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RESEARCH ARTICLE

Incentivizing the production of ecosystem services on working lands: The opportunities and challenges of funding "nature's contributions to people" in the U.S. Northeast

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Abstract

In the coming decades, promoting the production of ecosystem service provisioning will become increasingly important in the U.S. Northeast, which is expected to experience a number of impacts as a result of climate change, including rising temperatures, changes in precipitation and seasonality, and sea-level rise, among others (U.S. Global Change Research Program 2020). Incentives have been shown to motivate the adoption of sustainable production practices that provision ecosystem services across different types of working landscapes. Using data from a recent landscape assessment in the Northeast, this paper finds an incredible breadth of programs available to producers across a variety of working landscapes (e.g., agricultural lands and working forests) and for different production practices. These data also point to critical gaps in current programming and also highlight important opportunities for programmatic synergy and more holistic program design going forward. This paper concludes by discussing the results in the context of four main themes of particular relevance to the U.S. Northeast which include (1) working landbase and infrastructure, (2) livelihood provisioning, (3) scale, and (4) resilience.

Keywords: agriculture; aquaculture; ecosystem services; forestry; incentive programs; livelihoods; urban-to-rural gradient; working lands and landscapes

Introduction

In more than 10 years since the Millennium Ecosystem Assessment revealed that 60% of ecosystem services were at risk due to unsustainable use (MEA 2005), the stocks of natural capital from which these services flow are still shrinking (Costanza et al. 2014). Nonetheless, the biotic and abiotic components of natural capital continue to produce value for people, by way of ecosystems, species, freshwater, land, minerals, air, and oceans,

as well as natural processes and functions (Potschin et al. 2016). Evidence of these relationships exist very clearly in the study of working landscapes across urbanized regions.

In North America, "working landscapes" refer to places where active human presence and management can lead to some form of stewardship and conservation and includes dimensions of: (1) productive activity ("working") on the land (farming, ranching, forestry, etc.), (2) terrestrial scale ("landscape"), and (3) goods and services provided by and from the land (e.g., scenery and water) in a joint production function (Huntsinger and Sayre 2007). Working landscapes produce stocks of natural capital and flows of ecosystem services in the form of materials or goods with both nonmarket and market value (e.g., food for humans or livestock, and timber), as well as cultural capital (e.g., cultural goods as capital assets) (Licciardi and Amirtahmasebi 2012). The metropolitan areas surrounding working landscapes, including cities and towns, receive services from working landscapes and also provide locally specific services to their inhabitants and communities like any other complex ecosystem or landscape (Bolund and Hunhammar 1999).

Producers are ecosystem engineers of working landscapes, and they are active managers in creating externalities that can be beneficial beyond the scale of their property (Jones et al. 1994; Ferranto et al. 2013). However, amidst competing uses for regional land and water resources in urbanized areas, there is a continued need for sustainable production practices that limit the degradation of natural capital and consequences for present-day and intergenerational farmers, other users, and the wider population. The adoption of sustainable agriculture and land management practices often requires concrete incentives, in combination with significant effort from farmers and the support of governments and public–private partnerships at national and local levels (Piñeiro et al. 2020).

Incentives have shown to motivate the adoption of sustainable production practices across different types of working landscapes (Bryan 2013); however, applying this generalization onto the dynamics of real-world, existing conditions requires a knowledge of the types of incentive programs and mechanisms actually available to eligible producers. In this paper, we begin to identify and thematically cluster the range of incentive options available across a national subregion, here the U.S. Northeast. We first provide a literature review that discusses the role of incentive programs to produce or support ecosystem services on working lands, with particular attention to the U.S. context. We then describe the justification and motivation behind this study, established by the Association of Northeast Extension Directors (NEED) and the Northeastern Regional Association of State Agricultural Experiment Station Directors (NERA). We then discuss our data set, selection criteria, and analytic strategy.

Using data from this landscape assessment research, we find an incredible breadth of programs available to producers of the U.S. Northeast, across different types of working landscapes (e.g., agricultural lands and working forests) and for different production practices. Overall, the availability of indirect incentive programs (e.g., technical education) exceeds the availability of direct incentive programs (e.g., cooperative/cost-share agreements). Most programs are available to producers, but many others are available to supporting entities, like municipal governments and research institutions. Many programs operate across geographic scales and are administered through the private, public, and public–private partnership sectors. However, despite the existence of such programs, it is unclear how program delivery will sustain a supply of ecosystem services or support vital and robust livelihoods on working lands.

In addition to these results, several trends and areas of concern in current programming were identified which may hinder the uptake, sustainability, and/or effectiveness of these programs to address underlying resources concerns. This paper concludes with a discussion of these gaps in the context of four main challenges that face the U.S. Northeast which

include (1) landbase and infrastructure, (2) livelihood provisioning, (3) scale, and (4) resilience.

Literature review

Ecosystem services as "nature's contributions to people"

While definitions vary, ecosystem functions and services are popularly known as "the benefits people obtain from ecosystems" (MEA 2005) and were developed to rationalize and economically value the functions of ecosystems (Danley and Widmark 2016). As part of this initial conceptualization, ecosystem services were described in four categories: provisioning services, regulating services, supporting services, and cultural services. To assign value to the diversity of benefits people receive from their environment, these benefits include not only economic functions such as production and profitability but also ecological and social functions (Bolund and Hunhammar 1999; MEA 2005). As such, ecosystem services have been framed to support the production of food and material goods and to maintain the continued function of the ecosystems that underlie these broader economic functions.

However, a stringent focus on only the products or outcomes of discrete ecological processes curtails the complexity of socio-ecological systems (Selman 2009), especially those inherent to working lands, landscapes, and urbanized regions. In recognition of the complex interactions between humans and nature, the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) established a multidisciplinary, expert-driven conceptual framework that links several elements and components of a socio-ecological system and includes nature, nature's contributions to people, anthropogenic assets, institutions and governance systems, and other indirect drivers of change, direct drivers of change, and good quality of life. For further discussion on applying the concept of "nature's contributions to people," please see the Information Note developed by the IPBES Multidisciplinary Expert Panel (IPBES 2022).

There are several benefits of using the IPBES "nature's contributions to people" as a starting point for a national subregional assessment, like that of the U.S. Northeast. First, the spectrum of subcategories outlined a generalized, standardized rubric by which to understand the complex interactions between practices, policies, and the natural environment of the U.S. Northeast. Because the framework is standardized and supported by an international group of subject-area experts, it can be compared to other regional, national, or international studies in the future. Second, the IPBES framework's three broad categories – regulating, material, and nonmaterial contributions – includes important resources, services, and commodities as well as the interdependencies of social, cultural, spiritual, and experiential contributions (Díaz et al. 2015). These services are conceptualized as "nature's contributions to people," which serves to frame economic and natural science measures of ecosystem services to scale beyond individual parcels and landowners.

Incentives that provision ecosystem services

In the interest of improving the provisioning of ecosystem services on working lands in the United States, there are two broad categories of approaches available, many of which apply to private landowners: regulatory approaches, and incentive-based approaches (Anderson 2001). Regulatory approaches require that landowners comply with a set of standards and are then subject to enforcement to ensure those standards are being met (Piñeiro et al. 2020). With the environmental movement of the 1960s and 1970s, regulatory mechanisms

were mainstreamed to curb some of the environmentally harmful impacts of heavy industry, including the Clean Air Act, Clean Water Act, and Endangered Species Act, among others (Anderson 2001). While these legislative measures successfully hedged some degradation, the most effective measures were in areas where point sources of pollution or discharge could be easily identified and enforced (Fiorino 2006). To address this gap, beginning in the 1980s, incentive-based programs became popularized in the United States for private landowners to be compensated when implementing environmentally friendly practices or achieving discrete outcomes (Stavins 2000).

Incentives-based approaches are intended to encourage eligible producers to voluntarily protect or enhance ecosystem services beneficial to their community (e.g., water quality and forestry), while simultaneously improving the productivity (e.g., crop yields) and the competitiveness (e.g., profitability and farm incomes) of the production sector (Piñeiro et al. 2020). These incentive schemes are administered by the public (e.g., federal agency) and private (e.g., nongovernmental organization) sectors and can require the implementation of certain practices (e.g., practice-based incentives) and/or the production of certain provisioning outcomes (e.g., production- or results-based incentives) (Niskanen et al. 2021).

The United States has arguably the longest-standing history with ecosystem service incentive programs (Schomers and Matzdorf 2013). Since the 1930s, a number of programs that were the forerunners to the modern Conservation Reserve Program (CRP) were initiated in response to the environmental consequences of the Dust Bowl, aiming to protect soils and regulate agricultural production (Baylis et al. 2008; Hellerstein 2017). More contemporary incentive programs, such as payments for ecosystem services (PES), trace their origins during the 1980s to the community conservation movement in both the Global North and South (Cranford and Mourato 2011). Alternatively labeled as integrated conservation and development projects (ICDPs) (Alpert 1996) or community-based natural resource management (CBNRM) (Brosius et al. 1998), these efforts sought to link conservation and development goals by boosting incomes, lessening pressures on natural resources, and achieving joint economic and ecological outcomes.

Over time, both conservation and development practitioners of the United States criticized these original approaches for reasons, including for not being cost-effective and for not achieving the desired outputs from either a conservation or development perspective (Cranford and Mourato 2011; Wunder 2015). In response to these critiques, alternative incentive structures including direct payments and other forms of compensation rose to the fore. By creating a market for conservation-related activities, these direct incentive programs aimed to incentivize private landowners to implement sustainable practices on their lands on a voluntary basis by providing economic compensation (Van Hecken and Bastiaensen 2010).

Initially, many of these direct incentive programs were focused on narrow types of ecosystem services, but over time these programs were gradually expanded to address other types of ecosystem services as well, including regulating and cultural services (Cranford and Mourato 2011). Despite notable successes and attractive options for new landscapes, like cities and urban areas (Richards and Thompson 2019), direct incentives and PES schemes in general have faced their own series of critiques in recent years. Some scholars argue that PES schemes are problematic for their potential to (1) create new externalities, (2) misplace rights and responsibilities, (3) crowd out existing motivations, (4) create efficiency-equity trade-offs, (5) increase monitoring costs, (6) have limited applicability, and (7) be top-down and undermine local agency (see Van Hecken et al. 2015; Chan et al. 2017). Additionally, the effectiveness of PES programs can be dependent on the institutional arrangements in which they are embedded. For example, while publicly funded PES

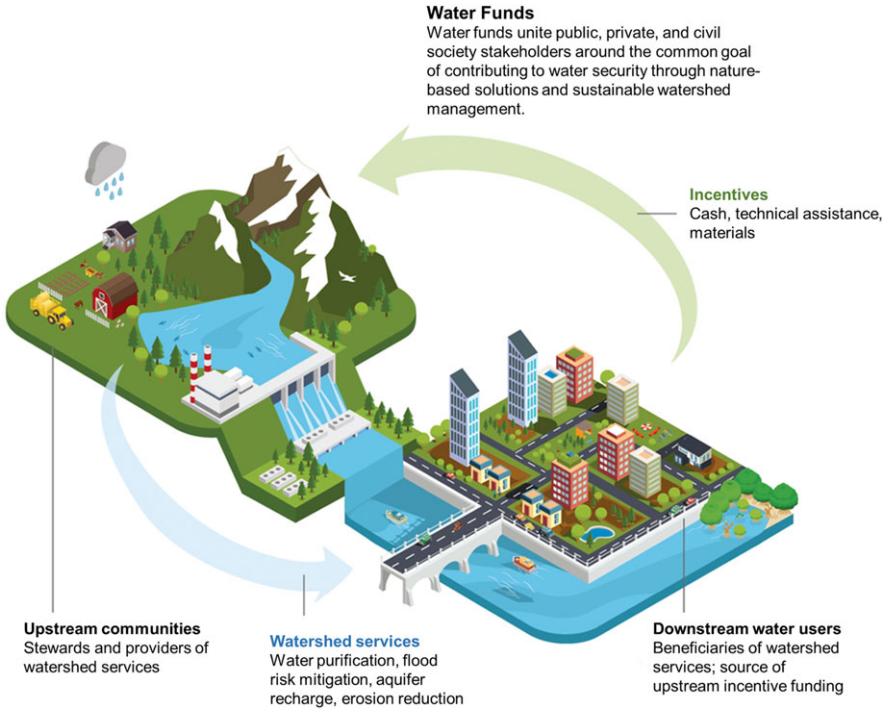

Figure 1. Water Funds are an example of a collaborative *direct incentive* program. "Upstream" water providers are allocated funding to enhance or restore water quality best management practices, paid by "downstream" water users that directly receive benefit from upstream practices. Photo credit: The Nature Conservancy (2022), Water Funds Toolbox.

programs are perceived to have higher effectiveness than privately managed PES, the administration of both public and private PES can entrench moneyed interests and reinforce status quo ecological and economic conditions (Merrick 2021).

Today, a range of incentive-based approaches have become popularized in order to encourage and to improve the provisioning of ecosystem services on private lands (Bryan 2013, Figure 1). Many programs now offer direct and indirect incentive schemes separately or in combination (Cranford and Mourato 2011). There is evidence to suggest that such mixed approaches work holistically to achieve goals of sustainable financing, flexible zoning, and recognition of local economic goals (Sims and Alix-Garcia 2017).

Methodology

Study area

Within the United States, the Northeast is measurably the most heavily forested and most densely populated region in the country (U.S. Global Change Research Program 2017), and the urban coastal corridor between Washington D.C. and Boston is one of the most developed environments in the world (U.S. Global Change Research Program 2020). Between 1996 and 2010, upland forests (51%), agriculture (13%), and open waters

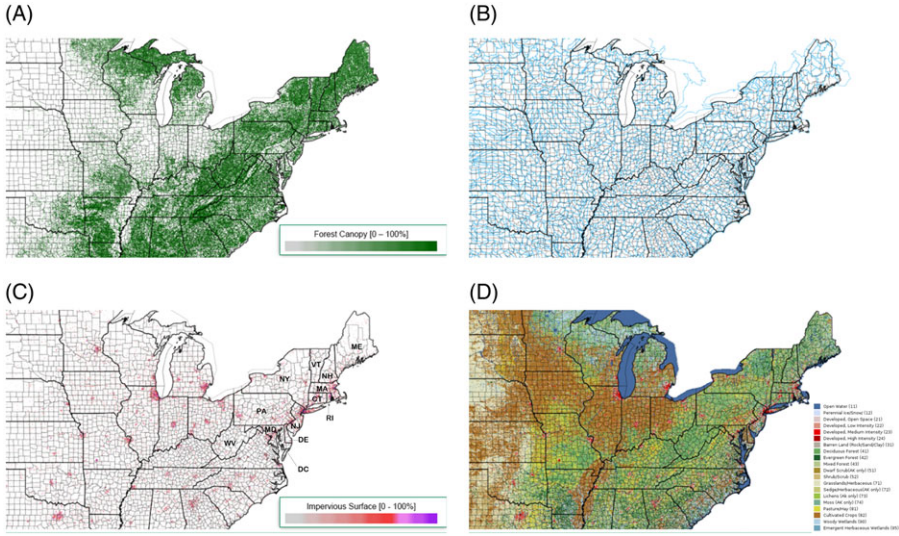

Figure 2. Cartographic representation of the U.S. Northeast region, showing (A) NLCD 2016 CONUS Tree Canopy (2016), (B) HUC Watersheds, (C) 2016 CONUS Impervious Surface, and (D) NLCD 2016 CONUS Land Cover. Credit: Authors, using the Multistate-Resolution Land Characteristics Consortium Viewer tool (https://www.mrlc.gov/viewer/).

(13%) were the most common land covers of the region; however, more than two-thirds of all new development during this time were classified as low intensity or open space developed, converted from lands previously categorized as upland forest and agriculture (NOAA 2010). When anecdotally compared to other regions of the United States, the diversity of land cover, density of undeveloped forest, and matrix of urban areas alongside agricultural landscapes exacerbate the need to sustain critical ecosystem services (e.g., food, fiber, and clean water) across multiple spatial scales and resource provisioning units (e.g., watershed) (Rickenback et al. 2011, Table 3).

Like elsewhere, the U.S. Northeast is expected to experience the regionally specific impacts of a changing climate. According to the U.S. Global Change Research Program (2017, 2020), the greatest increase in sea-level rise rate globally has been documented on the stretch of coastline from the Delmarva Peninsula in Virginia to the elbow of Massachusetts (2 to 3.7 mm per year – more than three times the global average). Additionally, rising temperatures (3.6°F (2°C)) and the frequency of heavy downpours in the Northeast are considered to be both the largest increases in temperature and in extreme precipitation anywhere in the contiguous United States (Figure 2).

At the same time, the region has struggled with a declining productive landbase (e.g., agriculture and other working lands) and increasing populations migrating toward the coastline (U.S. Global Change Research Program 2020), alongside decreasing regional self-reliance (Griffin et al. 2015). The region is also challenged by the expansion of privately owned lands. Ten million private individuals and families own over 35% of all U.S. forestlands, with concentrations exceeding 85% in parts of the eastern United States (Butler et al. 2016). Moreover, many ecologically important sites are on or connect to small private lands (Ruhl et al. 2013). Balancing land conversion – from forested or

agricultural land covers – with land conservation remains a notable challenge (U.S. Global Change Research Program 2017).

Together, these challenges can be broadly grouped into four trends and areas of concern that are particularly relevant to the U.S. Northeast due to its unique regional and geographic attributes. These areas of concern include (1) working landbase and infrastructure, (2) livelihood provisioning, (3) scale, and (4) resilience. While the following sections detail the results of this assessment, these categories are used in the final section to contextualize these results and identify gaps in current programming which may hinder the uptake, sustainability, and/or effectiveness of these programs to address underlying resources concerns.

Data collection

In 2020, the NEED and the NERA, in collaboration with the Northeast Regional Center for Rural Development (NERCRD), initiated a project to assess the landscape of ecosystem service provisioning programs and policies across the U.S. Northeast. The thesis and guidance for the landscape assessment were that broad regional adoption of ecosystem service production practices at scale, and with the right support, can increase agricultural and forest profitability and sustainability, position working landscapes as a primary leader in the fight against environmental degradation (rather than a primary culprit), and drive a new generation of young people to consider a career across supply chains of working landscapes (Extension Foundation 2021). In order to assess the landscape of incentive programs that provision ecosystem services in the U.S. Northeast, our team was hired as "Northeast Ecosystem Services Assessment Fellows" to inventory the scope, distribution, and key actors of programs across the region, and a steering committee convened once a month to oversee the project.

Our team developed an *a-priori* strategy to inventory and categorize national, regional, and state-level incentive programs. An initial list of inclusion/exclusion criteria was established (Table 1), and federal, state, and nongovernmental agencies and departments were systematically listed as an initial point to "snowball" and expand the search to additional agencies or organizations (see Coleman and Machado 2022 for a link to the full list of records; for example, the list of incentive programs from the U.S. federal government began by listing relevant agencies (e.g., U.S. Department of Agriculture (USDA), U.S. Fish & Wildlife Service, Environmental Protection Agency) and searching the websites of their departments (e.g., USDA Agricultural Research Service). The authors shared the task of coding federal and nongovernmental programs and divided state agencies evenly; draft codes were exchanged between authors, and instances of discrepancies were resolved. Highly localized programs available only at the county or municipal level were not considered in this report. Coding protocols were developed for each program and described its target ecosystem function or service, its incentive structure, and its institutional arrangements, and the coding categories became the major points of analytic inquiry and are further described below.

Classifying incentive mechanisms

To structure our understanding of incentive and finance mechanisms, we built on definitions and reports developed by the Food and Agriculture Organization of the United Nations (de Camino Velozo 1987), the U.S. EPA (e.g., Anderson 2001), and the academic literature (e.g., Piñeiro et al. 2020). This research stratified incentive programs and

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Table 1. Inclusion and exclusion criteria used to identify relevant programs

Category	Inclusion criteria	Exclusion criteria
Program Administration	U.S. public agencies, regional commissions/coalitions: • Federal government • State government • Multi-state actors • Agricultural experiment stations/Cooperative Extension	Municipal policy/ordinances, specific county- or municipal-level programs
	US private organizations, for example: • Audubon Society chapters • The Nature Conservancy • Watershed organizations • Land trusts • Foundations	Corporations with missions outside the scope of this project
Program Eligibility	Programs that fund: • Compliance/regulatory standards • Income lost or costs accrued as a result of conservation or production practice(s)	Sponsorship, advertisement, fundraising programs, and fee for service
	Programs that fit the following timeline: • Ongoing: presently active during FY 20/ 21 • In development: legally backed/funded program that is not yet implemented	Repealed, de-funded, or suspended programs
	Any USD amounts/eligible land units	
	All practices related to agriculture, animal husbandry, and land use/ management	Practices related to the capture/release of wildlife for leisure
	All types of producers (small farm/second income to large industrial operations)	

mechanisms as higher-level categories and by naming the specific type of mechanism used to deliver an incentive, further described below.

Direct incentives provide monetary support to protect, restore, enhance, or improve natural resources and land management practices. They also create an immediate impact on individuals and/or the community, either because they are given directly in cash (sum of money) or in-kind (provide transferable benefits that clearly improves everyday life) (de Camino Velozo 1987). Direct incentives can be delivered in-cash – as in the case of payment for ecosystem services (PES) – through cooperative/cost-share agreements, implementation grants, loans, loss adjustment, or land acquisitions/easements. In-cash compensation also includes marketable permits, which provide tradable credit for maintaining environmental impacts beyond a certain predefined baseline. These are often seen in the case of various mitigation banks for carbon or pollution. Direct incentives can also be delivered in-kind, as in the case of facility and/or infrastructure redevelopment or by providing access to tools and equipment.

On the other hand, *indirect incentives* are intended to protect, restore, enhance, or improve natural resources and land management practices without the transfer of direct monetary value. This includes fiscal support through certain tax abatements/credits, in-lieu fees, or certification based on the implementation of certain conservation activities or sustainable practices. Indirect incentives also include services, such as technical assistance and technical education, which provide access to medium- to upper-level technical staff or access to instruction free of charge. In addition, social benefits, whether through partnership programs aimed at harnessing the advantages of organized operations or preferred vendor programs, are also considered forms of indirect incentives.

Assigning ecosystem services or "nature's contributions to people"

In light of the evolving scope and conceptualization of ecosystem services, we relied on the paradigm of "nature's contributions to people" established by the IPBES (Pascual et al. 2017) to conceptualize ecosystem services. As laid out in the IPBES framework (Table 2), regulating contributions are those that regulate and maintain the natural processes of an environment (see Díaz et al. 2015). These include everything from habitat creation and maintenance to soil formation and the regulation of detrimental organisms and natural hazards. Material contributions consist of material flows from the environment to people and include everything from energy provisioning and food production to medicine and other harvestable materials. Nonmaterial contributions consist of nonmaterial flows from the environment to people and include things such as educational and volunteer opportunities, recreation, and cultural values.

Each incentive program or mechanism identified in this assessment was first coded by the primary, dominant category of ecosystem functions and services that it is intended to assist. While many programs undoubtedly incentivize more than one ecosystem function and service, programs were conservatively assigned a category based on the predominant inferred intention and mission of the incentive.

Naming key actors

The entity stated to be eligible for the incentive program, and its target working landscape was also identified in this assessment. Producers, or the owners or operators charged in running working landscapes, were the primary eligible actor of interest for this study. However, some incentive programs and mechanisms were exclusively available to public and private institutions to incentivize their support of working lands producers. These

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Table 2. Conceptualization of nature's contributions to people (NCP) or ecosystem services by the Intergovernmental Panel on Biodiversity and Ecosystem Services (IPBES) (Díaz et al. 2015)

Regulating Contributions	
• Habitat creation and maintenance – maintaining the ecosystem structures and processes that allow the other NCP to be provided • Pollination and dispersal of seeds and other propagules – the ways that nature contributes to productivity of plants through fertilizing seeds and dispersing seeds and other vegetation propagules • Regulation of air quality – regulation of CO2/O2 balance, ozone for ultraviolet-B absorption, and polluting gases • Regulation of climate – including regulating albedo, some aspects of greenhouse gas emissions, and carbon sequestration • Regulation of ocean acidification – maintaining the pH of the ocean through buffering the increases and decreases of carbonic acid (caused mainly by uptake of atmospheric carbon dioxide in the oceans)	• Regulation of freshwater quantity, location and timing – for both direst uses by people and indirectly for use by biodiversity and natural habitats • Regulation of freshwater and coastal water quality – capacity of healthy terrestrial and aquatic ecosystems to regulate water supply, delivery, and/or filter, retain nutrients, sediments and pathogens affecting water quality • Formation, protection, and decontamination of soils and sediments – sediment retention and erosion control, soil formation and maintenance of soil structure, decomposition, and nutrient cycling • Regulation of natural hazards and extreme events – preserved ecosystem' role in moderating the impact of floods, storms, landslides, droughts, heat waves, and fires • Regulation of organisms detrimental to humans – pests, pathogens, predators, and competitors
Material contributions	
• Energy – biomass-based fuels • Food and feed – wild and domesticated sources, feed for livestock and cultured fish • Materials and assistance – production of materials derived from organisms in cultivated or wild ecosystems, for construction, clothing, printing, ornamental purposes, and decoration	• Medicinal, biochemical, and genetic resources – plants, animals, and microorganism that can be used to maintain or protect human health directly or through process of the organisms or their parts
Nonmaterial contributions	
• Learning and inspiration – opportunities from nature for the development of the capabilities that allow humans to prosper through education, acquisition of knowledge and development of skills for well-being, information, and inspiration for art and technological design • Physical and psychological experiences – opportunities for physically and psychologically beneficial activities, healing, relaxation, recreation, leisure, tourism, and esthetic enjoyment based on the close contact with nature	• Supporting identities – basis for religious, spiritual, and social-cohesion experiences, for narrative story-telling and for sense of place, purpose, belonging, rootedness, or connectedness • Maintenance of options – continued existence of a wide variety of species, populations, and genotypes, to allow yet unknown discoveries and unanticipated uses of nature and ongoing evolution

supporting institutions include government agencies, nongovernmental organizations, research institutions, conservation districts, and more. It became important to parse the distinction between an eligible producer from an eligible supporting institution in order to follow the chain of an incentive program or mechanism from its originating funder to its eligible recipient (producer or supporting institution) and onto the ecosystem service or "nature's contribution to people" the program or mechanism is intended to provision. Using concepts and definitions from the USDA and scholars in landscape ecology, effort was made to define the scope of working landscapes and its producers or supporting institutions used in this assessment (Table 3).

Analytic strategy

The collated inventory of incentive programs and mechanisms was analyzed descriptively as discrete categories as well as by the connections between eligible entities, purveying organizations, and target ecosystem services. To visualize these connections, alluvial plots were used to link the relationships among these categories of interest. Alluvial plots are a type of flow diagram, tracing the magnitude and extent of connections between categorical data (Brunson 2020). Unlike histograms, the flows between categorical variables also represent the overall quantities, or frequency, of data as ribbons, where narrower ribbons represent fewer quantities (and smaller connections) and thicker ribbons represent larger quantities (and more robust connections).

In this study, the results focus on the distribution of categories and the most prevalent types of programs available to producers and supporting institutions across the U.S. Northeast. Results are summarized by the types of administering sectors providing the programs, distinguishing the public, private, and public–private partnership sectors as well as their geographic reach (available across all states, a subset of multiple states, or individual states only).

Potential overlaps or oversimplification are inherently present in data, and while the methodology was developed to be comprehensive, there cannot be 100% confidence that all programs in existence at time of data collection were captured nor an illustration of the complex systems, interactions, and trade-offs that affect producers and the production of ecosystem services. Nonetheless, this method of data aggregation and coding permits a replicable approach that can be used to compare the Northeast against other U.S. regions or that can be applied as a template for analyzing or comparing other multi-jurisdictional areas around the world.

Results

As of September 2021, a sample of 1,305 programs was identified for their objectives to incentivize ecosystem service provisioning and practices on farms and working lands in the U.S. Northeast. Overall, these programs target four primary working landscapes: (1) farming, food, and agriculture ($n = 590$); (2) working forests and woodlands ($n = 123$); (3) fisheries, aquaculture, and shellfish ($n = 84$); and (4) nonindustrial supporting landscapes and systems[1] ($n = 493$) (Figure 3). A small series of programs were available to multiple types of working landscapes ($n = 15$). Overall, the availability of indirect incentive

[1]The category nonindustrial supporting landscapes and systems refers to all landscape types not directly related to farming, woodlands, or fisheries, but which nevertheless provide vital services and functions which support these other types of working lands.

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Table 3. Scope of working landscapes and its producers or supporting institutions used in this assessment

Working lands/ premises	Agricultural land	Woodland and forestland	Fishery	Supporting regional landscape
	Land used primarily to produce farm commodities. The categories of "agricultural land" are cropland and pasture; orchards, groves, vineyards, bush fruits, and horticultural areas (such as nurseries); feeding operations; and others (USDA NAL 2021).	"Woodlands" are land used primarily to produce adapted wood crops and to provide tree cover for watershed protection, beautification, etc; this does not include farmstead and field windbreak plantings (USDA NAL 2021).	A "fishery" is any premise upon which breeding, hatching, or fish-rearing facilities are situated when such premises are required to have a license by the state fish and game code, including ponds for commercial use (USDA NAL 2021).	An area of land encapsulating working lands, with ecological structures, processes, and dynamics that affects and is affected by (interacts) with working lands (Forman 2014).
	Farmstead			
	Land used primarily for dwellings, barns, pens, corrals, gardens, and other uses in connection with operating farms or ranches (USDA NAL 2021).	"Forestland" is any land at least 10% occupied by forest trees of any size or formerly having had such tree cover and not currently developed for nonforest use (USDA NAL 2021).		
Affiliated producer/ manager	Crop and livestock farm owner/ operator	Woodland and forestry owner/ operator	Fish, shellfish, and aquatic plants farm owner/operator	Other landowner, manager, or operator
	A farmer, otherwise known as the "farm operator" (USDA ERS 2020) is the person who runs a farm and makes day-to-day management decisions. Given the complex ownership and land access arrangements in U.S. farming, federal program incentive benefits are available to an owner-operator, landlord, tenant, or sharecropper that share in the risk of producing a crop and is entitled to a share of the crop produced on the farm (P.L. 101–171, Sec. 1001).	The corporate, family, other private, and tribal owners of forest or woodlands are known as "private forest and woodland owners" (Butler et al. 2016).	The production of aquatic organisms under controlled conditions throughout part or all their life cycle is known as "aquaculture" (USDA ERS 2021).	The person or entity that retains ownership or legal operation of the land and enacts its access and use rights (to be on the land and make use of its resources).

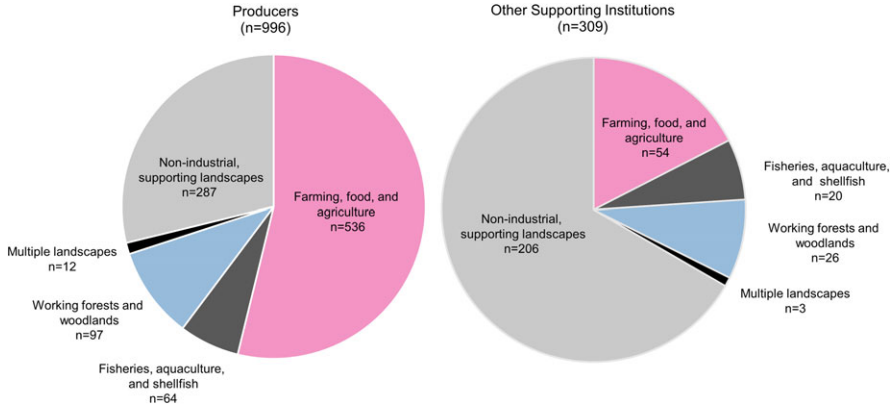

Figure 3. Distribution of sample by eligible actor and working landscape type.

programs ($n = 781$) exceeded the availability of direct incentive programs ($n = 524$) across landscapes and eligible actors.

Geographic and organizational scale

Incentive programs and mechanisms across the U.S. Northeast are available across geographic scales and are funded through the private, public, and public–private partnership sectors (Figure 4).

The greatest number of programs available to eligible producers across the United States ("Federal/National") come from the federal government ("Public"), particularly for food, farming, and agriculture from the USDA Agricultural Marketing Service ($n = 35$) and Farm Service Agency ($n = 19$). At the regional scale, incentive programs and mechanisms from the private and nongovernmental sectors were most abundant ($n = 67$) (e.g., Open Space Institute, Northeast Sustainable Agriculture Working Group) followed by public–private partnerships ("PPP") ($n = 55$). From this sample, most programs are for producers and provided by state agencies or departments ($n = 608$); however, this attention may be due to the systematic attention to state websites and department directories during data collection. Nonetheless, the availability of incentive programs and mechanisms available for producers of individual states was notably high for producers of food, farming, and agriculture ($n = 234$) (e.g., NY DEP's Land Acquisition Program) and working forests and woodlands ($n = 62$) (e.g., American Forest's VT Woods, Wildlife and Warblers Program).

Additionally, several outliers of the sample deserve attention. Public–private partnerships across the region (as a whole or involving multiple states) were noteworthy, particularly for producers of food, farming, and agriculture ($n = 11$) and fisheries, aquaculture, and shellfish operations ($n = 11$) (e.g., the Mussels for Clean Water Initiative coordinated by the U.S. EPA and the Partnership for the Delaware Estuary). Also, programs for supporting landscapes and systems have the widest availability to producers of individual states ($n = 282$).

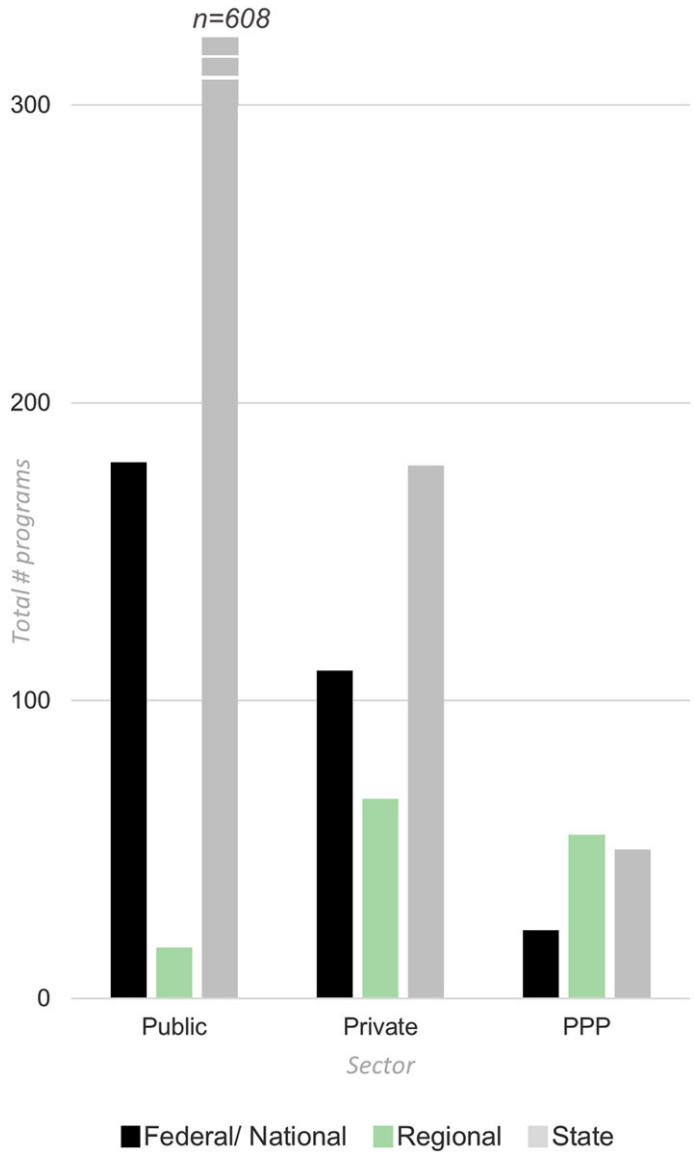

Figure 4. Distribution of sample by administrative sector and geographic reach.

Programs for food, farming, and agriculture

For producers of food, farming, and agricultural landscapes, the most prevalent indirect incentives were technical assistance ($n = 145$), certificates of compliance ($n = 89$), and technical education ($n = 74$), followed by direct incentives like financial loans or cost-share/agreements ($n = 28$) (Figure 5A).

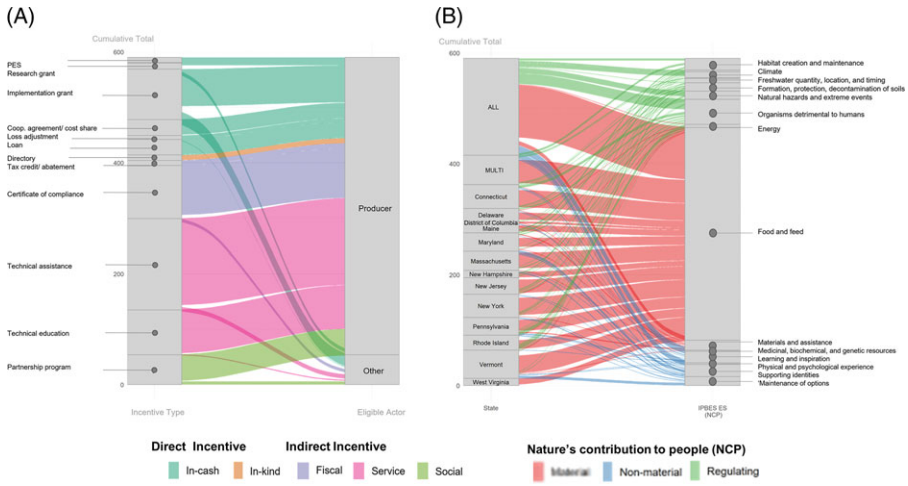

Figure 5. Distribution of sample for food, farming, and agriculture. A) The flows of incentive programs shown by incentive mechanisms (left) to the eligible agricultural producer or supporting sector ("other), colored by incentive type; B) the flows of incentive programs from its geographic origin (left) (individual state of the U.S. Northeast, available to all states ("ALL"), or multiple states ("MULTI")) to the resultant nature's contribution to people (NCP) (right).

The available technical assistance and education programs often focus on the professional development of a farmer across the span of a career. For example, New Farmer Training programs ($n = 9$) are operated by state-level Northeast Organic Farmer Associations (NOFAs) as well as by the Cooperative Extension programs in each state. Some NOFAs, such as in Rhode Island, offer an Advanced Grower Series, which offers technical education courses to long-term farmers. NOFAs in Vermont, New Hampshire, and Massachusetts also provide cost of production fact sheets, which contain "crop profitability comparisons, whole farm financial metrics, and tips for success when undertaking cost of production analysis." Other programs are intended to help the farmer's business as a whole, namely through implementation grants ($n = 17$) like Made in DC Market Access that facilitates DC-based businesses to access market opportunities.

Programs to certify organic practices, led by the USDA or the private sector, constitute the largest portion of certification programs ($n = 29$) and can be offset by related programs like the USDA Organic Cost Share which reimburse certified organic farmers and food processors for the total cost of certification. Other notable programs cover the material expenses for infrastructure or management practices, such as those to protect soils ($n = 51$, e.g., the Maryland Cover Crop Program) and to lesser extents, to manage water quantity for irrigation ($n = 2$, e.g., New York High-efficiency Agricultural Irrigation Water Management Systems) and to build the capacity of new and existing urban farms through infrastructure investments ($n = 15$, e.g., Urban Agriculture Infrastructure Grant in Washington D.C.).

The ecosystem services most incentivized to Northeast farmers (Figure 5B) are the production of food and feed ($n = 383$), followed by mechanisms that regulate detrimental organisms ($n = 45$). For producers, food production programs encourage specialty crops (e.g., USDA's Specialty Crop Block Grant Program and Specialty Crop Multi-State Program) and local food systems (e.g., Maryland Certified Local Farm Enterprise

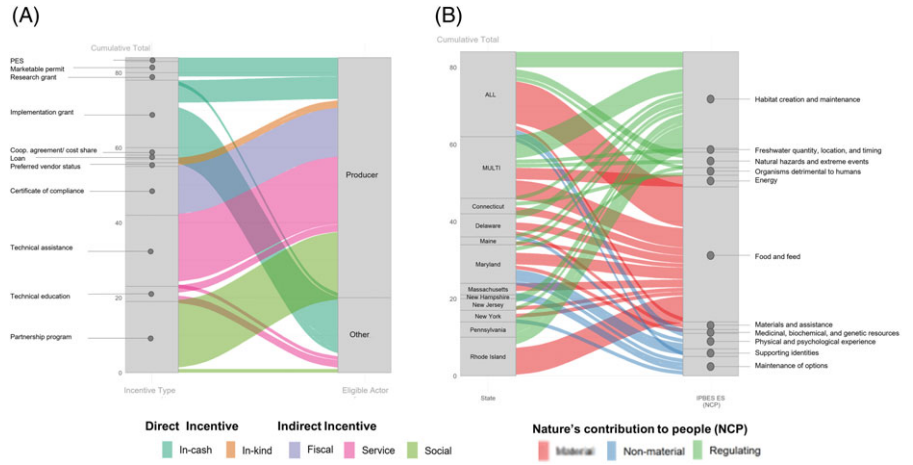

Figure 6. Distribution of sample for fisheries, aquaculture, and shellfish operations. A) The flows of incentive programs shown by incentive mechanisms (left) to the eligible producer or supporting sector ("other), colored by incentive type; B) the flows of incentive programs from its geographic origin (left) (individual state of the U.S. Northeast, available to all states ("ALL"), or multiple states ("MULTI")) to the resultant nature's contribution to people (NCP) (right).

Program). Other food production programs are also available to supporting institutions, such as schools, to fund either school gardens or farm-to-school programs. Programs that regulate detrimental organisms include foodborne pest and disease management as well as the management of invasive and nonnative species (e.g., Northeast Integrated Pest Management (IPM) Center grants). Another, like the USDA AMS Equipment Review (Dairy & Meat & Poultry), is a voluntary, fee-based program that provides an AMS certification to businesses in the food processing industry as a means of regulating contamination and disease issues.

Programs for fisheries, aquaculture, and shellfish operations

Fisheries, aquaculture, and shellfish operations constitute the smallest portion of this sample but still have several notable technical assistance programs ($n = 11$) (Figure 6A). At the federal level, the U.S. Food and Drug Administration offers the Seafood Hazardous Analysis Critical Control Point (HACCP) program, which provides guidance and certification for the aquaculture industry to ensure food safety on the part of producers. State-level resources include programs such as the Rhode Island Shellfish Harvester Education program, an effort of the Rhode Island Department of Health with support from the National Shellfish Sanitation program. This program provides training and certification to shellfish harvesters in the state with the goal of improving the delivery of safe products to consumers in Rhode Island.

The greatest number of programs, primarily from coastal states, incentivize the management of aquatic food and feed ($n = 35$) and support aquatic habitat conditions ($n = 25$) (Figure 6B). Of these programs, land leases appear to be an important component of planting, cultivating, and harvesting shellfish crops. The Connecticut Department of Agriculture, for example, offers the Shellfish Ground Leasing Procedure and Lease

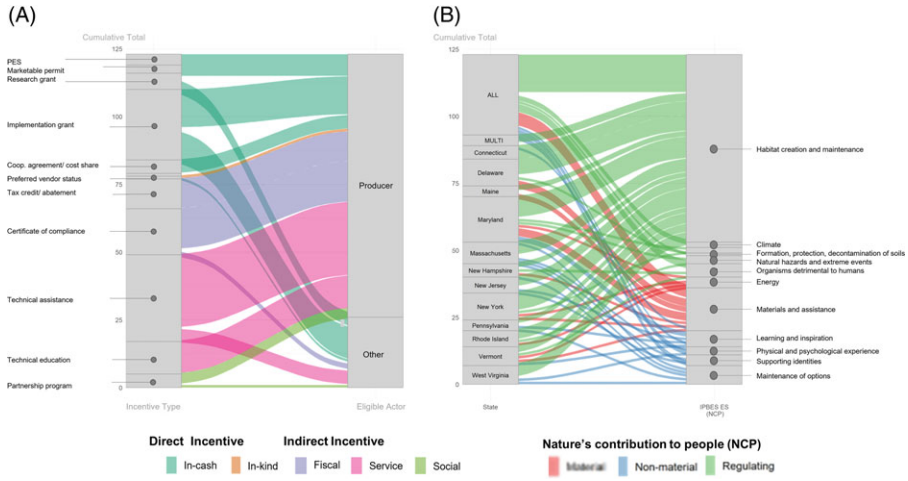

Figure 7. Distribution of sample for working forests and woodlands. A) The flows of incentive programs shown by incentive mechanisms (left) to the eligible producer or supporting sector ("other), colored by incentive type; B) the flows of incentive programs from its geographic origin (left) (individual state of the U.S. Northeast, available to all states ("ALL"), or multiple states ("MULTI")) to the resultant nature's contribution to people (NCP) (right).

Opportunities program. This program permits shellfish farmers to obtain underwater lands in Long Island Sound for planting, cultivating, and harvesting shellfish crops. The Long Island Sound area includes some 70,000 acres that is currently farmed – about 12,000 acres of this area is leased by the local shellfish commission. They offer additional leases to shellfish operations based on a competitive bid process. The Rhode Island Division of Fish and Wildlife also leases acreage to shellfish producers in the Inland Bay area. These leases are available for lands within defined Shellfish Aquaculture Development Areas (SADA), which offer expedited state- and federal-permitting processes, as well as for lands outside of those areas.

Programs for working forests and woodlands

For producers of working forests and woodlands, technical assistance ($n = 22$) and certificates of compliance ($n = 15$) are most abundant (Figure 7A). The USDA Forest Service Forest Stewardship Program is a prominent technical assistance and cost-share program that works in partnership with state forestry agencies, Cooperative Extension, and conservation districts to connect private landowners with the information and tools they need to manage their forests and woodlands. Certificates of compliance are available for harvesting wood for production; for example, the Forest Stewardship Council has a number of compliance-based programs, including the Group Certification, Family Forest Program, Forest Management Standards, and the Controlled Wood Standard, which certify sustainable forest stewardship and harvest practices in the Northeast.

Other programs also target family forests, or smaller-scale forestry operations, specifically ($n = 10$). For example, the American Tree Farm System (ATFS) also provides third-party certification of small family-owned forestland through an internationally recognized process that is endorsed by the Programme for the Endorsement of Forest Certification

(PEFC). To be certified, family forest owners must meet the ATFS Standards of Sustainability, which ensure that landowners are protecting and improving clean water, wildlife habitat, and more.

A smaller subset of programs focus on trees as a form of green infrastructure (GI) and exclusively support urban forestry ($n = 11$) or tree planting across landscape types ($n = 9$). For example, the Chesapeake Bay Trust and Maryland Department of Natural Resources offer the Green Streets, Green Jobs, Green Towns (G3) program that supports design projects, financing strategies, and/or implementation of GI-based street projects.

The largest ecosystem services incentivized to Northeast working forests and woodlands are habitat creation and maintenance ($n = 70$) and the production of forest and wood materials ($n = 16$) (Figure 7B). Large-scale reforestation efforts alongside resident-led, community tree planting are available to ensure widespread species diversity (e.g., Delaware's Seed Tree Law program was passed due to the long-term decrease in pine and yellow-poplar forests and requires that landowners reforest all harvested sites of 10 acres or more that contain at least 25% pine and/or yellow-poplar forests to ensure long-term forest health. At a smaller scale, programs like the Lawn to Woodland program (Maryland) or Project CommuniTree (West Virginia) convert unused lawn to forest cover by providing technical assistance, trees, and planting supplies.

In terms of incentivizing material goods from working forests and woodlands, programs improve the delivery of wood products for energy through direct benefits, as in the U.S. Forest Service's Community Wood Grant program, which provides money to install thermally led community wood energy systems or to build innovative wood product manufacturing facilities. Other programs provide in-kind benefits to owners of working forests, such as the Delaware Wood Directory, which is a list of primary (sawmills, loggers, etc.) and secondary (furniture makers, pallet manufacturers, etc.) wood processors that is distributed to improve the production of wood and lumber products.

Programs for nonindustrial, working landscapes

Of the landscape types, programs for nonindustrial working landscapes are most often available as implementation grants ($n = 76$) and land acquisition/easement programs ($n = 24$) (Figure 8A). Other available grants include those for wildlife habitat (e.g., New Hampshire's Dam Removal and River Restoration program), outdoor recreation (e.g., parks and trails), or community resilience (the Trust for Public Land's Climate-Smart Cities program).

The land acquisition and protection options for nonindustrial landscape owners are advertised to function to directly limit development pressures. Many states have some if not several land acquisition programs that expand existing state and wildlife management areas through land acquisitions. These programs can be narrowly focused on particular areas and habitats or can be more broadly focused, taking into consideration different parts of a landscape. Programs like the USDA NRCS Wetland Reserve Easement program uses either 30-year or permanent easements to restrict development in critical wetland areas. Another example is the USFWS Migratory Bird Conservation Commission (MBCC), whose funds allow for the purchase, lease, or easement of valuable habitat for migratory birds. Other programs like Delaware's Open Space Program, on the other hand, coordinate the acquisitions of various parts of the landscape by expanding state parks and preserves, fish and wildlife areas, state forests, and cultural resource sites.

The ecosystem services reported most frequently for nonindustrial working landscapes are programs that address water quality/quantity ($n = 82$) and natural hazards and extreme events ($n = 43$) (Figure 8B). The water quantity and quality programs aim to

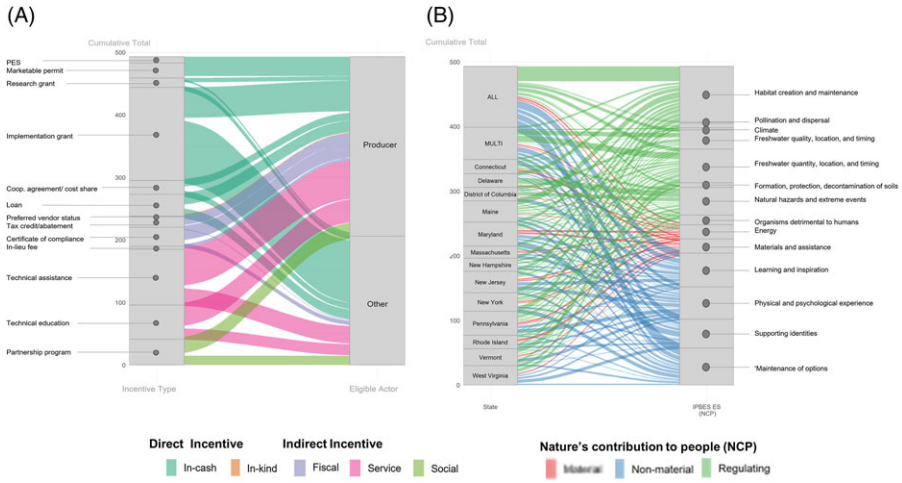

Figure 8. Distribution of sample for nonindustrial, supporting landscapes. (A) The flows of incentive programs shown by incentive mechanisms (left) to the eligible producer or supporting sector ("other"), colored by incentive type; (B) the flows of incentive programs from its geographic origin (left) (individual state of the U.S. Northeast, available to all states ("ALL"), or multiple states ("MULTI")) to the resultant nature's contribution to people (NCP) (right).

mitigate nonpoint-source pollution through mechanisms like mitigation banks and PES schemes. Nutrient trading, for example, is a promising strategy for introducing cost-effectiveness and market-driven efficiency into the realization of reducing nutrient runoff from a number of industries, including agriculture. The Maryland Departments of Agriculture (MDA) and Department of the Environment (MDE) have been working collaboratively to establish one such voluntary, market-based program to promote the use of trading as a viable option for achieving the state's nutrient reduction goals. Maryland Nutrient Trading Program is a program that envisions trading not only between sectors (cross-sector trading) within Maryland but also ultimately between Maryland and the other Bay states (interstate trading). Other programs address water quality issues through efforts to control point-source pollution and reduce impervious surface covers. This is of particular importance in urban areas, where runoff and stormwater can cause significant economic and ecological damage. Washington D.C. RiverSmart programs – in particular the Clean Rivers and Impervious Area Charge (CRIAC) incentive – are examples of other efforts to reduce impervious areas in urban centers. The RiverSmart program offers discounts to residents on their water bill and discounts of up to 55% off the District Department of Energy and Environment's (DOEE's) Stormwater Fee when they reduce stormwater runoff by installing GI. For the purposes of this program, GI includes things like green roofs, bioretention, permeable pavement, and rainwater harvesting systems. The use of GI helps to protect the Anacostia and Potomac rivers and Rock Creek, which are the main waterways in the city.

In addition, the Northeast has a number of loan and grant programs to regulate present, recurring, and future hazards. For example, the Delaware Hazardous Substance Site Cleanup Loan Program (HSSCLP), which provides loans to nonprofit organizations and businesses that are potentially responsible for site rehabilitation or brownfield developers with an executed agreement for investigating and remediating a hazardous substance

release at a site. Other programs that address hazards preparedness/maintenance from the national and state levels. The FEMA Building Resilient Infrastructure and Communities (BRIC) grant program, for example, supports projects in states, local communities, tribes, and territories to reduce risks from disasters and natural hazards. The BRIC program does this through capability- and capacity-building in communities and by encouraging innovation and partnerships that enable large projects, maintain flexibility, and provide consistency. What is unique about the BRIC program is that it categorically shifts federal focus away from reactive disaster spending and toward research-supported, proactive investment in community resilience. In Maryland, the community resilience grant has similar aims. It supports and funds local communities and nonprofits in their efforts to prepare for coastal flooding, storms, and other climate change-related consequences, while enhancing community resilience and sustainability through natural, nature-based, and GI projects.

Discussion

This assessment collated programs that incentivize the provisioning of ecosystem services available to producers and managers of the U.S. Northeast. From these results, several crucial gaps in current programming were identified which may hinder the uptake, sustainability, and/or effectiveness of these programs to address underlying resource concerns. These trends and areas of concern converge around several themes which are particularly relevant for the U.S. Northeast in the coming decades, namely: 1) working landbase and infrastructure, 2) livelihood provisioning, 3) scale, and 4) resilience.

Working landbase and infrastructure

In recent history, the U.S. Northeast has struggled with a declining productive landbase (e.g., agriculture and other working lands) and increasing population migrations toward the coastline (U.S. Global Change Research Program 2020). On top of this, the Northeast is the most heavily forested and most densely populated region in the country (U.S. Global Change Research Program 2017) and already faces climate change impacts, including rising sea levels and inconsistent precipitation. Together, these factors create complex challenges to the regional planning of a productive landbase and its affiliated infrastructure. From the assessment, significant gaps in programmatic availability were identified regarding the working landbase, while programmatic availability for infrastructure was more well represented.

In regard to the working landbase, there were substantially more programs available to target food systems landscapes than there were for working forests/woodlands. While food system programming is essential for a region with decreasing self-reliance (Griffin et al. 2015), the number of available programs is disproportionate to the regional land cover footprint in the Northeast, with significantly more tree canopy cover than agricultural production fields. Since there are critical linkages between forests and agriculture (Krause et al. 2013), between forested landscapes and food systems (Ickowitz et al. 2022), the physical adjacencies of these land cover types could become insightful study areas of future research.

This assessment also reveals an interesting trend for the availability of infrastructure programs in the region ($n = 40$). In the U.S. Northeast, ageing infrastructure – including roads, bridges, railroad lines, water and wastewater pipelines, culverts, and electrical power networks – are critical issues (U.S. Global Change Research Program 2017). The region has the oldest industry and building inventory in the United States, much of which was built

along coastal and riverine areas that are highly vulnerable to flooding and spillover effects of extreme weather events.

Interest and investment in GI is also widely available across the Northeast; for example, attention toward sustainability has, in part, increased desire to generalize tree planting programs as a biotechnological tool (Seamans 2013) or as a nature-based solution (Escobedo et al. 2019). A small but emergent portion of our results demonstrates the region's willingness and interest in community tree planting ($n = 9$), some aspects of environmental stewardship ($n = 61$), and land protection ($n = 16$) as complementary strategies to traditional gray infrastructure.

From this assessment, it is also clear there are relatively few programs available to incentivize the preservation and redevelopment of traditional local infrastructure (also called gray infrastructure), including implementation grants for vulnerable roadways in flood zones ($n = 3$) and loans or tax credits for historically significant buildings and cultural corridors ($n = 4$). With several exceptions, these programs are mostly directed toward nonindustrial, working landscapes. Together, the availability of both gray and GI programs is essential for a region with such pronounced infrastructural challenges.

However, regardless of available infrastructure options, community need, or administrative priorities, local-level actors still bear some of the most extensive responsibilities for implementing context-based, community-level solutions to the provisioning of ecosystem services, and cooperation between organizations, governments, and residents. In this regard, programs that incentivize both gray and GI solutions will be increasingly important resources for county and municipal-level organizations as they are forced to adapt to climate change, shifting land uses, and population trends across the region.

Livelihood provisioning

To better understand how the programs reviewed in this assessment might impact ecosystem service provisioning in the Northeast, it is also important to understand how these programs intersect with the livelihoods of people that own and operate working lands. Indeed, one aspect of the declining regional self-reliance and landbase in the Northeast is the decline in working lands livelihoods (USDA-NASS 2017). For years, the sector has struggled with a declining number of farms, producers, and landowners, as well as with issues of farm succession and farmland preservation; and while this represents an extension of a larger trend across the United States, it is particularly acute in the Northeast due to several unique pressures, including urbanization (Oberstein 2016). While an abundance of incentive programs, such as those that provide business-related technical assistance ($n = 55$), loans ($n = 19$), or implementation grants ($n = 23$), are important for counteracting these trends, the results indicate that the extent and efficacy of these programs are not sufficient. Rather, the results of this assessment indicate a considerable need to expand programs that directly impact working lands livelihoods in significant material and immaterial ways.

In such a context, there is a pressing need to increase the appeal of working lands careers to a wide range of young people. With the additional challenges of a changing climate and an increasingly precarious economic reality (see Kalleberg 2018), however, such efforts become even more difficult. Addressing the livelihoods of working lands and related problems in the Northeast will require policy and programmatic solutions that allow producers from any generation or at any level of experience to tread an uncertain career. Put another way, the challenge is not just how to make working lands livelihoods more appealing, it is how to make working lands careers a *good livelihood option* for young people

entering the labor market at a time of unprecedented economic precarity and climatic disruption. The question then becomes how to achieve this through programming and policy.

One way to answer this question is by understanding landowner decision making. The reality of landowner risk aversion is principally related to some of the trade-offs that often arise through ecosystem service provisioning programs. Across production scales, but especially for family-operated and/or small-scale producers and working lands managers, the provisioning of ecological services cannot come at the expense of economic profitability. In this sense, working lands producers are inherently risk-averse, meaning they operate according to what James Scott (1977) calls the "safety-first principle," whereby the livelihood subsistence must first be guaranteed – whether directly, through on-farm production/consumption or indirectly, through income-generating activities – before risk-taking activities, such as changing practices or implementing new technologies, can be justified. It could be beneficial to know more about the motivations and mechanisms that drive the ways in which risk is determined when margins are thin and market conditions often volatile.

During the development of new or existing ecosystem service provisioning programs, it will continue to be important to know how risk aversion of regional producers presents itself. We would expect that a risk-averse producer to not be motivated by indirect incentives, even though, based on the results of this assessment, these incentives are most common in the Northeast ($n = 781$, 59.8%). Instead, programs that provide direct economic compensation to producers may offset the risks of practice adoption, especially for smaller-scale producers. Programmatic design and implementation should consider these dynamics and incorporate efforts in order to offset risk as directly as possible. Creative policy solutions like basic income or cash transfer schemes (Izquierdo-Tort 2020), risk sharing strategies (McDonald and McCormack 2022), or programs that provide health care (Becot et al. 2020) and childcare (Inwood and Stengel 2020) can serve to support working lands livelihoods amidst a confluence of intersecting challenges.

Risk aversion may be also be variable across scales of geography or administrative oversight, which could exacerbate, instead of eliminating, equity concerns, such as what types of working land producers have access to programs, even if these programs are nominally available to all. Larger-scale producers may be able to bear more risk than small-scale producers and therefore be able to take advantage of a wider variety of programs. In this sense, projects may be self-selecting in terms of what kinds of producers have the time, labor, finances, and capability to engage with these programs and which do not (Jack and Jayachandran 2019). These scalar dynamics will be more explicitly discussed in the next section.

Geographic and organizational scale

Another programmatic gap that emerged from the assessment has to do with scale and the difficulty of fostering cross-scalar thinking between different institutions and program types. Here, scale refers to programmatic scales and between landowner types (i.e., small-, medium-, and large-scale producers and producers across institutional scales). One way this can be seen is in the proportion of programs provided at the state and federal scale versus those that operate across scale. While there were numerous programs that function at either of these institutional scales, there were significantly fewer that explicitly connect across these scales; for example, programs from public–private partnerships constituted 10% ($n = 130$) of our sample compared to the dominant public ($n = 814$, 62.4%) or private sectors ($n = 361$, 27.7%) alone. Public–private partnerships, which are particularly adept at doing this, especially when it comes to management across state lines and

within watersheds, were nevertheless relatively few in comparison with the many state and federal programs available.

To address the entangled spatial challenges of ecological and institutional systems, the landscape of ecosystem services incentive programs requires "cross-boundary, multiscalar management." This interwoven complexity offers an opportunity to monitor and prioritize the variety of relationships between ecological processes, ecosystem service scope (i.e., what constitutes a service?) and scale (i.e., how to bridge local practices with global challenges, such as climate change mitigation?), as well as socioeconomic functions embedded in the landscape (i.e. food and commodity production, livelihood provisioning, and cultural heritage). It also offers the opportunity to develop and consistently use ecosystem service indicators (Boyd et al. 2015) that better link biophysical processes and socioeconomic processes. Additionally, this cross-scalar complexity opens space for ecosystem services research and programming to directly support decision making for different landowners operating at different scales (Olander et al. 2017).

Moreover, programs that are designed to promote a single ecosystem service can be quite effective at creating measurable environmental changes at the farm scale, especially when these programs are paired with the appropriate incentive structure. However, the utility of such programs is limited, as improvements in specific metrics for a single ecosystem service do not necessarily translate to improvements in other ecosystem services or their provisioning across a landscape. As Bennett et al. (2009) explain, "[e]cosystem management that attempts to maximize the production of one ecosystem service often results in substantial declines in the provisioning of other ecosystem services." In other words, there are trade-offs between services and scales that are inherent in the structure of provisioning programs, regardless of whether these programs focus on discrete practices and services or on more diversified sets of practices and services.

To address the multiscalar challenges and address these scalar trade-offs, a next-step critical assessment is needed to better understand how different programs operate differently and at different scales. This type of work will provide insights to further improve ecosystem service provisioning across the diverse urban and rural landscapes of the Northeast. Notable differences exist between land management practices exclusively tailored to an individual parcel versus those practicing cross-boundary, multiscalar management (e.g., Rickenback et al. 2011). Single owners of large tracts of working forests, for example, may be more enticed by the new forms of carbon sequestration incentive programs that are available only to large acreages and not smaller tracts of land. At the same time, farmland-adjacent riparian buffer systems, with countless abutting land owners, may be better suited for material-based incentive programs, like a free tree or native plant giveaway or subsidy intended to strategically and systematically improve pollution interception, wildlife habitat, and flood surge, among others. Using the database and sample created for this study, opportunities to research these domains and more is now possible for the U.S. Northeast.

Determining the appropriate mix of services and scales for improving provisioning across particular working landscapes is a research challenge across the U.S. Northeast going forward. In order to do this, new kinds of scientific thinking and institutional arrangements that encourage multiscalar thinking and cross-boundary collective action are required and include landowners, resource managers, and policy makers (Rickenbach et al. 2011).

Resilience

Resilience is most often defined as "the ability of a system to sustain itself through change via adaptation and occasional transformation" (Magis 2010). Resilience exists at and across multiple scales and applies to everything from individual farms and/or working lands operations, to products, markets, and ecosystems. Particularly relevant to ecosystem service provisioning in the U.S. Northeast are questions about social/community and landscape resilience. Despite this, however, very few of the programs reviewed in this assessment directly referred to community and ecosystem resilience ($n = 88$, 6.7%) and even fewer engaged with resilience beyond the scope of supporting landscapes. The inattention to other types of resilience – community-, individual-, and household-level resilience, for example – represents another significant gap in the current programmatic landscape across the U.S. Northeast.

Recently, community resilience in urban and rural areas has taken an integrated approach to climate change adaptation and transformation, pointing to important social, ecological, economic, and cultural dimensions that must be incorporated at the local, community scale (Berkes and Ross 2013). Ideally, this involves the "existence, development and engagement of community resources by community members to thrive in an environment characterized by change, uncertainty, unpredictability and surprise" (Magis 2010). Community resilience in this sense also relies on the ability of nature and ecosystems to exert landscape resilience (Xu et al. 2021) and support interconnected social, ecological, economic, and cultural dimensions.

As these definitions highlight, resilience thinking is an important area of inquiry, not only to anticipate and prepare for sudden disruptions, like natural hazards or disaster, but also to test the adjustment of ecosystem service incentive programs amidst rising uncertainty and unpredictability. Planning for and building resilience into institutions, programs, and policies is an essential part of confronting the inherent complexity related to climate change, economic precarity, and social demands that working lands will face in the coming decades. From the assessment, however, the availability of programs and policies that address resilience beyond supporting landscapes was not immediately clear and could be a productive area of future research. This gap in knowledge would be particularly useful for institutions across the U.S. Northeast to understand, especially with the region's uniquely high population density, a combination of urban and rural environments, and expansive tree and forest cover.

Conclusion

In the coming decades, the U.S. Northeast is expected to experience a number of impacts as a result of climate change, including rising temperatures, changes in precipitation and seasonality, and sea-level rise, among others (U.S. Global Change Research Program 2020). These impacts have varying implications for working lands and landscapes across regions as well as the ecosystem services generated production operations. In such a context, incentivizing the production of ecosystem services in the U.S. Northeast is critical for promoting land management behaviors that improve ecological performance and increase socio-ecological resilience. A crucial question now facing the U.S. Northeast and other regions is how to do so in ways that also support working land production and related livelihoods at the same time.

This assessment, which reviewed approximately 1,300 programs that incentivize the production of ecosystem services on working landscapes across the Northeast, provides a number of insights into current programming strengths and weaknesses. In particular,

it highlights several critical opportunities for future research, such as those around the working landbase and infrastructure, livelihood provisioning, scale, and resilience in the U.S. Northeast. This assessment has also provided a number of directions for future policies and programs to better improve ecosystem service provisioning going forward (see Coleman and Machado 2022 for further discussion).

Data availability statement. The data that support the findings of this study are openly available through the Extension Foundation Publication bookshelf at https://online.flippingbook.com/view/749315583/

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