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MAPPING ECOSYSTEM SERVICES FOR THE SOUTHEAST UNITED STATES

Conservation and Restoration Priorities for Wild Pollinator Habitat

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CONTENTS

Ecosystem Service Mapping Series Overview

Ecosystem services, the benefits that natural ecosystems provide to people, vary spatially. Mapping where they are abundant or in short supply is useful for a variety of purposes, including land-use planning, assessment of conservation and restoration priorities, identification of environmental equity issues, and communication with diverse stakeholders. The Nicholas Institute for Environmental Policy Solutions at Duke University, supported by the Southeast Climate Adaptation Science Center, has mapped the supply and demand of a variety of ecosystem services at the landscape level across the southeastern United States. The results for each ecosystem service can be used individually to identify target areas for conservation and restoration to support that service or overlaid with other ecosystem services to identify areas that can provide multiple benefits.

Map products for each ecosystem service are available on ScienceBase, and more information about the project, including methods briefs for the other ecosystem services, can be found on the Nicholas Institute website.

Summary of This Brief

This methods brief focuses on wild pollination, which is beneficial to the production of many pollinator-dependent crops. This analysis maps the supply of potential wild pollinator habitat and the demand for pollination from agriculture. Regional priority areas for conservation and restoration of wild pollinator habitat are identified based on several metrics derived from these supply and demand maps. Spatial datasets for these priority areas and associated metrics are available on ScienceBase.

INTRODUCTION

Wild insect pollination has significant positive effects on pollinator-dependent crop production. While managed honeybees are often used to provide pollination to pollinator-dependent crops, visits by wild insect pollinators have been shown to be more effective in increasing fruit set than managed pollinators, and wild insect pollination increases fruit set even when managed pollinator visitation is high (Garibaldi et al. 2013). This suggests that managed pollination cannot completely replace wild pollination, and that wild pollinators perform a valuable function even when managed pollinators are used. In addition, the presence of wild pollinators can mitigate decreases in managed honeybee visitation caused by adverse environmental conditions such as high winds (Brittain et al. 2013).

The total value of the pollination services provided by wild, native insects has been estimated at $3.07 billion annually (2003 dollars) in the United States (Losey and Vaughan 2006). While this is a rough estimate that includes many assumptions about the distribution of wild pollinators, the use of managed pollinators, and pollination requirements of specific crop types, it provides an indication of the scale of wild pollination in the United States. Wild insect pollination may become even more important in the future; research suggests that honeybees may be more susceptible to changes in climate than native bees, and managed honeybee populations are already in decline due to a variety of factors (Rader et al. 2013).

The distribution of croplands and wild pollinator habitat influences the level of wild pollination on croplands. Many studies, including a synthesis of 23 studies on wild pollinator foraging distance, show that wild pollinator activity on cropland decreases as a function of distance from pollinator habitat (Ricketts et al. 2008). This relationship has previously been used to identify priority areas for wild pollinator habitat conservation and restoration in the Gulf coastal plain (Olander et al. 2017). Several studies have also shown a positive linear relationship between the proportion of surrounding area in natural land cover and wild pollination activity at scales ranging from 750 meters to 1.5 kilometers (Kremen et al. 2004; Morandin and Winston 2006; Benjamin et al. 2014; Holzschuh et al. 2012). Two of these suggest that 30% of the surrounding landscape should be in natural land cover to maximize yield and ensure sufficient pollination from native organisms (Kremen et al. 2004; Morandin and Winston 2006). However, other studies show a weak or no relationship between the proportion of natural land cover and wild pollinator activity (Winfree et al. 2008; Kovacs-Hostyanszki et al. 2016). The degree of landscape heterogeneity may determine the influence that the area of pollinator habitat has on wild pollinator activity. In heterogeneous landscapes, with patches of pollinator habitat interspersed with cropland, the relatively short distances between crops and pollinator habitat facilitate pollinator activity even when the total area of pollinator habitat is relatively small. In homogenous landscapes, much more pollinator habitat is required to generate sufficient pollinator activity on large, contiguous expanses of agricultural land (Winfree et al. 2008).

To assess the spatial distribution of potential wild insect pollination in the southeastern United States, we mapped the supply of potential wild pollinator habitat and the demand for pollination from agriculture. An estimated travel distance for wild pollinators was used to predict relative pollinator activity based on distance from surrounding habitat patches. We used this information along with the proportion of pollinator habitat within travel distance of areas with pollination demand to identify priority areas for restoration of pollinator habitat (areas with high demand for pollination and low supply of pollination) and priority areas for conservation of pollinator habitat (areas with high demand for pollination where pollination supply currently appears to be sufficient, but loss of pollinator habitat could adversely affect wild pollination). We identified priority areas at both the county and the subwatershed (12-digit hydrologic unit code, or HUC12) scales.

METHODS

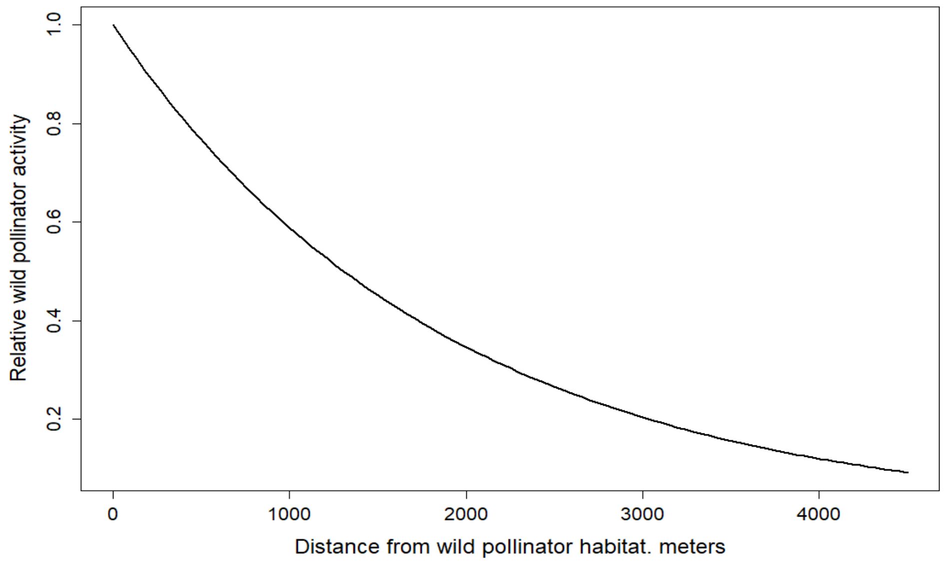
Demand for pollination was identified by the spatial distribution of pollinator-dependent crops. We considered only directly pollinator-dependent crops, which require insect pollination to produce the commercially valuable component (e.g., fruit). We did not include indirectly pollinator-dependent crops, such as alfalfa, cotton, broccoli, and carrots, in this analysis; these crops require pollination to produce seeds, but not to produce the commercially valuable component (Calderone et al. 2012). We used the Cropland Data Layer (CDL, 30-m resolution, USDA National Agricultural Statistics Service 2011) to identify areas of directly pollinator-dependent crops based on the list in Calderone et al. (2012) (see the Appendix for full list). We used an aggregation tool to identify patches of connected pollinator-dependent crops and excluded patches smaller than 10 acres in area to minimize errors from misclassification of pixels in the CDL. The CDL was spatially aligned with the National Land Cover Dataset (NLCD, 30-m resolution, Homer et al. 2015) prior to use using majority resampling, and both datasets were projected in Albers Conical Equal Area (North American Datum 1983).

Potential wild pollinator habitat was identified based on land cover types, following the pollination analysis in Olander et al. (2017), which defined forest, grassland, and wetland cover types as potential pollinator habitat. In this analysis, shrubland was also included as potential pollinator habitat because it has mean suitability values greater than 0.5 for both nesting and floral resources as assessed by expert opinion (Koh et al. 2016). Before using the NLCD to identify potential wild pollinator habitat, all NLCD pixels corresponding to CDL pixels identified as pollinator-dependent crops were reclassified as cropland to ensure that no pixels were identified as both pollinator-dependent crops and potential pollinator habitat. In the modified NLCD, any pixel classified as deciduous forest, evergreen forest, mixed forest, shrubland, grassland/herbaceous, woody wetlands, or herbaceous wetlands was considered potential wild pollinator habitat.

To assess whether the existing potential pollinator habitat is sufficient to provide wild pollination to pollinator-dependent crops, we used two metrics: relative pollinator activity on pollinator-dependent crops (based on distance to pollinator habitat) and the amount of pollinator habitat near pollinator-dependent crops. We quantified relative pollinator activity using information from a synthesis of 23 studies on crop pollinator foraging distances, which estimated that pollinator visitation was at 50% of its maximum at 1308 meters (Ricketts et al. 2008). We used an exponential decay function to model relative pollinator activity as a function of distance from pollinator habitat:

$$\text{Relative pollinator activity} = e^{(\text{distance, meters} * -0.0005299)}$$

Figure 1: Relative pollinator activity as a function of distance from wild pollinator habitat.



Using this equation, we calculated the relative pollinator activity on each pollinator-dependent crop pixel in the study area based on straight-line distance to pollinator habitat. This did not take into account any potential obstacles to pollinator movement, such as bodies of water or roads.

We measured the amount of pollinator habitat near pollinator-dependent crops as the proportion of a circle with a radius of 1,308 meters around each pollinator-dependent crop pixel that is covered by potential pollinator habitat. The distance threshold corresponds to the distance at which pollinator visitation was 50% of its maximum in the synthesis study described above.

The proportion of pollinator-dependent crops, mean proportion of pollinator habitat within flight distance of pollinator-dependent crops, and mean relative pollinator activity on pollinator-dependent crops were summarized by county and subwatershed (HUC12). These attributes were used to identify two sets of priority areas at the county and subwatershed (HUC12) scales: conservation priorities and restoration priorities. All priority areas (counties or subwatersheds) have at least 10% pollinator-dependent crops by area. This cutoff to be considered as a possible priority area was chosen to balance specificity in selecting areas with high demand for crop pollination and inclusiveness in selecting areas from across the study area (pollinator-dependent crops are concentrated in the Mississippi River Valley). The amount of pollinator-dependent crops by county ranged from 0% to 68%, but the mean was only 5% (at the subwatershed level, the amount of pollinator-dependent crops ranged from 0 to 91%, with a mean of 4.6%), so 10% pollinator-dependent crop coverage was selected as a reasonable cutoff. Counties and subwatersheds were scored low, moderate, or high on habitat area and mean relative pollinator visitation (Table 1).

Table 1: Scoring scheme for habitat area and mean relative pollinator activity metrics.

	Habitat area (mean proportion of potential pollinator habitat within pollinator flight distance)	Mean relative pollinator activity (based on distance to nearest pollinator habitat)
Low	<0.3	<0.9
Moderate	0.3–0.4	0.9–0.95
High	>0.4	>0.95

Thresholds for habitat area and mean relative pollinator activity shown in the table above were set based on literature and to identify a reasonable number of priority areas across the southeastern U.S. The mean relative pollinator activity among counties with at least 10% pollinator-dependent crops ranged from 66% to 98%; the mean was 89.75% (for HUC12s, the range was 33% to 99%, with a mean of 89.5%). Given the relatively high pollinator activity values in the study area, the threshold value for a low mean relative pollinator activity score was set at 90% to differentiate from areas with relatively sure likelihood of pollinator visitation on pollinator-dependent crops. This also matches the threshold used in a previous analysis to identify areas in need of pollinator habitat restoration (Olander et al. 2017). We used 95% mean relative pollinator activity as a threshold to identify areas that have a "buffer" before they reach the 90% threshold to score "low" on relative pollinator activity; these are lower priorities for pollinator habitat conservation than areas with 90–95% relative pollinator activity.

The habitat area metric (mean proportion of potential pollinator habitat within pollinator flight distance) among counties with at least 10% pollinator-dependent crops ranged from 2.5% to 46.1%, and the mean was 16% (for HUC12s, the range was 0.2% to 62%, with a mean of 19%). The threshold value for a low habitat area score was based on the research described above that identified 30% natural land cover as the minimum required for sufficient wild pollination. We chose 40% natural land cover as the minimum threshold for a high habitat area score to distribute the areas with greater than 30% habitat area relatively evenly between moderate and high scores.

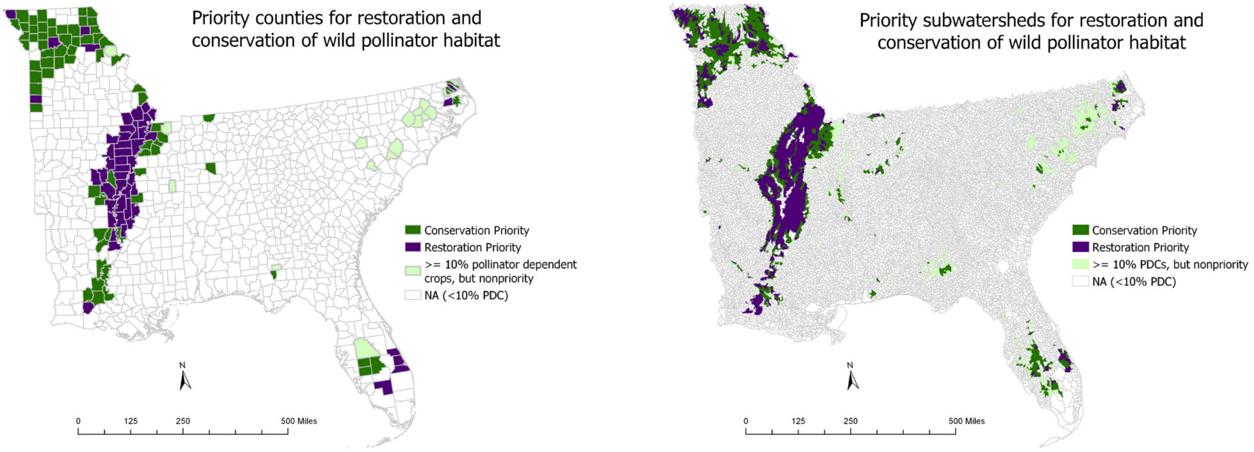
Habitat area and mean relative pollinator visitation scores were combined to identify priority restoration and priority conservation areas (Table 2). As described above, studies of landscape composition effects on wild pollination suggest that either a short distance from cropland to pollinator habitat or a large extent of pollinator habitat near cropland can support sufficient wild pollinator activity. Therefore, priority restoration areas must score low in both mean relative pollinator visitation and the proportion of natural land cover within pollinator flight distance. Conservation priority areas do not score higher than moderate for either criteria; a relatively small loss of pollinator habitat could move them into a low score for one or both criteria, so preservation of existing pollinator habitat is needed to ensure that wild pollination continues. Areas scoring high on either criterion are not priorities for conservation or restoration; a small loss of pollinator habitat in these areas is less likely to cause a decline in wild pollination.

Table 2: Criteria for identifying priority restoration and conservation areas for wild pollinator habitat.

		Habitat area (mean proportion of potential pollinator habitat within pollinator flight distance)		
		Low (<0.3)	**Moderate (0.3–0.4)**	**High (>0.4)**
Mean relative pollinator visitation, based on distance to nearest pollinator habitat	**Low (<90%)**	Restoration priority	Conservation priority	Not a priority
	Moderate (90–95%)	Conservation priority	Conservation priority	Not a priority
	High (>95%)	Not a priority	Not a priority	Not a priority

Applying these criteria to the entire study area at the county and subwatershed (HUC12) level identifies the following regional conservation and restoration priorities (Figure 2). These priorities are identified in the shapefiles provided on ScienceBase. It is also possible to use the other attributes included in the shapefiles to refine the prioritization for specific areas of interest (see “Datasets and Use” section for more details).

Figure 2: Regional conservation and restoration priorities for pollinator habitat.



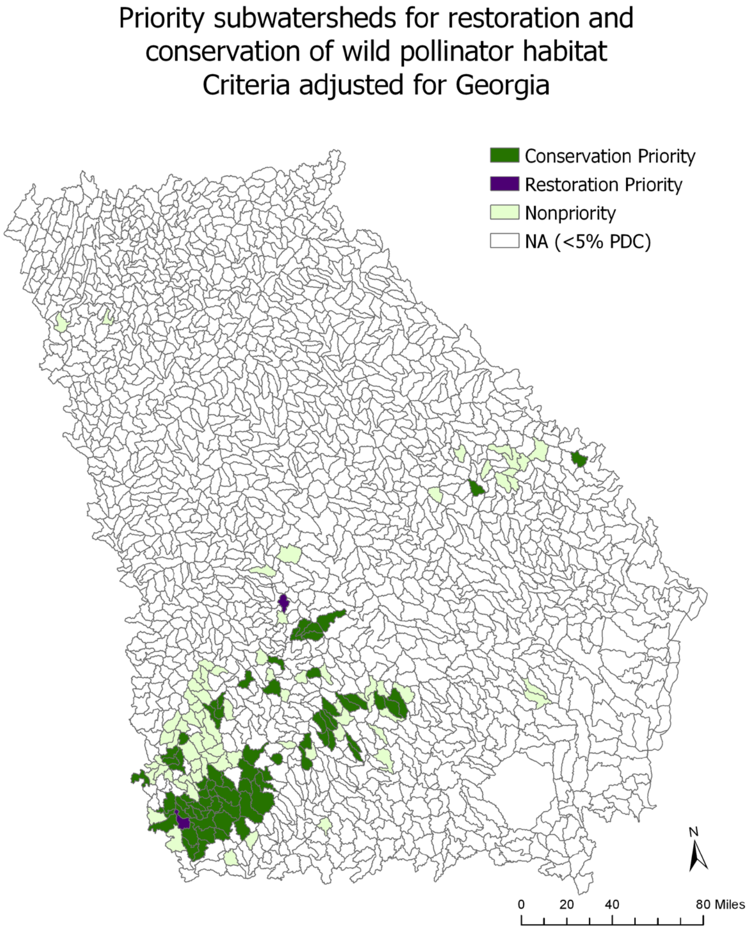
Counties or subwatersheds with less than 10% pollinator-dependent crops by area are not potential priority areas and are unshaded. Counties or subwatersheds with at least 10% pollinator-dependent crops by area are potential priority areas and are categorized as restoration priority, conservation priority, or non-priority following the criteria in the Table 2.

DATASETS AND USE

County-level and subwatershed-level datasets for the southeastern U.S., including priority conservation and restoration areas and the metrics used to identify priority areas, are available on ScienceBase. The priority conservation and restoration counties or subwatersheds can be used to identify where, at the regional level, conservation of existing pollinator habitat or restoration of pollinator habitat will provide the greatest benefit in terms of wild pollination of pollinator-dependent crops. These can also be overlaid with other data sources at the appropriate scale, including other ecosystem services maps, to find areas where conservation or restoration would provide multiple benefits.

The additional fields in the county- and subwatershed-level datasets have the necessary information to make slight changes to the identification of priority restoration and conservation areas. For example, if you are only interested in a geographical subset of the study area, you may wish to adjust the criteria used to identify priority areas if more appropriate thresholds are known. You can use the additional fields to extract priorities within your area of interest according to your defined criteria. For example, someone working in the state of Georgia, which has very few regional priority areas, may want to identify the highest priorities within that state for conservation or restoration of pollinator habitat. This can be accomplished by adjusting the thresholds in Table 2 based on the distribution of the attributes used as criteria in Georgia subwatersheds (or counties), as shown in Figure 3.

Figure 3: Priority subwatersheds for restoration and conservation of wild pollinator habitat in Georgia.



Criteria for priorities were adjusted based on relevant attributes of Georgia subwatersheds: the minimum cutoff for consideration as a priority was lowered from 10% pollinator-dependent crops by area to 5%, and the thresholds for mean relative pollinator visitation were increased from 90% and 95% (low/moderate and moderate/high thresholds, respectively) to 95% and 97%.

If you wish to make more extensive changes to how priority areas are identified, such as calculating metrics at a different level of aggregation or using a different distance to estimate pollinator visitation, you will need to use the underlying raster datasets used to calculate the metrics in the county- and subwatershed-level priority datasets. The raster datasets used to calculate metrics related to the supply and demand for wild pollination are available on ScienceBase. These include:

- Pollinator habitat (30-m resolution)
- Pollinator-dependent crops (30-m resolution)

- Proportion of pollinator habitat within travel distance of pollinator-dependent crops (30-m resolution)
- Relative pollinator activity based on distance to pollinator habitat (30-m resolution)

When using these data, please keep in mind that they are designed for landscape-level assessments; due to inaccuracies in the national-scale input datasets, they should not be used to conduct field-level assessments of wild pollination. This information can be used to identify possible target areas for restoration or conservation of wild pollinator habitat, but field validation of potential project areas is necessary to confirm that potential habitat areas are providing wild pollinator habitat and that nearby pollinator-dependent crops exist.

LIMITATIONS

It would be ideal to assess the status and trends in wild pollination by estimating the level of wild pollinator activity (e.g., number of flower visits) in fields of pollinator-dependent crops. However, this would require a much better understanding of the relationship between particular wild pollinator species and specific types of pollinator-dependent crops, in addition to a method for estimating activity levels of wild pollinator species. A model exists for an index of pollinator activity, but it was developed for native bees specifically and requires data about the bees' activity level and use of various land cover types for nesting and foraging during each season (Lonsdorf 2009). This model forms the basis of the InVEST pollination model, and is therefore available in a user-friendly format (Sharp et al. 2016). This model was not designed for non-bee pollinator species, and the required activity and habitat suitability data has not been collected from field studies.

There is variation in flight distances among wild pollinators, and environmental conditions can affect foraging flight distances. This analysis does not take either of those details into account. The literature on foraging flight distances by crop pollinators includes a wide range of results. Studies on bee species have shown that under most circumstances, bees travel under one kilometer to feed (Elliot 2009; Gathmann and Tscharntke 2002; Knight et al. 2009; Kreyer et al. 2003; Kerr 1959; Osborne et al. 1999). However, some studies have shown that many bee species can travel much further distances when necessary (Beekman and Ratnieks 2000; Beil et al. 2008; Kreyer et al. 2003; Osborne et al. 2008). The wide variation of estimated foraging flight distances can be attributed to effects including but not limited to forage quality, pollinator specialization, time of year, and pollinator body size.

There are many species of wild, native pollinators found in the southeastern United States, and some pollinator species are selective about the types of crops they pollinate. In this analysis, we assume that pollinator habitat within pollinator range of a pollinator-dependent crop contains a pollinator species capable of pollinating that crop type. Without more specific information on pollinator species distributions and habitat preferences, we are not able to assess whether a particular area designated as pollinator habitat is likely to contain the pollinator species required for the nearby crops.

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APPENDIX: POLLINATOR-DEPENDENT CROPS

The following table lists crop types identified as directly pollinator-dependent by Calderone (2012). Cropland Data Layer (CDL) class values follow in parentheses for those crop types present in the CDL. Italicized crops are not included as crop classes in the CDL.

Pollinator-dependent crops (CDL class)	
*Blackberry**	Double crop soybeans/cotton (239)
Blueberry (cultivated and wild) (242)	Double crop soybeans/oats (240)
Boysenberries	Double crop corn/soybeans (241)
Cranberry (250)	Double crop barley/soybeans (254)
Loganberries	Double crop winter wheat/soybeans (26)
*Raspberry (red)**	*Alfalfa (seed)*
Strawberry (221)	Almond (75)
Citrus (72)	*Cotton (seed)*
Grapefruit	*Macadamia*
Lemon	*Non-alfalfa legume seed*
Lime	Rapeseed (34)
Orange (212)	Sunflower (6)
Tangelo	Apple (68)
Tangerine	Apricot (223)
Temple	*Avocado*
Cucumber (fresh/pickled) (50)	Cherry (sweet/tart) (66)
Muskmelon (cantaloupe/honeydew) (209, 213)	*Kiwifruit*
Pumpkin (229)	Nectarine (218)
Squash (222)	Olive (211)
Watermelon (48)	Peach (67)
Grapes (69)	Pear (77)
Peanut (10)	Plum (220)
Soybeans (5)	Prune (210)

[*] These crops are included as "caneberries" in the CDL but were not included as pollinator-dependent crops in this analysis. This omission will be corrected in the next update of this dataset, but is not expected to influence the priority areas identified because blackberries and raspberries are not grown in large quantities in the southeastern U.S.

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Dataset Citations

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Review

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Nicholas Institute for Environmental Policy Solutions

The Nicholas Institute for Environmental Policy Solutions at Duke University is a nonpartisan institute founded in 2005 to help decision makers in government, the private sector, and the nonprofit community address critical environmental challenges. The Nicholas Institute responds to the demand for high-quality and timely data and acts as an "honest broker" in policy debates by convening and fostering open, ongoing dialogue between stakeholders on all sides of the issues and providing policy-relevant analysis based on academic research. The Nicholas Institute's leadership and staff leverage the broad expertise of Duke University as well as public and private partners worldwide. Since its inception, the Nicholas Institute has earned a distinguished reputation for its innovative approach to developing multilateral, nonpartisan, and economically viable solutions to pressing environmental challenges.

National Ecosystem Services Partnership

The National Ecosystem Services Partnership (NESP) engages both public and private individuals and organizations to enhance collaboration within the ecosystem services community and to strengthen coordination of policy and market implementation and research at the national level. The partnership is an initiative of Duke University's Nicholas Institute for Environmental Policy Solutions and was developed with support from the U.S. Environmental Protection Agency and with donations of expertise and time from many public and private institutions. The partnership is led by Lydia Olander, director of the Ecosystem Services Program at the Nicholas Institute, and draws on the expertise of federal agency staff, academics, NGO leaders, and ecosystem services management practitioners.

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