Geospatial Analysis of Nonmarket Values to Prioritize Forest Restoration

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Abstract: Forest restoration is necessary for maintaining healthy watersheds and the ecological spatial networks that provide environmental goods and services. Consideration of the dollar value of these provided benefits in restoration planning is essential to the efficient use of limited resources available to project implementation. Nonmarket valuation is a methodology of economics commonly used to estimate monetary values for environmental goods and services that are not typically bought or sold in a traditional market. Valuation studies are prolific within the restoration literature; however, the use of nonmarket values as decision support is not well represented. We introduce a method using Geographic Information Systems (GIS) to spatially analyze the results from a nonmarket valuation study that estimated dollar values for the attributes of forest restoration characteristic of a semi-arid watershed in the Southwest United States. Map layers were created for the five attributes valued by the study and represent areas in the watershed that are designated as critical habitats, determined to influence surface water quality, prone to high-severity wildfire, representative of culturally significant areas, and contribute to aquifer recharge. A series of overlay analyses were performed to create a composite benefit map that spatially displays nonmarket values throughout the watershed. The per acre benefit values range from USD 0 to USD 104 where all five attributes are present.

Keywords: decision support; forest restoration; GIS; nonmarket valuation; spatial prioritization

1. Introduction

Forests across the western US have significantly altered composition and structure due to a century of Euro-American management practices. The logging of fire-resilient, old-growth trees left behind young, vulnerable stands, whereas fire exclusion allowed high-density tree establishment and increased surface fuels, leaving them susceptible to uncharacteristic high-severity wildfires [1]. Ponderosa pine stands that once contained 50 trees per acre can now be found exceeding 1000 trees per acre (approximately 4047 m²) [2]. Restoring forests to resemble pre-settlement, fire-adapted conditions within a historic range of natural ecological variability by reducing tree density and reestablishing the natural low-intensity fire regime is the focus of forest restoration for land managers in the arid southwestern United States [2–4]. The common restorative method applied to pine forests in Arizona, USA, is mechanical thinning followed by prescribed burns, which costs roughly USD 1000 per acre [2]. Ponderosa pine forests cover approximately 20% of the Salt–Verde River watershed in Central Arizona (Figure 1) [5]. Thinning and burning treatments applied to forests throughout the watershed would cost approximately USD 1.7 billion.

Project prioritization tools to optimize restoration in decision making are available and widely used by US land managers. Among the decision support tools is the Wildland Fire Risk and Cost Management Tools Package (R-CAT), a risk reduction and fire suppression cost savings estimator required by the US Forest Service for funding proposals [6]. Intended for use with R-CAT, Fitch et al. [7] developed a regression model using modeled wildfire behavior to predict wildfire suppression costs. Ager et al. [8] presented a decision support
model that delineates forest treatment areas, which reduces the risk of stand-replacing fires in ponderosa pine forests. The Forest Vegetation Simulator is a modeling platform informed by over four decades of research that forecasts the vegetation response to proposed management actions [9]. Volger et al. [10] pioneered a prioritization method that uses optimization methods and production possibility frontiers to graphically display the opportunity costs of restoration objectives (i.e., vegetation departure, insect risk, timber value, wildfire risk, and wildfire hazard) to aid with efficient management decisions. The optimization identifies the opportunity costs of alternative treatments, and the production possibility frontiers graphically analyze the tradeoffs between the projects [10]. The US Forest Service projects, Forests to Faucets, and the Watershed Condition Classification produced spatial data that delineated priority watersheds for restoration activities [11,12]. Recent studies [13] have developed restoration prioritization for ecosystem services using approaches such as the Relative Aggregated Value of Ecosystem Services (RAVES) index. This index integrates only ecological information and societal values. Other studies, such as Wickham et al. [14], developed restoration prioritization approaches based only on the landscape context.

Figure 1. The Salt and Verde River watershed, Arizona, USA. Map layers were created using the North American 1983 Datum, GCS North American 1983, Transverse Mercator projection, and NAD 1983 State Plane Arizona Central FIPS 0202 coordinate system.
Advancements in remote sensing, light detection, and ranging (LiDAR) methods provide a high-resolution reconstruction of current and historical ecological spatial networks allowing decision makers to detect areas that have been impacted by and may be most vulnerable to shifts in land use, management practices, climate, and other natural occurrences such as forest fires [15–17]. Molin et al. [16] paired Landsat satellite imagery with geospatial data in an assessment of the restoration costs and outcomes to optimize landscape-scale restoration investments. Molin et al. [16] estimated the implementation and opportunity costs of restoration based on the characterization parameters of 900 m² land units throughout the Piracicaba River basin, Brazil, and identified an opportunity for cost savings when implementing a cost-reduction strategy to prioritize restoration in land units with the lowest restoration costs as the primary driver for selection. However, we support the claim that without the consideration of the nonmarket value of environmental goods and services, ecological restoration is commonly undervalued and not optimally implemented [18]. Loomis and González-Cabán [19] advocated the employment of nonmarket valuation to inform US Forest Service managers of the monetary nonmarket benefits of wildfire management for use in decision making. Nonmarket valuation estimates monetary values for goods and services that are not typically bought or sold in a traditional market [20] and is commonly used to value ecosystem goods and services [19]. Previous research shows positive values for many nonmarket goods and services provided by forests [21–23]. Environmental valuation studies are becoming more popular in the current literature due to their ability to guide policy change worldwide. Czajkowski et al. [24] used a discrete choice experiment to determine individual willingness to pay (WTP) values for tree species and access to recreational amenities to inform a country-wide management plan in Poland. Hanley et al. [25] used the attributes of ecology, aesthetics, and riverbanks to estimate the value of improvements in river ecology. Häyhä et al. [26] combined a biophysical assessment with economic valuation results to find the recreational value of tourism from tourists’ WTP for provisioning, regulating, and recreational services in Italy. Although valuation studies are prevalent, few published studies produce environmental valuation results that are readily incorporated into the decision-making process [27].

Some environmental valuation studies recognize this difficulty and have utilized GIS to present the spatial distribution of biophysical services or social values. Moore et al. [19] provided decision makers with a method that maps nonmarket values as relative priority areas from highest priority to lowest. Czajkowski et al. [24] used GIS methods paired with the results from a choice experiment to explain the spatial patterns and clustering in individual WTP for forest attributes. This method makes use of the respondents’ zip codes and forest data to explain the spatial relationship between the WTP values and the respondents’ location and environmental characteristics of forests. Campbell et al. [28] used kriging methods to interpolate the averaged individual WTP values estimated for the attributes of rural landscapes from 100 electoral divisions across the entirety of the Republic of Ireland as a means of benefits transfer. Elsasser et al. [29] used the WTP results from two stated preference studies, a contingent valuation study, and a choice experiment to map the spatial distribution of the benefits of recreational access to forests and increased forest biodiversity, respectively, across Germany. The results produced individual maps to show the average annual monetary benefit of each forest ecosystem service for every German municipality. Our study differs in that it uses the WTP from a choice experiment and open-source spatial data to create a composite benefit map showing the spatial distribution of the aggregated nonmarket benefits for attributes as they exist on the land.

Our approach can be used to inform management decisions by providing stakeholders with a visualization of high-valued areas. We used Esri ArcGIS Desktop ArcMap 10.6.1., USA, a Geographic Information System software, to spatially represent the monetary nonmarket values across the Salt–Verde watershed estimated for the attributes or outcomes of typical forest restoration methods. We build upon previous approaches by presenting a method that delineates nonmarket values as areas representing a dollar-per-acre benefit value throughout the watershed. To make this study directly usable by US land and
resource management agencies, we use the acre in our analyses. The acre is the customary unit used to describe land area by US agencies. One acre of land equals approximately 4047 m². Considering the monetary nonmarket value of restoration during project planning identifies and prioritizes areas in the watershed with the highest benefit–cost ratio, resulting in more efficient use of limited funds [10]. Although current decision support tools assist with identifying priority watersheds and model responses to proposed strategies, we contribute to the current literature on restoration by directly integrating nonmarket values into prioritization.

2. Materials and Methods

2.1. Nonmarket Values of Forest Restoration

Mueller et al. [21] used the choice experiment, a stated preference method of nonmarket valuation, to estimate the monetary values for the attributes, or benefits, characteristic of forest restoration in the Salt–Verde watershed. The choice experiment engaged participants in a survey asking them to affirm their preferences for nonmarket goods or services provided by forest restoration. Survey respondents were solicited from a survey participation panel through email and web prompts. The choice experiment conducted by Mueller et al. [21] returned 549 complete responses from the residents of the Phoenix metro area, the perceived beneficiaries of the restoration. Respondents were asked to weigh the trade-offs between proposed hypothetical restoration projects that (1) protect critical habitats, (2) improve surface water quality, (3) restore forests prone to wildfire, (4) preserve culturally significant areas, and (5) increase groundwater recharge. Attributes were elected by evaluating local restoration goals and refined through a series of focus groups. Associated with each project was a fee the respondent would encounter in the form of a one-time payment on their water utility bill if elected. Respondents were asked to consider their household income when selecting their preferred project. The Fedorov algorithm was consulted to achieve the optimum experimental design. Presenting seven side-by-side comparisons of projects with different outcomes and costs allowed respondents to consider their preferred restoration outcome and their willingness to pay to receive the benefits.

WTP values from survey responses were estimated using a mixed logit model. Results of the model are presented as the per household WTP for a restoration project that produces each valued benefit and are summarized in Table 1. WTP estimates can be aggregated for restoration projects that provide two or more of the valued benefits. An estimated WTP per household in the Phoenix metro area to support a project that provides all five benefits is a one-time fee of USD 132.55 (the sum of all five WTP estimates). We use the per household WTP for each valued attribute of restoration in the Salt–Verde watershed from Mueller et al. [21] as the multiplier for map layer development in our nonmarket benefits spatial overlay analysis.

Table 1. Values calculated for dollar-per-acre benefit value estimates. The acre is the customary unit used to describe land area by US agencies and is the land unit used in this analysis. One acre of land equals approximately 4047 m².

| Benefit               | Estimated Value [21] (USD/Household) | Aggregated Benefit Value (USD × 10⁶) | Acres (×10⁶) | Benefit Value (USD/ac) | Raster Value (USD) |
|-----------------------|-------------------------------------|------------------------------------|-------------|------------------------|--------------------|
| Critical Habitats     | 41.92                               | 70.4                               | 1.24        | 56.80                  | 57                 |
| Surface Water         | 40.19                               | 67.5                               | 4.04        | 16.70                  | 17                 |
| Restricted Access     | 25.81                               | 43.4                               | 4.15        | 10.50                  | 11                 |
| Cultural Significance | 23.33                               | 39.2                               | 2.14        | 18.30                  | 18                 |
| Aquifer Recharge      | 1.30                                | 2.18                               | 5.31        | 0.41                   | 1                  |
2.2. Nonmarket Benefits Spatial Analysis

Spatial representation and overlay analysis of the benefits valued by Mueller et al. [21] were completed in ArcGIS Desktop 10.6.1 [30] following a five-step process to

1. develop criteria to define benefit areas,
2. locate spatial datasets that accurately display benefit areas,
3. create individual benefit area map layers,
4. calculate dollar per acre benefit values, and
5. reclassify raster map layers and complete final overlay analysis.

The first three tasks result in map layers defining the areas within the watershed that provide each benefit (benefit areas). Criteria, data, and map-layer development are unique to each benefit. Once the individual map layer construction is complete, the remaining two steps are executed resulting in the final composite benefits map delineating the dollar/acre benefit values. We detail the process described in this study to complete each step.

2.2.1. Develop Criteria to Define Benefit Areas

This study analyzes the benefits of restoration typically observed in the Salt–Verde watershed. Table 2 describes the criteria established to delineate each benefit area in the watershed. Generally, a benefit area is considered as land that contributes to, or impacts, each valued benefit.

Table 2. Benefit criteria and data used in map layer generation.

| Attribute          | Benefit Criteria (Step 1)                                                                 | Data Selection (Step 2)                                                                 |
|--------------------|-----------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|
| Critical Habitat   | Areas legally designated as critical habitats for endangered, threatened, and endemic species within the Salt–Verde watershed. | Polygon and line shapefiles delineating areas designated as critical habitats from Environmental Conservation Online System. |
| Surface Water      | Areas at risk of wildland fire important to surface drinking water that receive \( \geq 508 \) mm of precipitation. Ponderosa pine forests average 508–762 mm of precipitation that accounts for nearly all the annual stream flow [31]. | The FIR_FOR3 attribute field from the US Forest Service Forest to Faucets dataset is an index of wildland fire threats to forests important to surface drinking water [12]. Mean 30-year normal annual precipitation data (1981–2010) from PRISM Climate Group. |
| Restricted Access  | Areas in the watershed prone to high-severity wildfires.                                 | The PER_FIRE_3 attribute field from the US Forest Service Forest to Faucets dataset is an index of watersheds that are at high risk of wildland fire. |
| Cultural Significance | Data showing only tribal land designation to protect the sensitivity of cultural site locations. | A polygon shapefile delineating area designated as tribal land downloaded from Arizona State University. |
| Aquifer Recharge   | Areas exceeding 1500 m in elevation that receive snowfall. Recharge is dominated by winter precipitation at higher elevations. Blasch et al. [32] suggested that recharge predominantly occurs at elevations above 1500 m. | One-third arc-second elevation rasters in ArcGrid format were downloaded from the USGS’s National Elevation Dataset (NED). Annual mean total snowfall for Arizona was used with elevation to determine areas of recharge [32]. |

2.2.2. Locate Spatial Datasets That Accurately Display Benefit Areas

Spatial datasets were chosen for each valued attribute based on the criteria established in Step 1. Open access datasets were selected to promote transferability and use by decision makers. Table 2 summarizes the datasets used to construct the individual benefit map layers.

2.2.3. Create Individual Benefit Map Layers

A map layer delineating the area where each benefit is present in the watershed was created using the datasets collected in Step 2. Map-layer development and preliminary
spatial analysis were executed in Esri ArcGIS Desktop ArcMap 10.6.1., USA, [30]. In some instances, multicriteria analysis was required to best interpret the benefit area for the map layer [33]. Data transformation and processing are unique to each benefit and are defined below. All imported data files were projected in NAD 1983 State Plane Arizona Central FIPS 0202. Spatial analyses were executed using the Map Algebra Spatial Analysis Raster Calculator in ArcMap with a 30 m cell output [30]. The processing extent for all datasets was set to the Salt–Verde watershed boundary.

- **Protection of Critical Habitat for Threatened, Endangered, and Endemic Species.** Spatial data designating critical habitats were provided in two separate files: a polygon and a line shapefile. Line segments represent stream reaches designated as critical habitats. Line segments do not have a calculable area. For proper use in spatial analyses, line data were transformed into a polygon area. A 200 m buffer was placed on each side of the critical habitat line feature class to create a stream polygon with a 400 m width. Some stream reaches were accounted for in the polygon shapefile. Streams included in the polygon shapefile downloaded from the data site exhibited an approximate 400 m width, justifying the 200 m buffer. The critical habitats map layer was completed by merging the buffered line segments and the original critical habitat polygon and then dissolving the boundaries to form one congruent critical habitat feature class. The Merge Tool and Dissolve Tool were used to perform this task in ArcMap.

- **Improved Surface Water Quality.** The Forests to Faucets project led by the US Forest Service produced nationwide spatial data mapping watersheds important to surface drinking water resources, forests that are crucial in the protection of drinking water, and areas where watershed degradation due to wildland fire, development, and insect and disease outbreaks threaten drinking water supplies [12]. The Forest to Faucets FIR_FOR3 attribute field ranks the wildland fire threat to the HUC 12 watersheds that are important to drinking water resources from 0–100, where 0 is no threat and 100 is the greatest threat [12]. All HUC 12 watersheds with values greater than 0 were selected and clipped to the Salt–Verde watershed boundary. The Dissolve Tool was used to create a single threatened watershed polygon layer. The threatened watershed polygon was further refined using mean 30-year normal annual precipitation data (1981–2010) obtained from the PRISM Climate Group [34]. Areas of the watershed that receive 508 mm or more of precipitation were selected for the analysis [31]. The precipitation raster was reclassified as all cells with values of 508 or greater to have an output value of 1 and all other values of 0 to represent the presence or absence of the criteria. The threatened watershed layer was converted to a raster using the Feature to Raster Tool and then multiplied by the precipitation raster using the Raster Calculator. As in a traditional multiplication equation, the product of a map grid cell with a value of 1 multiplied by a map grid cell with a value of 0 is 0, producing a map layer where only threatened watersheds that receive 508 mm or more of precipitation in a year are expressed.

- **Restricted Access During Wildfire Season.** The US Forest Service Forest to Faucets PER_FIRE_3 attribute field is an index of the percent of the HUC 12 watershed that is at high risk of wildland fire [12]. HUC 12 watersheds within the Salt–Verde watershed that show that 100% of the area is at risk were considered to represent areas that are prone to closures during wildfire season and selected to create the restricted access feature class. The HUC 12 watershed boundaries were dissolved to form a single polygon and then the Feature to Raster Tool was used to convert the polygon to a raster.

- **Preservation of Culturally Significant Areas.** The polygon shapefile delineating tribal lands in Arizona was clipped to the Salt–Verde watershed boundary layer. No further processing was required other than conversion to raster format using the Feature to Raster Tool. Designated tribal lands were selected to represent culturally significant areas to protect the locations of cultural sites. We recognize the limitation of our data to incorporate areas of cultural significance outside the boundaries of tribal lands.

- **Increased Aquifer Recharge.** One-third arc-second elevation rasters were downloaded in ArcGrid format from the USGS’s National Elevation Dataset (NED). Eleven individual
1 × 1 degree data frames were stitched in ArcMap using the Mosaic to New Raster tool and masked with the Salt–Verde watershed boundary [30]. The elevation raster was reclassified, with input values exceeding 1500 m having an output value of 1 and all other values with an output value of 0. A stable-isotope study completed in the area suggests that aquifer recharge is dominated by winter precipitation occurring at elevations above 1500 m [32]. Snowfall data were acquired in raster format and were reclassified to have all input values greater than 0 to have an output value of 1. The reclassified elevation and snowfall rasters were multiplied using the Raster Calculator. Areas with snowfall occurring in elevations less than 1500 m were eliminated as they were not likely to receive recharge from snow.

2.2.4. Calculate Dollar-per-Acre-Foot Benefit Values

The aggregated nonmarket value for each attribute was calculated by multiplying each per household willingness-to-pay estimate by 1.68 million, the number of households in the Phoenix metro area [35]. The aggregated value for each benefit assumed what the residents of the Phoenix metro area would pay to restore each benefit area in its entirety. Each aggregated benefit value was then divided by the number of acres present in its corresponding benefit map layer providing a dollar/acre benefit value (Table 1). The total benefit area present in each map layer was calculated in ArcMap using the Calculate Geometry command and added to the attribute table. The benefit area was divided into the aggregated dollar benefit value to obtain the dollar/acre benefit value and added as an attribute to the attribute table using the Field Calculator tool [30]. The acre is the customary unit used for land area by US land and resource management agencies and is the land unit used in this analysis. One acre of land equals approximately 4047 m$^2$.

2.2.5. Reclassify Raster Map Layers and Complete Overlay Analysis

All benefit area map layers underwent varying degrees of transformation in prior steps producing a raster grid with a 30 m grid cell (900 m$^2$). The objective of the final overlay analysis was to stack all map layers and sum the dollar/acre nonmarket values of the benefits present in each grid cell column. To achieve this, each map layer was reclassified using the ArcGIS Reclassify Tool. Grid cells where the benefit criteria were not met were assigned, or maintained if previously assigned, a value of 0 to represent a 0 USD/acre benefit or no benefit present. Grid cells where the benefit criteria were met were assigned an output value equaling the calculated dollar-per-acre benefit (Table 1). Similar GIS methods have been used to assign to grid cells the restoration implementation and opportunity costs to evaluate the cost savings of prioritizing restoration projects based on costs [16]. The final overlay analysis was executed using the Map Algebra Spatial Analysis Raster Calculator to add the benefit area map layers [30]. The addition of map layers summed the values in stacked grid cells, resulting in the total dollar/acre benefit value of each 30 m grid cell.

3. Results

3.1. Map Layers

The nonmarket value benefit area map layers delineate areas that (1) are designated as critical habitats (Figure 2a), (2) are important for surface water resources (Figure 2b), and (3) are subject to forest closures due to high risk of wildland fire (Figure 2c), (4) are considered culturally significant (Figure 2d), and (5) contribute to aquifer recharge (Figure 2e). The willingness-to-pay values were aggregated for each benefit layer and divided by the number of acres in the represented area of the watershed (Table 1). Small areas designated as tribal lands do not appear in the figure due to the resolution of the map layer. However, they were included in the dollar/acre benefit value calculation and can be viewed at a higher resolution. The per acre benefit values used in spatial analyses were rounded to the nearest dollar to simplify the map calculations. The aquifer recharge was calculated as having a per acre benefit value of USD 0.41 that was rounded up to USD 1. Rounding USD 0.41 down to USD 0 would have misrepresented the benefit area in the final
benefit value map. Critical habitat was the highest valued benefit of restoration estimated by Mueller et al. [21] and was also the highest valued per acre benefit in the watershed. Increased aquifer recharge was the lowest valued benefit and continues to have the lowest value per acre. The preservation of culturally significant sites was the second lowest valued attribute of restoration. However, areas of cultural significance exhibited the second highest value per acre due to a smaller spatial representation.

Figure 2. Map layers representing each benefit value used in spatial analysis. (a) Area designated as critical habitat is valued at $57 per acre. (b) Land that is vital to quality of surface water resources is valued at $17 per acre. (c) Land prone to forest closures due to wildland fire risk is valued at $11 per acre. (d) Area considered culturally significant is valued at $18 per acre. (e) Area contributing to aquifer recharge is valued at $1 per acre.

Map layers were created using the North American 1983 Datum, GCS North American 1983, Transverse Mercator projection, and NAD 1983 State Plane Arizona Central FIPS 0202 coordinate system.
valued at $17 per acre. (c) Land that is prone to forest closures due to wildland fire risk is valued at $11 per acre. (d) Area considered culturally significant is valued at $18 per acre. (e) Area contributing to aquifer recharge is valued at $1 per acre. Map layers were created using the North American 1983 Datum, GCS North American 1983, Transverse Mercator projection, and NAD 1983 State Plane Arizona Central FIPS 0202 coordinate system.

3.2. Spatial Overlay

The addition of all five benefit area map layers using the Map Algebra Spatial Analysis Raster Calculator resulted in a composite map identifying thirty-two benefit values throughout the Salt–Verde watershed (Figure 3). The mapped values are a sum of all the benefits present in that area. Values ranged from 0 USD/acre, where no benefits valued resulted from restoration to 104 USD/acre in areas where all five benefits were the result of restoration. Nearly 2M acres (8094 km²) (~23%) exhibited a 0 USD/acre benefit. Areas that were designated as having a 0 USD/acre benefit have no data present in the raster grid and were therefore represented on the map in white. Approximately 14,500 acres (59 km²) (~0.17%) were estimated to have a 104 USD/acre benefit value. Areas where values for all five attributes of restoration were present, were restricted to the reaches of the tributaries of the Salt River and were mapped in red to signify importance. Aggregating the benefit values produced an approximate total benefit of USD 222 million for restoration in the Salt–Verde watershed.

Figure 3. Benefit spatial overlay results with NAFF project locations plotted. Map layers were created using the North American 1983 Datum, GCS North American 1983, Transverse Mercator projection, and NAD 1983 State Plane Arizona Central FIPS 0202 coordinate system.
The Northern Arizona Forest Fund (NAFF), a collaborative effort between the National Forest Foundation and Salt River Project formed to collect and allocate private donations to fund restoration specifically in the Salt–Verde watershed, supported six restoration projects during the 2018 restoration year. Point data for the locations of restoration projects funded and implemented by the NAFF in 2018 were plotted on the benefit value map [4] (Figure 3). NAFF projects were implemented in areas with benefit values ranging from 18 USD/acre to 86 USD/acre. Twin Springs Thinning, Long Valley Meadow Restoration, and Black River Riparian Restoration projects were all estimated to have a per acre benefit value of USD 86. Sierra Anchas Erosion Control and Trail Restoration occurred in an area with an estimated 57 USD/acre value. Rosilda Springs Restoration exhibited a 29 USD/acre value and was relatively close to the Twin Springs site. Aspen Creek Thinning was estimated to have the lowest value at 18 USD/acre. None of the 2018 NAFF projects were in areas having the lowest benefit value (0 USD/acre) or the highest benefit value (104 USD/acre).

4. Discussion

Bagstad et al. [36] analyzed and compared seventeen different ecosystem service tools for widespread use, three of which are the most applicable to this study and are considered most effective in nonmarket valuation studies: SolVES, EcoAIM, and ESValue. SolVES is a GIS tool that also requires user-provided environmental data to assess, map, and quantify nonmarket values estimated for ecosystem services [37]. However, SolVES does not estimate monetary values, rather, the program provides a value index. EcoAIM and ESValue are proprietary tools for mapping stakeholder preferences for ecosystem services. EcoAIM calculates a weighted average of publicly available GIS layers relevant to the service of interest [36]. ESValue uses expert and literature-derived data to compare what can be produced with what participants want produced to evaluate the tradeoffs between natural resource management strategies. Both ESValue and EcoAIM are not easily accessible to the public and require contracting with tool developers. All three tools are not feasible for widespread use and require further development and/or resources.

Utilizing GIS to spatially analyze WTP offers a method for incorporating nonmarket values into the ecological restoration decision-making process [38]. Spatially displaying nonmarket benefits relates social values to the environment and contains practical implications for policy and decision making [37]. Economic nonmarket valuation studies are typically site-specific and need to undergo a value transfer to adapt the results to a new project site [24,28,39,40]. Although benefit transfers are a practical way to obtain nonmarket values where data are limited or do not exist, primary valuation results are preferred [41]. We utilized primary valuation estimates to eliminate the need for a benefit transfer calculation. Watershed, forest, and project managers can use the GIS methodology offered in this study to incorporate nonmarket values in a benefit–cost comparison of prospective restoration sites. The total nonmarket benefit value of the project can be derived by applying the project boundaries to the benefit map and calculating the total area of each estimated value contained within the boundary. Our aggregation assumes a constant marginal value of an attribute of restoration and therefore provides an average value of restoration across the benefit area. Incorporating benefit values allows decision makers to reach a benefit–cost ratio that more closely resembles the total economic value of a project leading to better-informed project prioritization. The analysis method requires basic GIS skills and utilizes data files that are available and accessible from open sources. It is the responsibility of the GIS user to select data that accurately portrays areas producing the valued benefit. Careful consideration of data quality will reduce output variability.

Our results have broader implications for large-scale ecological restoration projects. The Four Forest Restoration Initiative (4FRI) is a collaborative landscape-scale restoration effort committed to restoring forest resiliency and ecosystem function in ponderosa pine forests over 2.4 million acres (9713 km²) of the Coconino, Kaibab, Tonto, and Apache–Sitgreaves National Forests in Arizona [3]. Restoration implemented by 4FRI considers the benefits provided by projects to communities, the economy, ecosystems, and biodiversity [3].
Nonmarket values for the benefits of restoration estimated by Mueller et al. [21] pertained directly to ecological restoration included in the 4FRI project area. Utilizing the GIS method to spatially analyze the nonmarket valuation results offered by this study can inform 4FRI stakeholders of the nonmarket economic benefits of a healthy ecosystem valued by local communities.

The NAFF looks to maximize the benefits produced by their small-scale projects by selecting restoration sites in the Salt–Verde watershed adjacent to the 4FRI project areas [4]. In 2017, the NAFF invested USD 1,000,000 into seven small-scale restoration projects throughout the Salt–Verde River watershed [4]. Selecting areas with high nonmarket economic benefits will increase the overall benefits provided to stakeholders and downstream users and promote economic efficiency. The locations for the restoration projects funded by the NAFF in 2018 were extracted from a map published in the Northern Arizona Forest Fund—Year in Review in 2017 [4]. The benefit values for the project sites were derived by plotting the point data locations on the benefit value map. Three projects were plotted in areas that were estimated to have a nonmarket benefit value of 86 USD/acre, which falls on the higher end of the benefit value spectrum (0–104 USD/acre). Two of the project sites, Rosilda Springs and Aspen Creek, were in areas with relatively low per acre benefit values. The Aspen Creek Thinning project was estimated to have an 18 USD/acre benefit value (Figure 3). The Twin Springs and Aspen Creek projects both restored approximately 150 acres (0.6 km$^2$) and the Long Valley project, 80 acres (0.3 km$^2$). The estimated nonmarket benefit values produced by the projects were roughly USD 12,900, USD 2700, and USD 6880, respectively. Forest thinning methods tend to consume more of the budget than other restoration tactics. Although no project sites were plotted on stream reaches that offered the highest benefit, a reach of the Black River was designated as providing the highest benefit value (104 USD/acre). Our project nonmarket benefit estimates assumed a constant dollar/acre rate throughout the entire project area based on the placement of the point data. Applying a project boundary polygon to the composite benefit map would provide a more accurate estimate of the total nonmarket value of the project.

5. Conclusions

Consideration of the nonmarket dollar value of the benefits provided by restoration is essential during the planning phase to efficiently use limited resources for project implementation. Our method offers a way for decision makers to meaningfully incorporate nonmarket benefit values into the decision-making process. Previous restoration planning applications, such as SolVES or RAVES, overlook the interpretation and consideration of monetary nonmarket value estimates. We used GIS to aggregate the willingness-to-pay values estimated by a choice experiment throughout the study area. The per acre benefit values estimated by this study are directly transferable to all stakeholder-supported types of projects in the Salt–Verde watershed, such as the NAFF projects and some 4FRI project areas, without the requirement of a benefit transfer. Although data used in this study are specific to the Salt–Verde River watershed, the method is easily adapted to other site locations through the selection of site-appropriate data and requires only some knowledge of GIS operations. Our approach of using publicly available data makes the process more accessible to restoration planners than approaches requiring proprietary or private data. Consideration of nonmarket benefits during the decision-making process can lead to a more economically efficient implementation of restoration projects along with a justification to public and private donors for their contributions. A benefit value map can help support the “why here, why now” question that is often left unanswered by restoration managers.

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Data Availability Statement: Publicly available datasets were analyzed in this study. Critical habitat data can be found here: https://ecos.fws.gov/ecp/report/table/critical-habitat.html (accessed on 19 November 2018). Surface water data can be found here: https://www.fs.fed.us/ecosystemservices/FS_Efforts/GetF2FData/index.php (accessed on 30 November 2018) with precipitation data here: http://www.prism.oregonstate.edu/normals/ (accessed on 10 December 2018). Restricted access data can be found here: https://www.fs.fed.us/ecosystemservices/FS_Efforts/GetF2FData/index.php (accessed on 6 December 2018). Cultural significance data can be found here: https://geo.library.arizona.edu/ (accessed on 8 January 2019). Aquifer recharge data can be found here: https://viewer.nationalmap.gov/basic/ (accessed on 19 December 2018) and https://geo.library.arizona.edu/ (accessed on 19 December 2018).

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