

Strategically Placing Green Infrastructure: Cost-Effective Land Conservation in the Floodplain

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S Supporting Information

ABSTRACT: Green infrastructure approaches have attracted increased attention from local governments as a way to lower flood risk and provide an array of other environmental services. The peer-reviewed literature, however, offers few estimates of the economic impacts of such approaches at the watershed scale. We estimate the avoided flood damages and the costs of preventing development of floodplain parcels in the East River Watershed of Wisconsin's Lower Fox River Basin. Results suggest that the costs of preventing conversion of all projected floodplain development would exceed the flood damage mitigation benefits by a substantial margin. However, targeting of investments to high-benefit, low-cost parcels can reverse this equation, generating net benefits. The analysis demonstrates how any flood-prone community can use a geographic-information-based model to estimate the flood damage reduction benefits of green infrastructure, compare them to the costs, and target investments to design cost-effective nonstructural flood damage mitigation policies.



1. INTRODUCTION

Floods caused more fatalities and property damage than any other natural disaster in the United States during the twentieth century.¹ Almost unique among the likely effects of a changing climate, flooding will affect every U.S. region, coastal and inland, urban and rural.² To build resilience, many communities are changing local land use through investments in “green infrastructure”, locating natural areas strategically in the landscape to lower flood damages.

The possible advantages of using green infrastructure for flood control have been considered in theory³ and recommended in practice⁴ for decades. The empirical literature on biophysical impacts of green infrastructure is growing.^{5,6} A few analyses have estimated significant net economic benefits from watershed-scale nonstructural flood damage mitigation approaches, including green infrastructure,^{7,8} but the peer-reviewed literature remains insufficient to support large-scale public investments in these techniques on economic grounds,⁹ a particularly important criterion in the current fiscal environment.

This paper undertakes an economic analysis of one form of green infrastructure—retaining open space in floodplains to reduce expected future flood damages—in the case of the East River Watershed (ERW), a subwatershed on the eastern border of the Lower Fox River Basin in Wisconsin. The majority of the ERW lies within Brown County, home to the city of Green Bay. The ERW is an excellent case study for two reasons: there are flood concerns, and much land in the floodplain is slated for development in the near future.

Retaining open space in the floodplain can reduce future flood damages in two ways. First, with less development in the floodplain, damages to buildings and other assets will be lower during a flood. Since 1993, the Federal Emergency Management Agency (FEMA) has funded the purchase and conversion to open space of more than 20,000 flood-prone properties, in partnership with states and communities, for just this reason. This reduction in exposure from limiting development is the focus of our paper. Second, less impervious surface area in the floodplain reduces runoff, which can decrease peak discharge for rainfall events and lower flood heights. This analysis does not examine this potentially important hydrologic impact resulting from land use change.

We estimate the avoided flood damages and the costs associated with shifting projected future development out of the floodplain between 2010 and 2025. Results suggest that the costs of preserving all undeveloped parcels in the ERW 100-year floodplain that would otherwise be developed by 2025 would exceed the benefits of reduced building-related flood damage. But targeting land preservation investments based on expected flood damage to preserve only certain parcels would reduce costs enough that conservation efforts would yield net benefits. Targeting investments based on preservation costs, as well as expected flood damage, would have even higher net benefits.

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Considering additional benefits from green infrastructure such as increased recreational opportunities and water quality improvements could reinforce these findings.

2. METHODS

The analysis first estimates avoided flood damages in the ERW from open-space preservation. We then estimate the economic cost of open-space preservation. Finally, we analyze three targeted funding scenarios that reduce the total cost of open-space preservation policies, while retaining much of the benefit.

2.1. Estimation of Avoided Flood Damages. Economic estimates of the benefits of reducing flood damages are usually either based on avoided cost estimates of damage to structures and contents,¹⁰ or stated preference surveys, which simulate market transactions to assess the trade-offs people would be willing to make for reduced expected damages.^{11,12} Although the most appropriate measure of benefits is willingness-to-pay (WTP), we use avoided flood damages, which underestimate WTP for risk-averse individuals. The challenges associated with WTP estimates and the cost of such studies (prohibitive for many local governments) lead us to focus on avoided flood damages.

To estimate avoided flood damages, we use Hazus (version MRS, run using ArcGIS 9.3.1, SP1), a geographic-information-system (GIS)-based model developed by FEMA and the National Institute of Building Sciences to estimate losses from floods and other natural hazards. We use the riverine flood module, which couples a flood hazard analysis (depth and velocity of inundation) with an analysis of economic losses to estimate physical damage to structures and their contents, as well as other infrastructure. To implement the flood hazard module, Hazus relies on a Digital Elevation Model (DEM) to delineate the stream network for a region.¹³ For the loss module, Hazus draws from national databases of the inventory of structures by census block and site-specific information on critical facilities.¹⁴

Hazus can operate at three levels. A Level 1 analysis uses default data and models. The default DEM is from the National Elevation Data set maintained by the U.S. Geological Survey (USGS), with a resolution of 1 arc-second (about 30 m). A Level 2 Hazus analysis integrates more detailed user-supplied data, such as on the location or characteristics of structures, and/or a higher resolution DEM. A Level 3 analysis incorporates data from studies that undertake more advanced modeling, such as a flood depth layer calculated from more sophisticated hydrology and hydraulics models.¹⁵

We perform a Level 2 analysis to estimate building-related losses from flooding in the ERW for both 2010 development and projected future development in roughly 2025. The difference in these losses is our estimate of the avoided flood damages from preventing conversion of all land that is in agriculture or open space in 2010, but expected to develop by 2025. This retention of open space that would, counterfactually, have converted to development is an investment in green infrastructure.

We update the default Hazus building inventory with local land use and property value data, and use a 1/3-arc-second (10-m) DEM from USGS. The higher-resolution DEM improves the delineation of the stream network and thus estimates of flood depth. For our 2010 runs, we update the default building count and replacement cost estimates based on parcel-level GIS files obtained from Brown County's Planning Department. A parcel-level file of 2010 land use allowed us to match each parcel in the watershed to one of the 32 Hazus occupancy classes (e.g., single-family residential, mobile home, retail trade, hospital, light industrial). Some matches (e.g., single-family residential dwellings) were

straightforward, while others required assumptions. For example, Brown County maps identified specific utility and communications structures, such as power substations and landfills; we mapped these into the Hazus class "light industrial".

We used tax-assessor data to update Hazus default estimates of total exposure for each structure category in each census block. Wisconsin requires that property assessments be based on market value (with exceptions for farm land and a few other categories) and evaluated once every 5 years, thus we felt that this update would improve the accuracy of our estimates. We compared our Hazus output using these updates to the use of the default inventory and found the difference in loss estimates to be fairly small. However, this finding may depend on local conditions; in areas with rapid development, for example, the Hazus default inventory may poorly reflect current development.

Because the future land use projections are less detailed than the 2010 information (e.g., a parcel might have been coded as residential in 2025, but not identified as a single-family home, condominium, duplex, etc.), we made assumptions about which of the 32 Hazus categories would be used for each newly developed parcel based on the 2010 distribution of land uses in the county. Each parcel was then assigned the mean value of that class in the watershed from the 2010 assessor's information. From this, counts and values for our 2025 scenario were aggregated to the census block level, and the Hazus inventory was updated. The Hazus assumption of uniform inventory throughout the census block will introduce some error in our estimates. Blocks are larger in more rural areas, making estimates of damages in these locations more uncertain but also, as they are less developed, a smaller share of total building damages. The uniformity assumption would be particularly problematic if development within larger rural blocks clustered in or out of floodplains. Additional details about Hazus and our use of it are provided in the Supporting Information (SI).

Floods are often discussed in return periods. For example, there is a 1-in-100, or 1% chance of a 100-year flood (or greater) occurring in any given year, equivalent to a 26% chance of flooding over the life of a 30-year mortgage. We convert estimates of building-related damages from individual flood events to an average annualized loss (AAL) estimate. The AAL is the sum of the probabilities that floods of each magnitude will occur, multiplied by the damages if they do.¹⁶ In the absence of a probability distribution for flood damage, we use estimates of damages for seven flood event magnitudes: 2-, 5-, 10-, 50-, 100-, 200-, and 500-year. We then assume damages are constant in the intervals between return periods and equal to the average of damages at each end point. For example, for the return interval 2–5 years, we add the damages for the 5-year flood to those for the 2-year flood and divide by 2. Since the x -year flood gives the probability of that flood or greater occurring ($1 - F(x)$ where $F(x)$ is the cumulative probability distribution), the probability of a flood occurring in the interval between a x -year flood and a y -year flood (for $y > x$) is equivalent to $1/x$ minus $1/y$. We do this for each interval and then calculate the total average damage across all "bins". Hazus can apply this methodology to calculate the AAL, but it is computationally intensive, so we calculate the AAL ourselves. This binning approach to the AAL is straightforward; more advanced tools are available when needed.¹⁷

The estimates of avoided flood damages presented here should be taken as indicative of magnitude, not as precise predictions. Hazus makes many simplifying assumptions in the hydrology, hydraulics, and damage estimation modules. For instance, Hazus

does not model hydrologic changes that may accompany land preservation. The goal of this analysis was not to develop precise flood damage predictions but to demonstrate how flood-prone local communities can use this approach to evaluate investments in floodplain conservation.

2.2. Estimation of the Costs of Preserving Parcels.

Engineering cost estimates suggest that restricting development is costly.^{18,19} However, these do not reflect the full opportunity cost of green infrastructure, a cost which, as far as we know, has been estimated in only a few cases.^{20,21} In our case, the assessed values of parcels slated for development between 2010 and 2025 provide a rough estimate of the opportunity costs of preservation, in the case of a fee simple purchase option in which the land becomes publicly owned. There are other policy options, however. For example, governments can purchase agricultural or conservation easements, retaining private ownership but restricting allowable activities. Easement cost will vary by parcel. Average costs for Wisconsin are not available, but results from other programs and findings in the literature provide some guidance. The Maryland Agricultural Land Preservation Foundation, for example, purchases farmland easements at an average per-acre price equal to approximately 60% of average property values.²² Messer²³ uses a “conservative” value of 50%, and Ferraro²⁴ assumes easement costs are between 40 and 60% of property values based on estimates from an appraisal company. We conservatively estimate easement costs at 60% of full purchase costs. Alternative approaches to securing open space to reduce future flood damages (not considered in this study) include zoning, development impact fees, and transfer of development rights programs.²⁵

2.3. Cost-Effective Targeting of Green Infrastructure Investments.

The final part of the analysis considers whether green infrastructure investments can be targeted to particular locations so as to preserve much of the benefit of a more expensive policy, but reduce the costs. This resembles other policy problems, such as the design of conservation areas to preserve biodiversity, or riparian restoration programs to improve drinking water quality. In the natural and physical sciences, one standard approach uses either a single biophysical criterion or a set of such criteria (often combined into a single index) to rank individual parcels or sites in terms of the benefits delivered by a policy intervention.^{26,27} Where policy analysis is performed in these cases, the prescription is first to fund the intervention that offers the greatest biophysical benefit, and then to continue to fund down the ranking until the budget is exhausted.

We analyze three scenarios that target based on the extent of flood damages and (in the third scenario) on costs. In the first scenario, we protect only those parcels that have a mean flood depth exceeding one foot in the 100-year flood. This cutoff is somewhat arbitrary, but identifies parcels that are at greater risk for more severe flooding and so we use it for illustrative purposes. Homes without basements will, on average, sustain damage of less than 10% of replacement cost when flooding is below one foot.¹⁶ In addition, a one-foot flood depth is the lowest flood depth for which recovery time (90 days) is estimated in a recent independent report on FEMA mitigation grants.⁸

Flood damages may vary with parcel size, as well as flood depth. Larger parcels may have more development than smaller ones, both because more and larger buildings are physically possible on larger parcels and because local zoning codes typically set building restrictions on a per-acre basis. A parcel with more buildings will generally sustain greater flood damage. Thus,

Scenario 2 multiplies parcel acreage by mean flood depth, and uses this as a proxy for the expected magnitude of flood damages to rank the parcels. We then assess the costs of preserving those parcels that account for 90% of total damages, an arbitrary cutoff, again for purposes of illustration.

These first two scenarios resemble the approach described in the literature cited above, since physical criteria, correlated with the benefits of a policy, are used to rank sites for public investment. An economically efficient approach to targeting parcels to reduce flood damages would, however, also consider the costs of each potential site,²⁸ ranking parcels according to their benefit-to-cost ratio.²⁴ Our third scenario uses a version of this approach. We divide the cost of preservation (property value) by our acre-foot measure of flood damages to obtain an estimate of roughly the cost per acre-foot of avoided flooding for each parcel. We then preserve only those parcels that are below the median of this measure.

3. RESULTS

Current land use in the ERW is shown in Figure 1. Residential and commercial areas dominate near the city of Green Bay, but more than 60% of land in the watershed is agricultural. Developed uses are increasing, and Brown County projects a 46% increase in residential, commercial, and industrial land uses by 2025.²⁹ Much of the increase in development is expected to occur in communities with a substantial portion of land area in the 100-year floodplain, largely along the East River and its tributaries.

3.1. Estimates of the Avoided Flood Damage from Floodplain Conservation.

Table 1 summarizes damage estimates for the seven categories of flood events in the 2010 base year. Estimates include total building, content, and inventory loss; business interruption loss; the number of at least moderately damaged buildings; and the truckloads of debris generated. Estimating agricultural losses using Hazus would have required many assumptions, including the timing of floods during crop cycles, and changes in crop yields. This was beyond the scope of our study, but it leads us to overestimate avoided flood damages by the amount of crop damage that would have occurred on properties that were in agriculture in 2010 but expected to develop by 2025. In the SI, we develop a rough estimate of the magnitude of this bias, which is very small.

As expected, losses increase with flood event severity (we report all estimates in 2010 dollars). The estimated building, content, and inventory loss for a 100-year flood event in the ERW is approximately \$84 million (for residential properties, Hazus estimates an average of \$132,600 of building and contents losses per damaged household). A 10-year flood generates losses about half this size, while a 200-year flood generates losses of \$95 million. These expected losses vary across the watershed, with depth of flooding and the density of affected structures.

The Brown County Planning Department forecasts an additional 54,819 residents in the county by 2025, creating demand for about 21,000 acres of new residential development and 2,447 acres of commercial development.³⁰ These forecasts, made available to us in GIS so that we could identify the particular parcels expected to convert, are the basis for our future development scenario. We identify all parcels that were in natural areas or agriculture in the 2010 tax assessor maps, but are projected to be in some developed use by 2025 in Brown County's forecasts. Table 2 summarizes the estimated flood damages for this future development scenario. Building losses increase, relative to 2010, by roughly \$3–15 million, depending

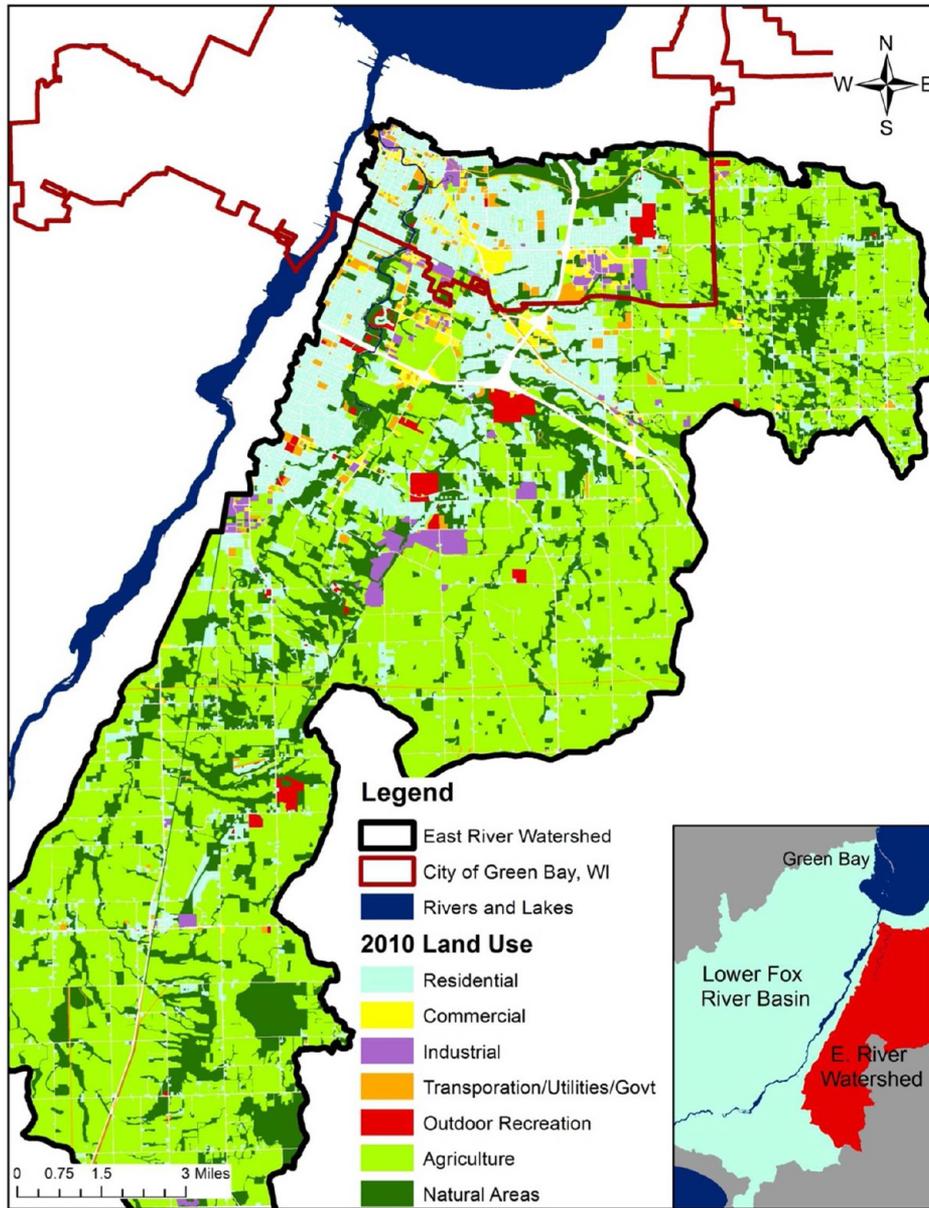


Figure 1. Land use in East River Watershed.

on the event. For the 100-year flood, for example, building losses increase from \$84 million to \$96 million with the additional acres of development.

Although flood magnitudes are often discussed in terms of return intervals, the AAL is a more intuitive number and easier to compare with the costs of policy alternatives. The 2010 AAL, the expected economic damage from flooding in any given year in the ERW with 2010 land use and development patterns, is \$19.43 million. The AAL for the future (2025) scenario is \$22.06 million. The difference, \$2.63 million, is the increase in expected annual flood damages from the additional development projected to occur by 2025. Correspondingly, this is an estimate of the annual benefits of avoided flood damages if the planned floodplain development does not occur.

3.2. Comparison of Flood Damage Mitigation with the Costs. We estimate the costs of both fee-simple purchase and easement purchase, and compare these with the “avoided AAL” benefit estimates from Section 3.1. We begin by assuming that government would want to prevent development of all 833

parcels that would receive any floodwater in a 100-year flood. Preventing development on these parcels would preserve 7403 acres of open space in the 100-year floodplain, at a one-time purchase cost of \$101.1 million. Annualized over 100 years at a 5% discount rate, our estimated cost for preservation of this land is just over \$5 million per year. If easements were purchased instead, the annualized cost would be approximately \$3 million per year. To provide some perspective, the 2012 Brown County budget includes revenues of about \$201 million and expenses of about \$285 million; property tax revenue for 2012 is expected to be about \$81 million (see Brown County, WI: Annual Budget (Adopted), http://www.co.brown.wi.us/i_brown/d/county_executive/12o_front_section.pdf at page 12, accessed March 5, 2012). The cost of even the cheaper easement purchase, \$3 million, exceeds our estimated avoided flood damages of \$2.63 million; this expenditure would not be economically justifiable.

3.3. Scenarios Targeting Open Space Preservation Investments. Flood damages across these 833 parcels are not distributed equally. As described in Section 2.3, we analyze three

Table 1. Summary of Damage Estimates for East River Watershed and Its Tributaries with Current Development Patterns

	2-year flood	5-year flood	10-year flood	50-year flood	100-year flood	200-year flood	500-year flood
total building, content, and inventory loss (million 2010\$)	22.49	36.48	47.48	70.22	83.66	95.32	108.88
business interruption loss ^a (million 2010\$)	0.79	0.94	1.05	1.19	1.30	1.41	1.50
number of buildings at least moderately damaged ^b	36	75	113	236	287	337	406
truckloads of debris generated (25 tons each)	36	58	74	110	129	150	173

^aBusiness interruption loss includes relocation costs, income loss, rental income loss, and wage loss. ^bHazus defines “moderately damaged” as a structure that is 10–50% damaged.

Table 2. Summary of Damage Estimates for East River Watershed and Its Tributaries with Projected Development in 2025

	2-year flood	5-year flood	10-year flood	50-year flood	100-year flood	200-year flood	500-year flood
total building, content, and inventory loss (million 2010 \$)	25.15	41.24	53.79	80.11	95.62	110.9	123.78
business interruption loss ^a (million 2010 \$)	0.79	0.94	1.05	1.19	1.31	1.42	1.50
number of buildings at least moderately damaged ^b	39	75	122	261	317	369	434
truckloads of debris generated (25 tons/truck)	36	58	74	110	129	153	172

^aBusiness interruption loss includes relocation costs, income loss, rental income loss, and wage loss. ^bHazus defines “moderately damaged” as a structure that is 10–50% damaged.

Table 3. Costs of Land Preservation in East River Watershed: Three Alternative Floodplain Targeting Scenarios^a

	scenario 1: targeting based on flood depth	scenario 2: targeting based on flood depth and parcel acreage	scenario 3: targeting based on costs, flood depth, and parcel acreage
total cost, fee simple purchase	\$72.9 million	\$22.8 million	\$9.8 million
annualized cost, fee simple purchase	\$3.67 million	\$1.15 million	\$496,000
annualized cost, easement purchase	\$2.20 million	\$690,000	\$298,000
number of parcels	575	328	417
acreage	4646	6385	6379

^aAll parcels that both lie in the floodplain of a 100-year flood and are predicted to be developed by 2025.

scenarios that target floodplain preservation investments based on the extent of flood damages and (in the third scenario) on costs (Table 3). As expected, the costs of all three scenarios are lower than the base case, since fewer parcels are purchased. In Scenario 1, we purchase only those parcels that receive more than one foot of water in a 100-year flood, at an annual cost of \$3.7 million for fee-simple purchase and \$2.2 million for easement purchase (again, over 100 years, with a 5% discount rate). Scenario 1 purchases 69% of all parcels slated for development that receive water in a 100-year flood (575 of the 833 base-case parcels), comprising 63% of acreage projected to convert to developed uses.

In Scenario 2, which targets based on both flood depth and acreage, far fewer parcels (328 of 833) are purchased. However, more acreage is protected—6385 acres, or 86% of all acreage that lies in the 100-year floodplain and is projected to be developed by 2025. The annual cost of Scenario 2 is much less at \$1.15 million for a fee simple purchase.

Scenario 3, which extends Scenario 2 to also target based on the cost of parcels, has the lowest costs of all, less than \$500,000 in annual terms for a fee simple purchase and even less for easement purchase. This estimate is less than half the cost of Scenario 2, even though 27% more parcels are purchased than in Scenario 2. The acreage of land protected from development is virtually the same as in Scenario 2, but Scenario 3 acquires relatively more inexpensive and small properties. This scenario essentially takes a “bang for the buck” approach, obtaining as much flood protection as possible with preservation dollars.

Figure 2 illustrates the differences in parcels preserved among the base case and the three scenarios. The three alternative scenarios all preserve less overall acreage than the base case. Figure 2 also shows projected agricultural and natural areas for 2025 to illustrate the proximity of preserved parcels to other areas of open space or development, which may be important for other ecosystem services.

The costs of all three scenarios are much lower than the cost of preserving all floodplain land slated for future development. But do the benefits of each scenario exceed the costs? We expect that they do; costs in Scenarios 2 and 3 are far lower—only 23% and 10%, respectively, of costs in the baseline case—and a large percentage of the total acreage is still protected. But precisely estimating avoided damages under these scenarios becomes more speculative than the baseline case as it requires us to say which types of buildings with what values are constructed over the 2010–2025 period on each parcel (such a parcel-level analysis cannot be done with the census block averaging in Hazus used in our baseline case). Still, to provide a rough estimate of avoided damages for the scenarios, we use the mean values for each property class as above and then select a single, conservative depth–damage function for each class from the Hazus library. Depth–damage curves relate building value to percent damaged based on flood depths. We use this function to estimate avoided structural building damages for our scenarios (see the SI for more information).

For Scenario 1, we find avoided future flood damages to buildings of roughly \$2.2 million. For Scenario 2, we estimate avoided

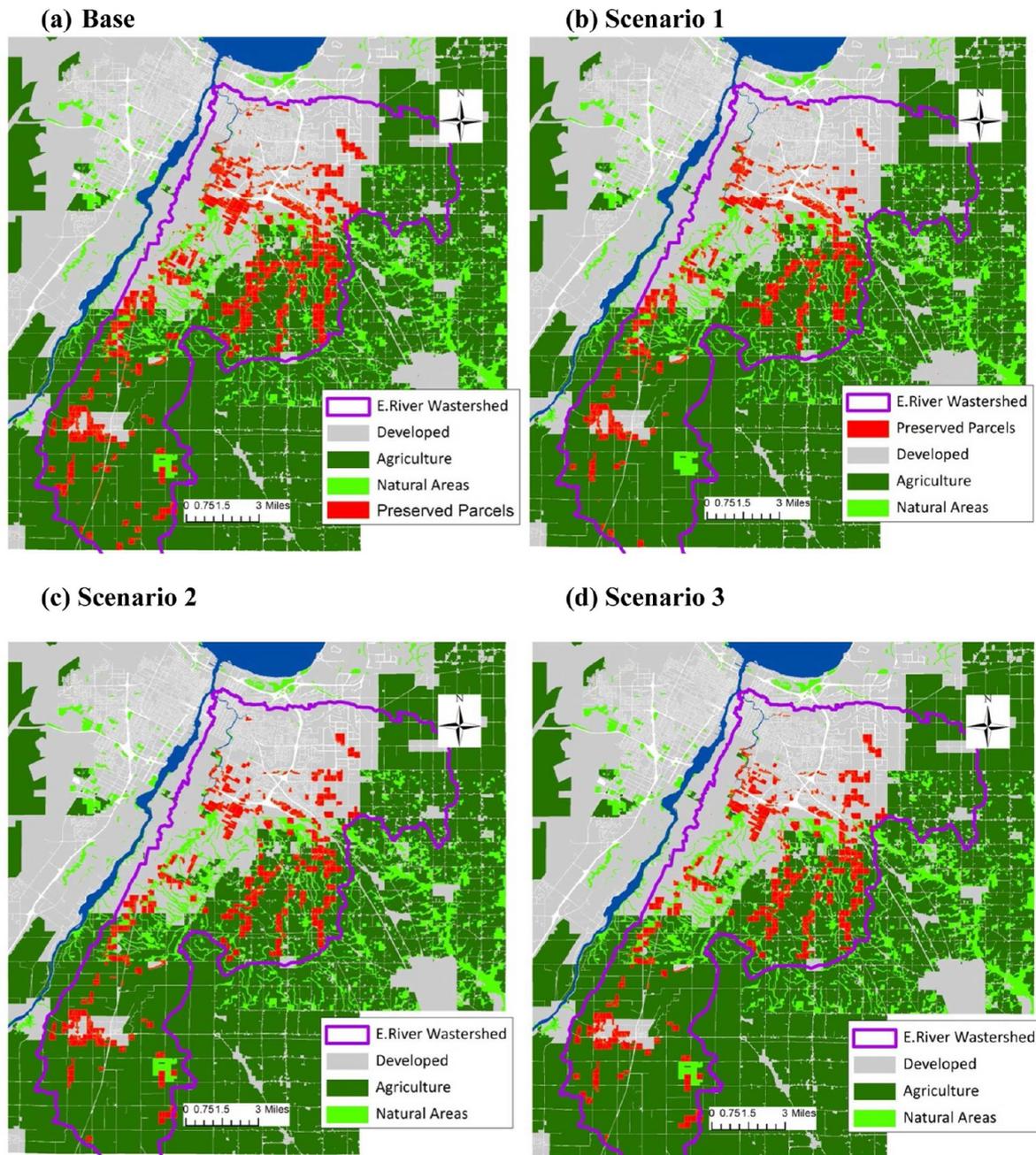


Figure 2. Parcels preserved in base case and scenarios 1–3.

damages at roughly \$1.2 million, and for Scenario 3, we estimate avoided damages at around \$1.5 million. We wish to stress the huge uncertainty in these numbers, given that they are for unknown future development and rely on uncertain depth–damage relationships. Still, they suggest that Scenarios 2 and 3 may generate benefits in excess of costs for both fee simple purchase and easement purchase. Careful targeting can thus produce cost-effective investments in floodplain conservation.

4. DISCUSSION

We demonstrate that, even if the costs of an extensive watershed-scale green infrastructure approach to flood damage mitigation exceed the avoided flood damages to property, careful spatial targeting of investments can reverse this equation. The analysis provides a blueprint for communities wishing to quantify trade-offs

in assessing land-use options for flood protection. Public agencies are investing in green infrastructure as a substitute for and a complement to the dams, levees, and other gray infrastructure that have typically been used to manage flood risk. Tools like those we apply here can help target these investments cost-effectively. Indeed, many state and local governments have already used Hazus for flood planning and management;³¹ economic analysis like ours is another potential application. Estimates of the avoided damages and costs of land preservation as a flood control policy could also be compared to those of gray infrastructure alternatives.

The third targeting scenario we implement is preferable from an economic perspective since it considers costs in parcel ranking and selection. This distinction is particularly important when (1) the benefits and costs of parcel selection are positively correlated (high-benefit parcels are also expensive to preserve); (2) costs

are more variable than benefits across space; and (3) the budget allows only a small fraction of the desired amount of preservation.²⁴ In each of these cases, selecting parcels according to the amount of benefit generated per dollar spent will result in greater net benefits than selection on the basis of benefits alone.^{23,24,32,33} In our case, the second and third points are valid. Costs are highly variable, as property values vary widely across parcels in the ERW floodplain; potential flood damage also varies across parcels but not as widely. In addition, a typical local government budget would allow only a small fraction of floodplain land to be preserved, making it more critical to choose the right parcels. If benefits and costs were also positively correlated (they are negatively correlated in our case), the differences in parcels selected under Scenario 3 and those in Scenarios 1 and 2 might be even greater (with resulting consequences for net benefits). Local governments should consider these rules of thumb in designing local land-use policies to reduce flood damages. Cost-effectiveness analysis is not a perfect substitute for full benefit–cost analysis, but it is a useful first step.

Results should be interpreted with several caveats in mind. First, we excluded crop damage from the flood damage estimates, though the upward bias this implies for our estimates is likely very small (see the SI). Another potential source of upward bias is an implicit assumption that avoided floodplain development will not be foregone, but rather located out of the floodplain. If this change in the spatial distribution of development generates reductions in benefits, such costs should also be considered.

In contrast, two choices lead us to underestimate avoided damages, potentially biasing downward the scale of conservation investment that can be justified on economic grounds. First, our avoided flood damage estimates exclude nonmarket flood damages, fatalities and injuries, displacement costs, and emergency response costs, all important components of a full benefit–cost analysis of hazard mitigation.³⁴ Second, we do not monetize the potential cobenefits associated with floodplain open space preservation. As green infrastructure reduces or redistributes impervious cover, affecting runoff, it could also improve water quality downstream (water quality problems in Green Bay are an ongoing concern). Further, preserved lands could improve wildlife habitat, reduce the urban heat island effect for parcels near downtown Green Bay, offer air quality benefits, provide recreational opportunities, and improve neighborhood aesthetics. The magnitudes of these benefits would depend on the type of open space (e.g., forested, wetland), access and ownership structure for preserved parcels, and proximity to centers of population and other protected lands. Detailed water quality modeling and nonmarket valuation studies, among others, would need to be undertaken to develop monetized estimates of these benefits.

Incorporating these additional values should only strengthen the merits of the green infrastructure approach. However, if these additional benefits vary spatially in a way that differs from the avoided flood damages, it is possible that the ranking of our targeting scenarios would change. Indeed, an alternative targeting approach might be more appropriate for a community wishing to consider a broader range of benefits. This is beyond our scope. To economically justify fee-simple purchase of *all* properties in the ERW's 100-year floodplain, given our results, cobenefits would need to amount to a little over \$1 million annually, or about \$4 per Brown County resident.

■ ASSOCIATED CONTENT

📄 Supporting Information

Additional details as noted in the text. This information is available free of charge via the Internet at <http://pubs.acs.org>.

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Notes

The authors declare no competing financial interest.

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