows provides information that is specific and usable, is a form of community empowerment, and can be deployed to advocate for more equitable allocations of resources.[112]

A. Watersheds as Ecosystem Service Suppliers

Watersheds host many different ecosystem services.[113] Here, we briefly describe some of those services as the background for focusing on flood control, a regulating ecosystem service, as a vehicle for exploring how ecosystem services mapping provides opportunities for normalizing equity as a part of the management process.

Our hypothetical Upstate New York[114] creek flows through a mix of rural and forested lands, through agricultural areas and suburban towns and, finally, into urbanized areas.[115] Along the way, the water system influences and is influenced by many land cover types and ecosystem features, is relied upon for many land uses, and presents different ecosystem disservices[116] to people living and working along the banks due to flooding during significant storm events. Hence, in this case study, we illustrate how attention to ecosystem services of the creek can help maintain the flood control benefits

---

111. *See* discussion *infra* Section III.B.

112. *Id.*

113. *Id.*

114. We use upstate New York because of the rich data on watersheds in this region, as well as to avoid complex questions of scarcity that would characterize a western watershed case study. This hypothetical is loosely based on the Poesten Kill Watershed, which flows from the Rensselaer Plateau of eastern New York westerly into Troy, New York, before entering the Hudson River in South Troy. For information about the Poesten Kill flooding history and ecosystem services mitigation projects, see *Poesten Kill Watershed Flood Mitigation*, RENSSELAER PLATEAU ALL., https://www.rensselaerplateau.org/floodmitigation [https://perma.cc/7RWD-PWDS].

115. Analyzing flood control benefit flows from rural, forested, and agroecosystems into urbanized areas is a common study approach, in large part because flood control services are directional, and flooding damages in urbanized areas are more pronounced. *See, e.g.*, Victor Martínez-García et al., *The Economic Value of Flood Risk Regulation by Agroecosystems at Semiarid Areas*, 266 AGRIC. WATER MGMT. 1 (2022); Nedkov & Burkhard, *supra* note 106, at 67.

116. *See generally* Julien Blanco et al., *Ecosystem Disservices Matter: Towards Their Systematic Integration Within Ecosystem Service Research and Policy*, 36 ECOSYSTEM SERVS., 2019, at 1, 2 (defining ecosystem disservices as "the ecosystem generated functions, processes and attributes that result in perceived or actual negative impacts on human wellbeing") (citation omitted); *see also* Jari Lyytimäki et al., *Nature as a Nuisance? Ecosystem Services and Disservices to Urban Lifestyle*, 5 ENV'T SCI. 161 (2008) (discussing ecological disservices in urban biodiversity studies).

of the creek where they are needed, while exposing the risks of losing such benefits due to the distribution of power over those ecosystem services.

This water system is not pristine and, in places, is not even safe for human use, as years of development and streambed modifications have created long-term negative impacts on the ability of watersheds to provide ecosystem services. Floods have caused significant damage, consistent with the recent rise in significant storm events in North America.[117] Flooding events typically cause death, property loss, physical injuries and infectious diseases, emotional distress, and impacts related to the loss of food and shelter.[118] In addition, flooding frequently results in disproportionate negative impacts in low-income communities due to disparities in infrastructure investments and community capacity to respond to storm events.[119] Traditionally, flooding risks have been addressed through a combination of grey, constructed infrastructure elements (such as culverts, dams, and dykes) and reconfiguring flows through dredging (such as dredging to channelize, widen, and deepen waterbeds) to increase the capacity of the watercourse to hold water and transport it elsewhere.[120]

From an ecosystem services perspective, we begin by identifying flood control opportunities presented by ecosystem structures and processes in our hypothetical watershed.[121] For our purposes here, the four relevant ecosystem

117. *See* Martínez-García et al., *supra* note 115, at 1 ("In 2019 alone, floods accounted for 49% of all natural disasters and 68% of the population affected by natural disasters worldwide."); Lelys Bravo de Guenni et al., *Regulation of Natural Hazards: Floods and Fires*, *in* 1 ECOSYSTEMS AND HUMAN WELL-BEING: CURRENT STATE AND TRENDS ASSESSMENT 441, 447 (Richard Norgaard ed. 2005) (discussing changes in flood occurrences and related damages).

118. Guenni et al., *supra* note 117, at 452.

119. *See id.*

120. Martínez-García et al., *supra* note 115, at 2; Keith H. Hirokawa & David Dickinson, *The Costs of Climate Disruption in the Tradeoffs of Community Resilience*, 41 W. NEW ENG. L. REV. 445, 470 (2019); ZACHARY CHRISTIN & MICHAEL KLINE, WHY WE CONTINUE TO DEVELOP FLOODPLAINS: EXAMINING THE DISINCENTIVES FOR CONSERVATION IN FEDERAL POLICY 7 (2017), https://www.aswm.org/pdf_lib/discincentives_for_conservation_in_federal_policy.pdf [https://perma.cc/BLU8-VS9D] ("Stream channel modifications have largely been pursued to protect adjacent land uses that may be threatened by flooding or fluvial erosion.").

121. *See* Gretchen C. Daily et al., *Ecosystem Services Supplied by Soil*, *in* NATURE'S SERVICES: SOCIETAL DEPENDENCE ON NATURAL ECOSYSTEMS 113, 113 (Gretchen C. Daily ed., 1997) (The analysis begins by recognizing that the water system offers more than a pile of marketable goods. Of course, if we understand nature as only a collection of goods (and not services), we might find that soil appears as "little more than ground up rock."); *see also* Steven Banwart et al., *Soil Processes and Functions Across an International Network of Critical Zone Observatories: Introduction to Experimental Methods and Initial Results*, 344 C.R. GEOSCIENCE 758, 759 (2012) ("Traditionally, soils have been largely managed with a single use in mind, primarily for food, feed or fibre production."). Wetlands might appear as breeding areas for

types in our landscape[122] that provide flood control services include forests, soils, agroecosystems, and wetlands, all of which provide critical services that support human well-being, making them valuable beyond their capacities to provide marketable goods. The focus here is on inventorying relevant flood control services to help us visualize the flow from the point at which the services are generated through where the beneficiaries of those services are. After introducing these systems, we explore how ecosystem services mapping can help us understand and engage questions of equity in decision-making processes.

1. Forests

The headwaters of our watershed contain thousands of acres of forested lands and wetlands. Although many forested areas are managed to maximize the production of forest products (lumber and paper products), forests provide a host of other life-sustaining ecosystem services. As noted by Norman Myers:

> They stabilize landscapes. They protect soils and help them to retain their moisture and to store and cycle nutrients. They serve as buffers against the spread of pests and diseases. By preserving watershed functions, they regulate water flows in terms of both quantity and quality, thereby helping to prevent flood-and-drought regimes in downstream territories. They are critical to the energy balance of the earth. They modulate climates at local and regional levels to regulation of rainfall regimes and the albedo effect; and at planet-wide level, they help to contain global warming by virtue of the carbon stocks in their plants (especially trees) and soils.[123]

Forests are essential components of flood preparedness, and a recent study found that reforestation could reduce flood peaks by twenty percent.[124]

---

snakes, rats, and mosquitoes. Trees would appear only as board-feet of lumber. Farms, likewise, are useful only for producing food. Yet, the ecosystem services perspective casts nature as a service provider—more than just a pile of goods—suggesting the need for a deeper inquiry into the structures and processes of the ecosystem to determine how they provide particular benefits.

122. Nedkov & Burkhard, *supra* note 106, at 78 ("Regulating ecosystem services are clearly dependent on spatial landscape patterns and interactions between adjacent ecosystems, which have to be taken into account in the assessment of their capacity.").

123. Norman Myers, *The World's Forests and Their Ecosystem Services*, *in* NATURE'S SERVICES: SOCIETAL DEPENDENCE ON NATURAL ECOSYSTEMS 215, 215–16 (Gretchen C. Daily ed., 1997) (citations omitted).

124. *See generally* Simon J. Dixon et al., *The Effects of River Restoration on Catchment Scale Flood Risk and Flood Hydrology*, 41 EARTH SURFACE PROCESSES & LANDFORMS 997, 997 (2016).

Forests regulate water flows by intercepting[125] water before it becomes a flood problem, while minimizing the conditions from which floods can cause damage:

> [T]he ecosystems (i.e. forest) redirect or absorb parts of the incoming water (from rainfall), reducing the surface runoff and consequently the amount of river discharge.[126] This ecosystem service plays its role before flood occurrence and in some cases can even prevent it . . . One role of forests and mitigating flooding in the case of melting snow is the reduction of wind velocity and delay of snow melt caused by warm winds.[127]

Forests are an important source of flood regulation in our watershed. Forest-management decisions upstream will influence the degree of flooding downstream users in our watershed will experience.

2. Soils

A second ecosystem feature in our watershed is the soil. By supporting most, if not all other ecosystem processes, soils "are so fundamental to life that their total value could only be expressed as infinite":[128]

> Like a sponge, soil absorbs precipitation and gradually meters it out to plant roots and into subterranean aquifers and surface streams. Soil shelters seeds and provides physical support and nourishment to plants. It consumes wastes and the remains of dead plants and animals, rendering their potential toxins and human pathogens harmless, while recycling their constituent materials into forms usable by plants. In the process, soil organisms regulate the fluxes of important greenhouse gases . . . . Soil plays a critical role in fueling the entire terrestrial food chain and it is an important feature of many aquatic systems as well.[129]

---

125. Ecosystem structures that provide flood control services can be preventative or mitigatory (or, in many cases, a mixture of both). For instance, a forest might prevent rainwater from accumulating on the ground by intercepting and absorbing water, reducing the amount of water flowing as runoff and flood waters. Wetlands and floodplains, on the other hand, perform a mitigation service by capturing and retaining flood waters and reducing flood flows. *See* Nedkov & Burkhard, *supra* note 106*,* at 68.

126. *Id.*

127. *Id.*

128. *See* Daily et al., *supra* note 121, at 128.

129. *Id.* at 113; Banwart et al., *supra* note 121, at 759–60 ("[S]oils provide . . . important functions including supporting and sustaining our terrestrial ecosystems, regulating the

Soils along our hypothetical creek vary from highly drained gravel and sandy loam to less permeable types, such as clay. The soils along the creek play a vital role in regulating water flows, and soil management decisions that are made upstream are key determinants in how flooding will be experienced downstream in our watershed.

3. Agroecosystems

Ecosystem services from agroecosystems are not well understood, but research into agroecosystem services continues to grow.[130] Agroecosystems provide numerous flood control benefits to downstream residents. Some agroecosystems are situated to "influence[] social welfare by regulating floods through water retention capacity of the vegetation and soil during a flood. This makes it possible to reduce peak flow of floods (by controlling runoff) and, consequently, the economic damage caused during flood events."[131] Relevant factors in assessing agroecosystem productivity include the agroecosystem type, farming practices (like buffer zones and no till planting), and even social benefits and values of agricultural products to the region.[132] Agroecosystem stakeholders exercise a significant amount of power in our watershed.[133] The decisions they make about how their land is used will have cascading impacts on the services and disservices experienced downstream.

---

atmosphere through carbon storage, filtering water, recycling waste, preserving heritage, acting as an aesthetic and cultural resource, whilst maintaining a vital gene pool and biological resource from which many of our antibiotics have been derived.").

130. The lack of attention to such services may be due to the fact that agricultural practices are typically focused on the production of goods and are thus contrasted with natural ecosystems. "Agroecosystems are created by humans to provide a specific provisioning service. This involves such a degree of anthropisation that human activities, mainly through agricultural practices, affect the innate functioning of these ecosystems. Therefore, agroecosystem services are not fully produced by agroecosystem functioning, and their provision is determined by the level of human activity within each agroecosystem. Agroecosystem services are, therefore, coproduced by both the natural ecosystem and the human hand." José A. Zabala et al., *A Comprehensive Approach for Agroecosystem Services and Disservices Valuation*, 768 SCI. TOTAL ENV'T, Dec. 2020, at 2. In addition, there may be reluctance to focus on agroecosystems because of the negative impacts that agricultural practices can have on air quality, water quality, habitat and biodiversity provision, and water availability.

131. Martínez-García et al., *supra* note 115, at 2.

132. *See* Zabala et al., *supra* note 130, at 2.

133. *See id.*

4. Wetlands

Wetlands are "one of the most ecologically diverse and productive ecosystems on the planet," and "have been identified as an important source of natural capital, providing a broad sweep of [ecosystem services], improving surface water quality, ensuring sustainable drinking water sources, mitigating the impacts of drought and floods, mitigating the impacts of climate change, providing habitat for wildlife and maintaining and enhancing biodiversity."[134]

Wetlands "almost always reduce floods (and their peaks) or delay them"[135] by capturing and retaining excess water during significant storm events, thereby reducing the likelihood that flood flows will cause damage.[136]

Each of these four types of ecosystem supplies flood control services to downstream users by reducing total runoff in storm events and spreading out the flows, thus reducing the peak flood levels. Yet, in our watershed, most of these ecosystems are controlled by upstream property owners, perhaps spread across different municipal jurisdictions, whose decisions about how they manage their respective ecosystems are not accountable for how those decisions impact downstream users. They do not pay for the right to disrupt downstream ecosystem benefits, so, as rational economic actors, they are unlikely to consider these costs. Hence, many of the downstream beneficiaries of flood control services have no voice in and no information about land use decisions upstream, even though these decisions could have far-reaching impacts on their lives and well-being.[137] The decisions upstream farmers, forest managers, landowners, and counties are making may be constrained by certain rules or norms, but rarely are such actors required to account for the impacts of their decisions on the degree of flooding felt in the downstream urban area.[138] Moreover, just as the downstream stakeholders have little information about how their lives are being shaped by upstream users, neither do the upstream users have good, usable information about the downstream impacts of their individual and collective decisions.[139] Benefit

---

134. *Id.*

135. MILLENNIUM ECOSYSTEM ASSESSMENT, *supra* note 33, at 37.

136. *Cf.* Stacey Dumanski et al., *Hydrological Regime Changes in a Canadian Prairie Basin*, 29 HYDROLOGICAL PROCESSES 3893, 3902 (2015) (finding that wetland drainage increases the magnitude and frequency of flooding).

137. Jeffrey Kok Hui Chan & Kuei-Hsien Liao, *The Normative Dimensions of Flood Risk Management: Two Types of Flood Harm*, J. FLOOD RISK MGMT., Feb. 24, 2022, at 5.

138. *Id.*

139. *See* Dumanski et al., *supra* note 136, at 3902. *But see* RENSSELAER PLATEAU ALLIANCE ET AL., POESTEN KILL WATERSHED AND FLOOD MITIGATION ASSESSMENT 5 (2019),

flows mapping can help change this; mapping can help communities—both those with and without decision-making power—understand how changing the landscape and interrupting valuable ecosystem services could impact a wide variety of stakeholders.

B. Ecosystem Services Demand & Opportunities To Manage from Equity

Exploring the supply of ecosystem services—here flood control services—helps us identify who holds power in the watershed. Conversely, recognizing stakeholders who need flood control services helps us identify ecosystem services vulnerability, which might appear as ecosystem services inequity, and chart pathways to create equity through the capture of ecosystem service opportunities. Here, we emphasize that at many locations along the creek, land use decisions impact the delivery of flood control services.[140]

Our creek originates in a rural area that is covered by thousands of acres of dense forest. As the creek flows through the watershed, it passes through diverse land cover, including farmland, rural and suburban areas. Eventually the creek flows into a highly urbanized area where it joins a much larger river. Before it feeds into the river system, it runs directly through a social and racially diverse urban neighborhood, with higher levels of people of color, lower levels of income, and lower levels of education than on average for both the larger urban area and the watershed as a whole. This neighborhood is poorly designed to absorb storm surges and the accompanying flooding, in large part due to population density, underinvestment, and a history of modifications to the creek bed to accommodate development needs. The urban neighborhood demand for flood control services is high.

At the point of origin, the forested area is primarily on privately owned lands. In New York, "74% of . . . forests are owned by more than 700,000 private landowners." [141] Unless harvesting activities interfere with certain

---

https://www.rensselaerplateau.org/_files/ugd/394ce1_e69c73f766dc45429ac2a20b03575f0a.pdf [https://perma.cc/R4Y5-D7BP] (finding one counterexample concerns the targeted acquisition of upstream lands and wetlands enhancement planning by the Rensselaer Plateau Alliance in Averill Park, NY, which was expressly intended to maximize flood control services in the region).

140. Jaramar Villarreal et al., *The Impacts of Land Use Change on Flood Protection Services Among Multiple Beneficiaries*, 806 SCI. TOTAL ENV'T., Feb. 1, 2022, at 8–9.

141. "Today, 61% of New York's land area is covered with almost 19 million acres of forest land, and 74% of those forests are owned by more than 700,000 private landowners. These private forest lands provide many public benefits including clean air and water, carbon storage, forest

classified streams, occur in designated wetlands, or will result in clear-cuts over twenty-five acres in the Adirondack Park, landowners are generally not required to obtain a state permit to harvest timber.[142] Local laws, ordinances, and regulations may apply, but the majority of timber harvesting on private land in New York is not directly regulated by the state and local governments.[143] As a result, pivotal decisions about how to manage forest ecosystems that provide flood control systems are often made without being subject to regulation or even stakeholder participation. Such is the case with many of the forested areas along our creek. Landowners may choose to clear entire riparian areas from one year to the next as part of their silvicultural strategy. Similarly, the farmers mid-stream might choose to clear a creek-abutting field and, in the process, over-till the soil and remove riparian zones in ways that undermine the flood control services that soil and riparian zones provide.[144]

Just downstream from the agricultural area, in a rapidly growing suburban area, developers may obtain land use permits that allow them to fill wetlands abutting the creek and pave over productive soils in order to build new single-family homes. Sometimes, these decisions involve public input through a permitting process, or perhaps even a city council decision that involves public hearing and opportunities for feedback. Largely, however, the decisions are being made beyond the control or notice of downstream stakeholders, especially where those decisions occur in different jurisdictions. Those who control the supply of services—the forests, farms, soils, and wetlands—hold power. The decision of the upstream forester might affect the downstream farmer; the decision of the farmer might affect the downstream suburban homeowner and so on. Power is, in this sense, relative. Yet the further downstream you move, the more power tends to wane.

By the time the creek reaches the racially and socio-economically diverse urban area, all critical management decisions have been made that shape the flood control service that the watershed can provide. At this position in the

---

products, jobs, scenic beauty, and outdoor recreation opportunities . . . . DEC's Division of Lands and Forests recognizes that private forest lands are an important component of New York's economy and character and we're here to help keep it that way. DEC provides a variety of programs including free site visits to help support sustainable forest management." *Private Forest Management*, N.Y. DEP'T OF ENV'T CONSERVATION, https://www.dec.ny.gov/lands/4972.html [https://perma.cc/FUT9-VS78].

142. *Timber Harvesting*, N.Y. DEP'T OF ENV'T CONSERVATION, https://www.dec.ny.gov/lands/5242.html [https://perma.cc/VA66-Y5S9].

143. *See id.*

144. *See Riparian Buffers*, N.Y. DEP'T OF ENV'T CONSERVATION, https://www.dec.ny.gov/chemical/106345.html [https://perma.cc/SM5A-FK59] (discussing efforts in New York to restore or replace riparian buffers).

watershed, stakeholders have minimal ability to control their supply of ecosystem benefits and instead bear the brunt of ecosystem disservices such as flooding.[145] As a result, communities that are already historically marginalized will benefit the least from ecosystem services and bear the brunt of ecosystem disservices.[146] Moreover, as with many historically diverse, poor and working-class neighborhoods, this urban neighborhood has already suffered disproportionately from environmental harms and under investment in critical infrastructure.[147] Ecosystem services inequities compound these existing systemic inequalities. The potentially cataclysmic flooding that results, in part, from upstream management decisions will have the worst effects on "poor and working-class neighborhoods" that "have historically developed where inland-flood risk is the greatest."[148] These communities often have higher levels of vulnerability due to poor infrastructure, lack of insurance, and decades of marginalization as a result of redlining, underdevelopment, and a century of local land use policies that have imbedded intentional and implicit practices of racial violence.[149] For these communities, mapping ecosystem benefit flows creates opportunities to disrupt past practices and advocate for equitable change.

Mapping ecosystem benefit flows provides access to information that can be a powerful tool for advancing change. Maps can be used both to produce new information and to translate otherwise impenetrable information[150] into

145. For a helpful description of these dynamics at play in a watershed, see Felipe-Lucia et al., *supra* note 65. ("[W]hereas 'upstream' populations may benefit from water quality, 'downstream' populations may not. Yet, the potential of ecosystems to benefit humans not only depends on the spatial characteristics of the flow of services but are derived from their multiple types of interactions. On the one hand, these depend on the interactions among ecosystem properties and ecosystem services causing trade-offs and synergies. On the other hand, the interactions among stakeholders, which are partially caused by power relationships, can determine the access to and management of ecosystem services.").

146. *See, e.g.*, Thomas Frank, *How FEMA Helps White and Rich Americans Escape Floods*, POLITICO (May 27, 2022, 4:30 AM), https://www.politico.com/news/2022/05/27/unfair-fema-climate-program-floods-00032080 [https://perma.cc/563T-P4TB].

147. For an excellent discussion of how past and present practices such as redlining and "climate redlining" intersect to compound the risks that many poor, working class, and diverse neighborhoods face, see Virginia Eubanks, *My Drowning City Is a Harbinger of Climate Slums To Come*, THE NATION (Aug. 29, 2016), https://www.thenation.com/article/archive/low-water-mark/ [https://perma.cc/CV8A-MNM7].

148. *Id.*

149. *See* Keith H. Hirokawa, *Race, Space and Place: Interrogating Whiteness Through a Critical Approach to Place*, 29 WM. & MARY J. RACE, GENDER, & SOC. JUST. (forthcoming 2023).

150. To illustrate the point, consider a description of flood control service supply by soils that might provide usable information on infiltration and storage capacity to a geologist or ecologist, but is markedly less helpful to someone unfamiliar with the terminology: "The initial

a format that is accessible for a broader range of stakeholders. Maps create opportunities to improve understanding of supply and demand and to identify the primary beneficiaries of ecosystem services as well as the larger pool of stakeholders. They show how power is distributed and where pivotal points of opportunity to redistribute ecosystem assets exist. Most importantly, the information in the maps serves as a new source of power for stakeholders to use to re-imagine how ecosystem services could be distributed more equitably.

IV. OPERATIONALIZING ECOSYSTEM SERVICES MAPPING

Ecosystem services mapping can be deployed through existing environmental law tools. For example, existing land use planning efforts would be improved through the addition of mapping benefit flows. Benefit flows mapping would facilitate a productive inquiry into the downstream impacts of land use changes and give a better indication (better than we currently have) of when land use changes would severely impact vulnerable communities. Similar to stormwater regulation (that is intended to prevent land use changes from increasing off-site stormwater flows onto neighboring properties), communities regulating ecosystem functionality adopt performance standards, such as "no net loss" standards (such as in habitat regulations)[151] Such regulations not only increase the appreciation of ecosystem services distribution, but also help minimize impacts for the loss of ecosystem benefits where they are needed.

Planning and land use frameworks also offer some potential for mitigating the impacts to ecosystem services that are revealed through ecosystem benefit mapping. Landowners seeking discretionary permits, for example, already have to mitigate some of the associated public costs (like increased traffic or

---

data in the Bulgarian classification system has been transformed into the FAO 1974 classification system which is adapted for the use in the AGWA tool. The highest mountainous part is covered by Cambisols (B), which makes up 25% of the area. Most of them are district Cambisols (Bd), which have mainly silt-loam texture. Rankers (U) are represented by two main subtypes: U3 situated in the eastern and northern parts of the municipality and U5 in the western part. Rankers cover the largest part of the area (about 30%) and have sandy-loam texture. Lithosols (l) have limited distribution in the higher part of some mountain ridges. Luvisols (L) are presented by two subtypes: chromic Luvisols (Lc) are located in the lower parts of the area alongside river valleys, while orthic Luvisols (Lo) occupy relatively higher altitudes. They cover about 25% of the area and have clay-loam structure. Eutric Fluvisols (Jd) are situated predominantly in the river valleys covering about 7% of the area. They are characterized by loam texture." Nedkov & Burkhard, *supra* note 106, at 69.

151. *See, e.g.*, VANCOUVER, WASH., MUN. CODE ch. 20.740, § 020 (establishing a "no net loss" standard for critical areas regulations).

increased burdens on wastewater treatment) through exactions. Exactions are funds or in-kind contributions from landowners given in exchange for discretionary land use permits, which the Supreme Court has approved to "enable permitting authorities to insist that applicants bear the full costs of their proposals . . . ."[152] By internalizing these external costs of development, exactions allow private market ordering to more closely align the level of development with a social optimum.[153] Just as the ecosystem services approach is designed to bring some of the human values of ecosystems into economic discussions about ecosystem degradation, ecosystem benefit mapping could support exactions based on damages to ecosystem services that result from changes in land use. This approach builds on the well-established economic and legal rational for existing exactions but provides a fuller accounting of the social costs of land use changes.

Ecosystem services mapping could also be integrated into existing environmental justice mapping tools. Although there is ample opportunity to add social dimensions into ecosystem services, as demonstrated in the hypotheticals above, there are also opportunities to incorporate ecosystem services information into economic and environmental justice mapping efforts. As part of Executive Order 14008, the Council on Environmental Quality has been developing an indicator mapping tool, Climate and Economic Justice Screening Tool or "CJEST", to identify environmental justice communities.[154] The resulting tool will help determine federal project and funding priorities for transportation, housing, and water and energy infrastructure development, among others.[155] However, the causes of harms and the solutions for burdens experienced by environmental justice communities may be outside the boundaries of those communities, as in the case of our hypothetical river basin. By adding ecosystem flows and benefits information into indicator mapping tools like the CJEST project, we can expand the scope of possible solutions.

---

152. Koontz v. St. Johns River Water Mgmt. Dist., 570 U.S. 595, 606 (2013); *see* Hannah J. Wiseman, *Taxing Local Energy Externalities*, 96 NOTRE DAME L. REV. 563, 564–65 (2020). *But see* Christopher S. Elmendorf & Darien Shanske, *Auctioning the Upzone*, 70 CASE W. RSRV. L. REV. 513, 526 (2020) (arguing that the cost recovery rational for exactions is largely pretextual).

153. Wiseman, *supra* note 152, at 568–69 (2020).

154. Exec. Order No. 14008, 86 Fed. Reg. 7619 (Jan. 27, 2021); WHITE HOUSE COUNCIL ON ENV'T QUALITY, RESPONSE BY THE WHITE HOUSE COUNCIL ON ENVIRONMENTAL QUALITY TO THE WHITE HOUSE ENVIRONMENTAL JUSTICE ADVISORY COUNCIL'S FINAL RECOMMENDATIONS: JUSTICE40, CLIMATE AND ECONOMIC JUSTICE SCREENING TOOL, AND EXECUTIVE ORDER 12898 REVISIONS THAT WERE SUBMITTED ON MAY 21, 2021, at 183 (2022). The beta version of the screening tool can be found here: https://screeningtool.geoplatform.gov/en#3/33.47/-97.5.

155. *See* WHITE HOUSE COUNCIL ON ENV'T QUALITY, *supra* note 154.

Finally, benefit flows mapping should also be a standard practice in environmental impact assessments required under state and federal law. Environmental Impact Statements, required under the National Environmental Policy Act for federal projects with a potential to significantly impact the human environment, already (and increasingly) involve mapping of the area of interest including relevant ecosystems and other important characteristic of those areas.[156] As a logical next step, benefit flows mapping would improve environmental analysis by making the impacts of the action under consideration more explicit, giving a geographic "face" to impacts that may otherwise seem amorphous or theoretical. Such an exercise, coupled with outreach targeted to the impacted communities, could also mitigate some of the power disparities at play in situations like the hypothetical considered above.[157] Mapping ecosystem services will improve environmental impact analysis.

These efforts to operationalize ecosystem services mapping will face challenges, including many of the challenges facing all local environmental governance efforts, including lack of scientific of institutional capacity, scale issues, races to the bottom, and lack of funding.[158] The scale issues may be the most challenging. Ecosystems often span multiple jurisdictions, and, as with the hypothetical stream above, decisions in one jurisdiction may burden people living in downstream jurisdictions in ways that their jurisdiction is unable to directly address through its own inherent powers.[159] But these scale issues and other challenges do not result from integrating ecosystem services mapping into planning and other efforts. While the scale challenges may make the integration more difficult if, for example, jurisdictions resist gathering information on the impacts of their decisions outside of their own jurisdictional area (and thus not affecting their constituents as directly), this resistance could be overcome through state-level requirements (for local and regional agencies) and through new guidance from federal agencies (for exercises like NEPA-mandated EISs). Once ecosystem services mapping becomes a standard part of environmental and planning exercises, the scale and other challenges should be more obvious to participants, and the information from the mapping exercises can help lay the foundation for the

156. Stephanie N.T. Landim & Luis E. Sánchez, *The Contents and Scope of Environmental Impact Statements: How Do They Evolve Over Time?*, 30 IMPACT ASSESSMENT & PROJECT APPRAISAL 217, 224 (2012).

157. *See generally* Felipe-Lucia et al., *supra* note 65.

158. *See* Karrigan Bork & Keith Hirokawa, *Trends in Local Ecosystem Governance*, 3 FRONTIERS CLIMATE, Sept. 2021, at 1.

159. *See* Felipe-Lucia et al., *supra* note 65.

improved cross-jurisdictional coordination that is required to overcome these challenges. This may seem ambitious, but an example provides some support.

Consider the large herds of ungulates in the greater Yellowstone area, particularly elk, mule deer, and antelope. These species provide a myriad of ecosystem services: "supporting (grazing), provisioning (food base for humans and carnivores), regulating (seed dispersal), and cultural (recreation and heritage)."[160] Scientists seeking to manage and sustain these herds made a breakthrough in recent years through "an understanding of how migration affects populations and ecosystem functioning, [and] more advanced mapping of migration habitats for conservation."[161] These maps enabled scientists to understand the role that habitats across a wide ecological and jurisdictional landscape play in supporting the herds and the services they provide, which in turn motivated conservation efforts that cut across multiple jurisdictions (including private land) at both the state and federal levels.[162] The protection of the migration routes is not perfect, but the mapping efforts laid the foundation for developing a system of coordinated protection across jurisdictions.

In this example, mapping helped improve our understanding of the scope of ecosystem impacts and the ways that actions in distant regions affect each other, which allowed for the development of better environment governance. In turn, this form of mapping and more informed governance can also empower disadvantaged communities that are often excluded from or on the losing end of decisions impacting ecosystem services.

V. CONCLUSION

Access to nature—and the benefits that come from functioning ecosystems—is poorly distributed across class, race, gender and throughout communities.[163] Mapping benefit flows fosters an understanding of the power relationships between ecosystem stakeholders while distinguishing between those with the opportunity to control the flow of ecosystem services and those whose well-being depends on them. It helps us identify ecosystem services inequities and move towards a more equitable distributions of resources.

---

160. Temple Stoellinger et al., *Where the Deer and the Antelope Play: Conserving Big Game Migrations as an Endangered Phenomena*, 31 DUKE ENV'T L. & POL'Y F. 81, 88 (2020).

161. *Id.* at 86.

162. *Id.* at 145–46.

163. *See, e.g.*, Cinnamon P. Carlarne, *Environmental Law & Feminism*, *in* THE OXFORD HANDBOOK OF FEMINISM & LAW IN THE UNITED STATES (Martha Chamallas, Deborah L. Brake, & Verna Williams eds., forthcoming 2022).

Ecosystem services are a form of wealth. This wealth is concentrated and controlled based on existing systems of power. Benefit flows mapping provides informational equity and can be used to advance and normalize equity in decision-making processes. What we hope is that this Article advances thinking about the ways in which benefit flows mapping can serve as a tool of community empowerment by identifying opportunities for developing more inclusive and equitable systems of resource allocation.