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Estimating the value of watershed services following forest restoration

Julie M. Mueller,[1] Wes Swaffar,[2] Erik A. Nielsen,[2] Abraham E. Springer,[2]
and Sharon Masek Lopez[2]

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[1] Declining forest health, climate change, and development threaten the sustainability of water supplies in the western United States. While forest restoration may buffer threats to watershed services, funding shortfalls for landscape-scale restoration efforts limit management action. The hydrologic response and reduction in risk to watersheds following forest restoration treatments could create significant nonmarket benefits for downstream water users. Historic experimental watershed studies indicate a significant and positive response from forest thinning by a reallocation of water from evapotranspiration to surface-water yield. In this study, we estimate the willingness to pay (WTP) for improved watershed services for one group of downstream users, irrigators, following forest restoration activities. We find a positive and statistically significant WTP within our sample of $183.50 per household, at an aggregated benefit of more than $400,000 annually for 2181 irrigators. Our benefit estimate provides evidence that downstream irrigators may be willing to invest in landscape-scale forest restoration to maintain watershed services.

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1. Introduction

[2] Declining forest health, climate change, and development threaten the sustainability of water supplies in the western United States. While forest restoration may buffer threats to watershed services, funding shortfalls for landscape-scale restoration efforts limit management action. The hydrologic response and reduction in risk to watersheds following forest restoration treatments could create significant nonmarket benefits for downstream water users. Historic experimental watershed studies indicate a significant and positive response from forest thinning by a reallocation of water from evapotranspiration to surface-water yield. In this study, we estimate the willingness to pay (WTP) for improved watershed services for one group of downstream users, irrigators, following forest restoration activities.

[3] In his early observations of "the Arid Lands" of the western United States, *Powell* [1879] observed that sustainable human development would require careful management of scarce water resources. Water management in the arid western United States, which generally receives less than 50.8 cm of precipitation annually, would require a recognition of the importance of forested headwaters for effective water resource management. As increasing population demands and climate change threaten the sustainability of water supplies in the arid West, forest restoration plays an important role in buffering the mounting threats to water resources. Despite the need for forest restoration, funding shortfalls remain a significant barrier to implementation of restoration plans.

[4] Across the United States, National Forest lands cover an area in excess of 78,104,329 ha and play a critical role in capturing precipitation, enhancing groundwater recharge and supplying high-quality water for downstream uses [*Kimbell and Brown*, 2003]. National Forests contribute the largest source of drinking water for the contiguous United States [*Furniss et al*., 2010], totaling over 329 billion cubic meters annually [*Brown and Froemke*, 2009]. National Forest lands are particularly important in the arid western United States, providing 51% of water supplies in the 11 contiguous Western states [*Brown et al*., 2005].

[5] The quantity and quality of water resources from National Forests is highly dependent on forest conditions and land management. Previous land management practices, particularly fire suppression and exclusion, have altered the composition and structure of western forests, contributing to declines in forest health [*Kauffman*, 2004]. Consequently, an estimated 4,875,519 ha is classified as unnaturally dense conditions with excessive woody fuels [*Snider et al*., 2003]. Unnaturally, dense forest conditions restrict water availability by increasing rates of evapotranspiration [*Baker*, 2003]. Water resources are further threatened by the environmental phenomena associated with impaired forest health, such as wildfire and insect outbreak. Additionally, seasonal drought and climate change have significant impacts on the quality and quantity of water from National Forests [*Berry*, 2010].

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[1] The W.A. Franke College of Business, Northern Arizona University, Flagstaff, Arizona, USA.
[2] School of Earth Sciences and Environmental Sustainability, Northern Arizona University, Flagstaff, Arizona, USA.

Corresponding author: J. M. Mueller, The W.A. Franke College of Business, Northern Arizona University, P.O. Box 15066, Flagstaff, AZ 86001, USA. (Julie.Mueller@nau.edu)

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[6] Global climate change will have a profound impact on southwestern water resources, including reduced stream flow due to higher evapotranspiration rates and increases in the frequency and severity of drought conditions. Climate projections for western North America indicate temperature increases of 2°C–5°C by 2040 [*Intergovernmental Panel on Climate Change (IPCC)*, 2007] and precipitation decreases of up to 15% for the same period [*Routseenoja et al*., 2003]. *Leung et al*. [2004] suggest that climate change will significantly affect water resources in the western United States by the mid 21st century, with a 1°C temperature increase expected to decrease stream flows in the southwestern United States by approximately 14% [*Christensen et al*., 2004]. Climate projections also forecast an increase in the variability of extreme weather events, including drought. Not surprisingly, Arizona has experienced varying levels of drought since 1996, with some of the worst since the late 19th century [*Sheppard et al*., 2002].

[7] Increased incidences of drought and consequent declines in water availability will have significant impacts on high water-use sectors. Irrigation accounts for the largest use of surface water nationally and claims more than 70% of total water use in Arizona [*Colby*, 2007]. Climate change could cause a reduction of the number of farmed acres in Arizona by 4%–20% [*Owen*, 2009]. Improving the condition of the forested watersheds that supply surface water for irrigated agriculture may enhance water supplies and buffer the projected losses caused by climate change.

[8] Previous forest management practices have caused widespread declines in forest health, predisposing them to uncharacteristically severe wildfires [*Kauffman*, 2004]. Severe wildfire can negatively impact water resources by burning vegetation, and exacerbating erosion and sedimentation. Erosion and sedimentation result in decreased water quality and significant potential damage to water-delivery infrastructure. For example, sediment and silt removal costs following wildfire in one of Denver, Colorado's municipal watersheds, amounted to $40 million [*Stanton and Zwick*, 2010]. Trends indicate an increase in the severity and frequency of large wildfires in the western United States since the 1980s [*Westerling et al*., 2006], particularly in southwestern Ponderosa pine (*Pinus ponderosa*) forests. An average of 179,397 ha burned annually between the years of 1993 and 2001 in Arizona and New Mexico [*Snider et al*., 2003].

[9] Ecological restoration can play a pivotal role in restoring ecosystem health and mitigating catastrophic wildfire potential [*Allen et al*., 2002]. The Four Forest Restoration Initiative (4FRI) seeks to restore more than 970,000 ha of Ponderosa pine (*P. ponderosa)* forests across four National Forests in Arizona. Ecological restoration generally involves a combination of mechanical thinning and prescribed burning to restore forests to within their "historic range of variability" [*Mast*, 2003; *Wu et al*., 2011]. Restored forests maintain a more resilient structure that encourages natural surface fire regimes, discourages tree seedling recruitment, overstocking, and the consequent threat of stand-replacing wildfire [*Mast*, 2003]. After treatment areas are initially thinned, maintaining this forest condition requires follow-up management, such as frequent burning, as well as restoration monitoring.

[10] Without large-scale intervention, fire suppression and rehabilitation costs will continue to grow, impeding the ability to maintain and restore forest conditions into the future [*Covington*, 2000; *Snider et al.*, 2006]. Costs, however, remain a significant barrier to restoration. Including overhead, average restoration costs are $2000/ha, totaling billions of dollars at the landscape scale [*Holl and Howarth*, 2000; *Wu et al*. 2011]. Although commercial utilization of restoration by-products may offset initial costs, funding remains uncertain for maintenance restoration activities and restoration monitoring. Despite high restoration costs and the scale of the challenge, numerous economic analyses confirm that it is more cost-effective to restore forests than to pay the costs associated with severe wildfire [*Wu et al*., 2011; *Daugherty and Snider*, 2003; *Berry*, 2010]. In this study, we investigate potential economic benefits that may assist policy makers in offsetting cost barriers. We hypothesize that irrigators will be willing to pay (WTP) a positive dollar amount to contribute to watershed restoration. Furthermore, we hypothesize WTP to be a function of the respondent's attitudes about the importance of current water issues, understanding of the impacts of forest restoration on watershed services, current costs for irrigation, and ability to pay for restoration.

2. Benefits

[11] Forest restoration through the 4FRI will include treatments in three major watersheds: the Salt, Verde, and Little Colorado River watersheds (see Figure 1). Hydrologic responses including enhanced water yield, enhanced snowpack retention, and reduced risk of catastrophic

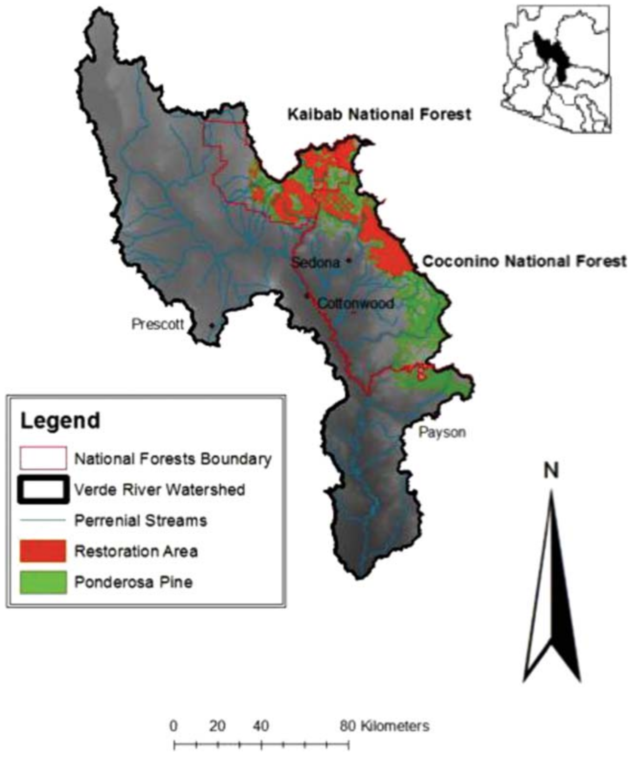

Figure 1. Forest restoration in the Verde River watershed in Arizona.

wildfire and associated flooding are expected within the 4FRI watersheds following restoration treatments. Extensive research has shown that alterations in forest vegetation can have demonstrable changes in stream flow quantity and quality [*Baker*, 1986, 2003]. In a recent systematic review, it was determined from historic experimental watershed studies that when 20%–100% of a conifer-dominated watershed was treated, there was a 10%–40% increase in water yield. Results are highly variable, and diminish within 5–10 years for surface-water yield increases without continued fire or mechanical vegetation management. Increased water yields are primarily attributed to decreased canopy interception and evapotranspiration, up to a 17% decrease for a ponderosa pine stand [*Dore et al*., 2012]. The decreases in water loss to interception and transpiration occur as increased overland flow and ultimately streamflow [*Baker*, 2003].

[12] Volumes of increased water yield by forest thinning in the Verde River watershed were estimated by the U.S. Bureau of Reclamation as part of the Central Yavapai Highlands Water Resources Management Study [*U.S. Bureau of Reclamation*, 2011]. The estimates were based on the observed responses of the Beaver Creek Experimental Watershed to historic forest thinning [*Baker*, 1986]. It is estimated that between 4.5×10^6 and 6.0×10^6 m^3/yr of water could be generated by reductions in forest basal area at an annual cost of between \$1.05 and \$2.20 per m^3 of water.

[13] Snowpack accumulations in high-elevation forested watersheds provide an important source of water, particularly in the southwestern United States. The distribution and accumulation of snowpack is largely determined by the density and spatial arrangement of forest overstory [*Ffolliot et al*., 1972]. Forests with a dense overstory canopy intercept a higher percentage of snow, thus exposing snow to losses from evaporation and sublimation [*Baker*, 2003]. Forests with lower tree densities, such as restored forests, have a greater capacity to accumulate and retain winter snowpack. Increased snowpack accumulation and retention will prolong spring snowmelt and enhance groundwater recharge of regional aquifers [*Baker and Ffolliot*, 2003]. The regional aquifers provide perennial baseflow to the Verde River and some of its tributaries (see Figure 1). Enhanced watershed services may serve as an important buffer to watershed health and water supply under increasing demand and uncertain environmental conditions. Taken together, enhanced water yield, enhanced snowpack retention, and decreased risk of catastrophic wildfire will result in significant benefits or "watershed services" for downstream water users.

3. Study Purpose

[14] We estimate the WTP for irrigators in the Verde River watershed for projected increases in watershed services following landscape-scale forest restoration using the dichotomous-choice contingent valuation (CV) method. The study was conducted in the Verde River watershed of northern Arizona (see Figure 1). The study area was chosen because the 4FRI landscape-scale restoration initiative plans to restore approximately 121,400 ha in the Verde River watershed. The Verde River is representative of watersheds in the western United States in which upstream forests are vital for capturing and delivering reliable, high-quality water supplies. Surface water diverted from the main stem of the Verde River through a ditch system supplies property owners who have irrigable land and water rights with water for irrigation. Further downstream, water uses include hydropower, municipal supply to the greater Phoenix area, and recreation. Downstream users are likely to have positive values for improved watershed services. Our study, however, focuses on actual irrigators within the Verde Valley.

4. Methods

[15] The CV method was applied to estimate the values of watershed services. The CV method is a stated preference method of nonmarket valuation where respondents are asked to state their preferences for an environmental good or service that is not bought and sold in traditional markets. Many CV studies, including the one presented here, apply the dichotomous-choice elicitation format as recommended by *Carson et al*. [2003]. The dichotomous-choice CV method involves sampling a large number of respondents and asking if they would vote in favor of a referenda and pay a particular randomly assigned dollar amount.

[16] Similar studies using CV have estimated values of nonmarket water-related ecosystem services. See *Brouwer et al*. [1999] for a meta-analysis of wetland CV studies. *Loomis* [1996] used CV to find a WTP of \$73 annually among Washington residents for dam removal and restoration of ecosystem services and the associated fishery on the Elwha River. *Pattanayak and Kramer* [2001] used CV to estimate drought mitigation services provided by tropical forested watersheds in Ruteng Park, Indonesia. *Loomis et al*. [2000] used CV to estimate the value of five water-related ecosystem services on the Platte River in Colorado and found a WTP of \$252 annually per household.

[17] Our study contributes to the current body of research on the benefits of watershed services in several ways. First, while previous CV studies have estimated the WTP for various water-related ecosystem services, no known studies have estimated the nonmarket value of additional water-related ecosystem services following a change in vegetation management, such as forest restoration. In addition, our study investigates the WTP for a specific group of downstream water users-irrigators in the arid Southwest.

[18] Finally, we use less commonly applied Bayesian estimation to obtain WTP estimates. While dichotomous-choice CV studies are a significant part of the nonmarket valuation literature starting in the 1980s, the first estimates using Bayesian methods do not appear until 2004 [*Yoo*, 2004; *Fernández et al*., 2004]. We follow the Bayesian estimation method outlined in *Yoo* [2004]. For our study, WTP is obtained through a nonlinear function of parameter estimates postregression. While a point estimate of WTP is easily obtained through the estimated coefficients in commonly estimated maximum likelihood models, maximum likelihood methods require additional simulation postestimation to obtain a distribution of WTP. Bayesian methodology is particularly useful for WTP because it provides a distribution of parameter estimates postestimation without any additional simulation.

4.1. Sample Selection

[19] A sample was selected from surface-water users (ditch associations) within Yavapai County, Arizona. All of the ditches were within the Verde River basin. Thirteen ditch associations divert water from the Verde River and its tributaries around the incorporated towns of Camp Verde, AZ and Cottonwood, AZ. Of the 13 ditches, four were selected based on the number of users they serve and their engagement with previous research studies. Most of the ditches are on the tributaries of the Verde River. The variability in size of user within ditches is similar. Once the sample was selected, addresses were obtained from the Yavapai County Assesor’s office of properties that border the four sampled ditches.

4.2. Focus Group and Survey Design

[20] A focus group was held with the leaders of the four sampled ditch associations to test and validate the survey instrument. A draft of the survey was distributed and completed by the informants, and their recommendations were used to guide the survey design and development. After discussing the survey instrument, support in encouraging their ditch users to complete and return the survey was requested.

[21] Data were obtained from a dichotomous-choice CV survey of sampled irrigators. The survey was designed using the Dillman Tailored Design Method [*Dillman*, 2007]. Water users were sent a signed cover letter, colored survey booklet, and a return envelope. A reminder postcard was sent, and nonrespondents received a second mailing of the survey booklet. We also sent a reminder postcard to nonrespondents for the second mailing.

[22] Because obtaining accurate estimates requires detailed descriptions of the resources being valued and the contingencies in question [*Loomis et al.*, 2000], the first section of the survey included a watershed map and diagrams of three different watershed condition scenarios (see Figure 2). Diagrams displayed three watershed conditions: “current watershed condition,” “restored watershed condition,” and “watershed condition following wildfire” with a text description of the hydrologic responses associated with each watershed condition. Respondents were not given specific changes in water yield in the survey booklet. However, we were able to approximate changes in water yields in a meta-analysis following the survey. For the “current condition,” we estimate a continuing gradual diminishment of surface-water yield, which likely has diminished as much as 26% since the forest density of pre-settlement, prior to 1860 [*Covington and Moore*, 1994]. We estimate between 4.5×10^6 and 6.0×10^6 m^3/yr of increase in water yield for the “restored condition”. Under restored conditions, it is anticipated that high-severity or “catastrophic” fire will be reduced and low-severity fire behavior will be restored [*Fulé et al.*, 2012]. The hydrologic response to the “condition following wildfire” is an area requiring extensive further research to quantify because of the uniqueness and randomness of each fire and the climatic conditions following fires. However, we qualitatively represented this wildfire watershed condition as a situation where average and peak streamflows will increase [*Debano et al.*, 1996], water yields are likely to become more irregular in timing [*Baker*, 2003], there would be increased risk of downstream flooding [*McCord*, 1996], increased erosion and sedimentation [*Debano et al.*, 1996], and decreased water quality [*Debano et al.*, 1996].

[23] Following the watershed condition diagrams were attitudinal questions about forest restoration, water supply, and the WTP question. The final section of the survey included demographic questions and solicited respondent’s comments.

[24] The WTP question read as follows:

[25] “Suppose you were asked to vote on a referenda suggesting water user contributions for maintaining watershed restoration. If the referenda were passed, water users would be charged an annual fee. By law all fees collected would be spent on forest restoration activities that would improve watershed services. If the water user contribution program were to cost you $ X annually, would you vote in favor of the referenda”,

where “X” equals a random bid amount inserted into surveys. Bid amounts ranged from $10 to $1000, weighted with higher frequencies from $10 to $100 and lesser frequencies from $100 to $1000. Bid amounts were selected based on average annual irrigation district fees indicated by

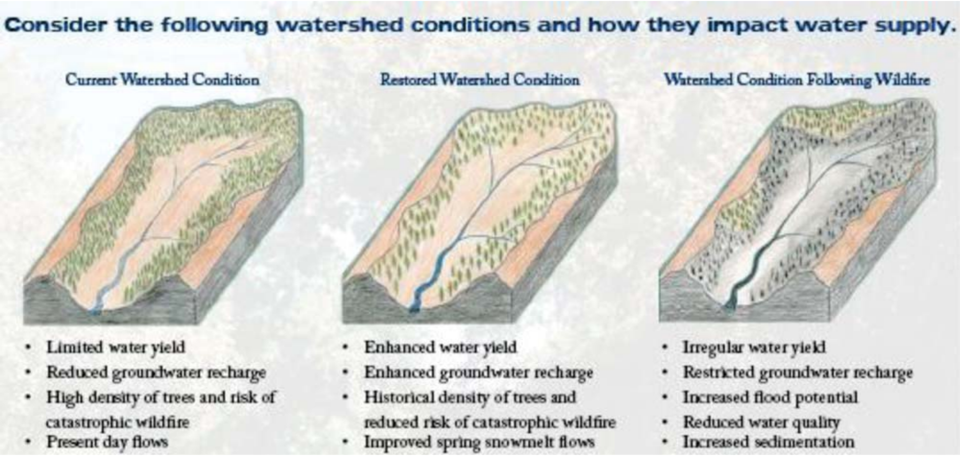

Figure 2. Diagram of three different watershed conditions that was included in the survey booklet.

Table 1. Bid Distribution

Bid Amount	Frequency
\$10	87
\$20	90
\$30	90
\$50	90
\$60	90
\$70	90
\$90	90
\$100	90
\$120	70
\$150	70
\$200	70
\$240	50
\$300	50
\$350	20
\$400	20
\$450	20
\$500	20
\$600	20
\$1000	10
Total	1137

informants during the focus group session. Table 1 shows the frequency and distribution of bid amounts for the entire sample.

4.3. Respondent Certainty

[26] After the WTP question, respondents were asked to rank their certainty of their response on a scale of 1–10, where 1 is "not at all certain" and 10 is "completely certain." A large body of research exists on reducing hypothetical bias by using certainty responses [*Champ and Bishop*, 2000]. Hypothetical bias occurs when responses to hypothetical CV questions do not elicit true values. That is, hypothetical bias occurs when respondents answer a hypothetical question in a way that is inconsistent with their actual behavior. While respondent uncertainty results in hypothetical bias, little theoretical guidance exists in explaining why respondents are uncertain [*Akter et al.*, 2009]. To investigate hypothetical bias, *Champ and Bishop* [2000] performed a split sample experiment where some respondents were asked their WTP to invest in wind energy for 1 year, while others were offered a hypothetical opportunity. *Champ and Bishop* [2000] found evidence of hypothetical bias—the WTP of the respondents with the hypothetical opportunity was higher than those with the actual investment opportunity. However, when respondents who were less certain of their answer to the hypothetical WTP question were coded as voting "no," the hypothetical bias was eliminated. Therefore, we choose to follow the approach suggested in *Champ and Bishop* [2000].

4.4. Method of Estimation

[27] We estimate the WTP function with a standard probit model using Bayesian techniques. Following *Cameron and James* [1987], the standard probit model is based on the assumption of an underlying WTP function

$$\mathrm{WTP}_i = x_i'\beta + \mu_i, \tag{1}$$

where x_i is a vector of explanatory variables, β is a vector of estimated coefficients, and μ_i is a random error term. The WTP function is not observable to the researcher, yet latent WTP is represented by the respondents′ "vote" on the WTP question. Let y_i represents the respondent's vote, =1 if "yes" and 0 if "no." Assume μ_i are independent and normally distributed with a mean 0 and standard deviation σ, and Bid_i is the randomly assigned bid amount for each respondent i. The probability of a "yes" vote, given the explanatory variables and random error is equal to the probability that the individual's unobserved WTP is greater than the bid amount. Therefore,

$$\begin{aligned}\Pr(y_i = 1|x_i) &= \Pr[\mathrm{WTP}_{\mathrm{i}} > \mathrm{Bid}_{\mathrm{i}}],\\ &= \Pr\left[x_i'\beta + \mu_i > \mathrm{Bid}_{\mathrm{i}}\right],\\ &= \Pr\left[\mu_i > \mathrm{Bid}_{\mathrm{i}} - x_i'\beta\right],\\ &= \Pr\left[z_i > \mathrm{Bid}_{\mathrm{i}} - x_i'\beta/\sigma\right],\end{aligned} \tag{2}$$

where z_i is the standard normal random variable and σ is a variance parameter. The standard probit model with n observations thus has the likelihood function:

$$\begin{aligned}\log L = \textstyle\sum_{i=1}^{n} \Bigg\{ &\mathrm{WTP}_i \log\left[1 - \Phi\left(\frac{\mathrm{Bid}_i - x_i'\beta}{\sigma}\right)\right]\\ &+ \Big[1 - \mathrm{WTP}\Big]_i \log\left[\Phi\left(\frac{\mathrm{Bid}_i - x_i'\beta}{\sigma}\right)\right]\Bigg\}.\end{aligned} \tag{3}$$

[28] We estimate the probit model using Bayesian estimation and Gibbs sampling [*Gelfland et al.*, 1990]. Let WTP represent a latent variable on n observations. WTP for an individual is then a function of the explanatory variables, x_i, and the other parameters of interest β and σ. β_0 and s_0 are the initial values of the parameters of interest, N denotes the normal distribution, and IG denotes the inverse gamma distribution. Thus,

$$\mathrm{WTP}_i \sim N\left[X_i'\beta, \sigma^2\right], \tag{4}$$

and β and σ are independent with

$$\beta|\sigma^2 \sim N\left[\beta_0, \sigma^2 B_0^{-1}\right], \tag{5}$$

and

$$\sigma^2 \sim \mathrm{IG}\left[\frac{\gamma_0}{2}, \frac{\gamma_0 s_0^2}{2}\right]. \tag{6}$$

The Gibbs sampler works using Markov chain Monte Carlo (MCMC) simulation. The Gibbs sampler starts with initial values (in our case, the initial values are set = 0) and draws β and σ through 20,000 simulations. We drop the initial 19,000 draws. The draws are dropped for "burn-in," since we use noninformative priors for the distributions on ourestimated parameters. Thus, we focus on the later iterations of the Gibbs sampler for our vector to estimate WTP. We use the final 1000 draws in our analysis. Unlike traditional Maximum Likelihood estimation techniques, because we use MCMC methods to estimate WTP, we don't have to use additional simulation procedures to estimate WTP from the regression coefficients. Therefore, WTP draws are a product of our estimation.

5. Results

5.1. Response Rate

[29] Of the mailings sent to 1137 households, 99 surveys were undeliverable. Three hundred and thirty-five respondents returned their surveys for a response rate of 32%. This represents a significant response rate given the contentious nature of water issues in the arid southwest. In *Loomis et al.*'s [2000] study, a response rate ranging from 25.7% to 41% was reported, depending on whether or not all responses were recorded. *Loomis*'s [1996] study of WTP for dam removal recorded a higher response rate: 77% for Clallam County residents, 68% for Washington State residents, and 55% for U.S. residents.

5.2. Respondent Attitudes Toward Forest Restoration

[30] Respondents were asked questions about their awareness of the restoration initiative in the Verde River watershed and how it may impact their water supply. Seventy-eight percent of respondents indicated that they were not aware of 4FRI before receiving our survey. Approximately 86% of respondents chose "yes" when asked if they believe that forest restoration will have a positive impact on their water supply. These results indicate that, while most respondents were not aware of proposed restoration plans, most believed that restoration would result in additional watershed services.

[31] Respondents were also asked to rank the importance of water issues considering the full range of issues they face. On a scale of 1–5 where 1 is "not important," 2 is "slightly important," 3 is "moderately important," 4 is "very important," and 5 is "extremely important," the average was 4.6, indicating that water issues remain a pertinent issue to our respondents.

[32] Respondents were asked to rank their concern for the following threats to their water supply on a scale of 1–5, where 1 is "not at all concerned," 2 is "slightly concerned," 3 is "moderately concerned," 4 is "very concerned," and 5 is "extremely concerned":

(1) Catastrophic wildfire
(2) Overallocation of water
(3) Drought
(4) Global climate change

Summary statistics are reported in Table 2. Our data show respondents are less concerned about climate change than they are about overallocation of water and drought; however, the mean for climate change is 3.02, indicating that respondents are, on average, "slightly concerned" about climate change. While wildfire was expected to be a threat of particularly high concern, respondents were, on average, less concerned about wildfire than they were for overallocation of water and drought. However, it is important to note that our sample consisted of irrigators who have rights to use the water.

Table 2. Summary Statistics for Attitudinal Variables

Variable Name	Mean	Standard Deviation	Minimum	Maximum
Wildfire risk	4.06	1.0389	1	5
Overallocation of water	4.25	0.9754	1	5
Drought	4.23	1.0348	1	5
Global climate change	3.36	1.4663	1	5

5.3. Respondent Certainty

[33] Following the approach suggested by *Champ and Bishop* [2000], we present results with WTP responses recoded as "no" for those with certainty levels less than 8. Average respondent certainty was 8.2 (see Figure 3).

5.4. WTP Estimates

[34] WTP is obtained using the parameter estimates from the probit. Following *Hanemann* [1984], WTP from a standard probit is

$$\frac{-\alpha}{\hat{\beta}_{\text{Bid}}},$$

where

$$\alpha = \hat{\beta}_0 + \left(\hat{\beta}_1 \times \overline{X}_1\right) + \left(\hat{\beta}_2 \times \overline{X}_2\right) + \ldots + \left(\hat{\beta}_{K-1} \times \overline{X}_{K-1}\right)$$

for all the explanatory variables except for $\hat{\beta}_{\text{Bid}}$. We predict WTP as a function of the following explanatory variables:

[35] (1) *Awareness*: Is the respondent aware of 4FRI?

[36] (2) *Degree of Concern for Water Issues*: On a scale of 1–5 where 1 = not at all concerned and 5 = very concerned.

[37] (3) *Overallocation of Water*: On a scale of 1–5 where 1 = not at all concerned and 5 = very concerned.

[38] (4) *Drought*: On a scale of 1–5 where 1 = not at all concerned and 5 = very concerned.

[39] (5) *Irrigation Costs*: Reported annual irrigation costs (categorized).

[40] (6) *Annual Income*: Reported annual pretax household income (categorized).

[41] The probit results are reported in Table 3. The estimated coefficient on bid amount is negative and shows the Bayesian equivalent of statistical significance. The estimated coefficient on awareness is negative and not statistically significant. Although not significant, the estimated coefficient on awareness weakly indicates that respondents aware of 4FRI are less likely to vote "yes." The estimated coefficient on positive restoration impact is positive and statistically significant, indicating that respondents who believe that forest restoration will have a positive impact on watershed services are more likely to vote "yes."

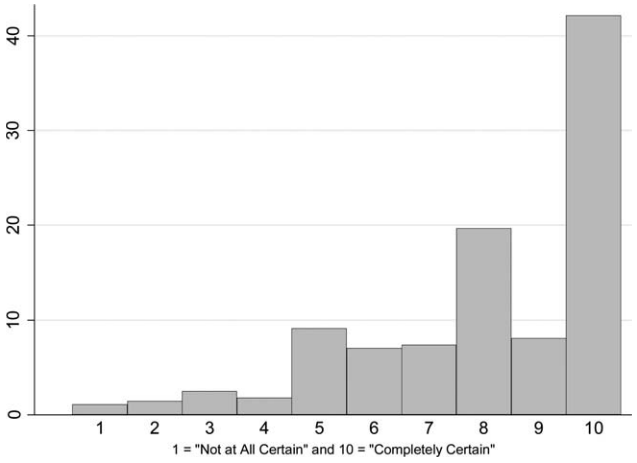

Figure 3. Respondent certainty for WTP question.

Table 3. Bayesian Probit Model Results

Variable	Coefficient	Standard Deviation	*P* Level	Means
Constant[a]	−2.423036	0.927681	0.0030	
Bid[b]	−0.001508	0.000877	0.0380	
Awareness	−0.249727	0.296411	0.1970	0.2261
Positive restoration impact[b]	0.771327	0.491482	0.0500	0.9226
Overallocation of Water	0.042740	0.152011	0.3770	4.1400
Drought[a]	0.439531	0.160951	0.0030	4.1875
Irrigation costs[c]	−0.138822	0.068383	0.0200	5.5620
Annual Income[a]	0.132567	0.042268	0.0000	6.0290
			Mean WTP	$183.50

[a] indicates significance at the 10% level,
[b] at the 5% level, and
[c] at the 1% level.

Although not statistically significant, our results indicate that the more concerned a respondent is about overallocation of water, the more likely the respondent is to vote "yes." The more concerned respondents are about drought risk, the more likely they are to vote "yes" on the WTP question. The more the respondent currently pays in irrigation costs, the less likely they are to vote "yes." Respondents who report a higher income are more likely to vote "yes" on the WTP question.

[42] Using *Hanemann*'s [1984] formula, the mean WTP from the estimated coefficients is $183.50 annually. We also calculate the mean WTP and a 95% confidence interval using the draws from the Gibbs sampler. The entire distribution of the WTP estimates is shown (see Figure 4). The mean WTP from the draws is $197.69 with a 95% CI lower bound of $153.97 and upper bound of $241.39. In other words, we can be 95% confident that the true mean WTP is between $153.97 and $241.39. Our WTP estimates are significantly higher, without controlling for respondent uncertainty. When we estimate the model without certainty recoding, our mean WTP is $282.85. We thus choose to focus on our certainty-coded results as a conservative estimate of WTP for policy analysis.

6. Discussion and Policy Implications

[43] Our results have significant implications for demonstrating the value of improved additional watershed services following forest restoration for Verde River irrigators. Our sample consists of 1137 irrigators, and there are approximately 2181 irrigators in the Verde River watershed receiving potential benefits from 4FRI restoration. Using our average WTP estimate, if there are 2181 irrigators who would benefit from 4FRI, this represents an annual aggregate benefit of 2181 × $183.50 = $400,214. Using the lower bound and upper bounds of our WTP estimate, if there are 2181 irrigators who would benefit from 4FRI, this represents a lower bound aggregate benefit of 2181 × $155.97 = $355,823 and an upper bound aggregate benefit of 2181 × 241.39 = $526,484. The aggregate measures assume that nonrespondents hold the same WTP values as the average elicited in the sample. If we assume that the WTP we estimate only represents the mean WTP for 32% of our sample (our response rate) and that nonrespondents have a zero WTP, the aggregate benefit is 32% × 2181 × $183.50 = $120,068. The WTP estimated for irrigators would cover the cost of restoring approximately 161 ha/yr. Although this may represent a small area within the 4FRI, the irrigators represent only one potential group of beneficiaries from 4FRI restoration. In addition, 4FRI has a predicted budget shortfall of $4 million. Thus, potential contributions from irrigators could reduce the shortfall by as much as 10%.

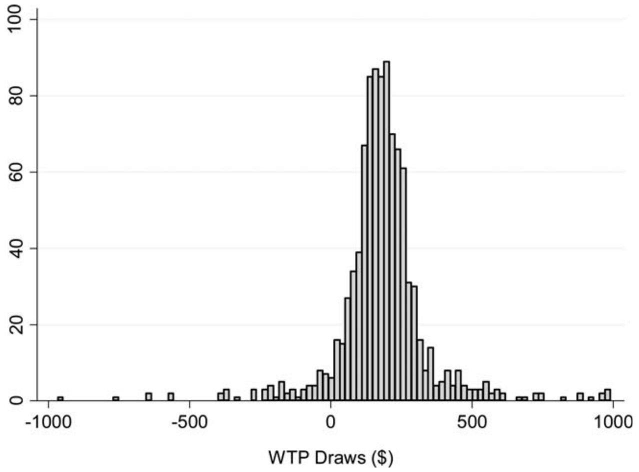

Figure 4. Distribution of WTP estimates.

[44] It is important to note that our irrigators were not provided with any exact estimate of changes in water yields due to the restoration. Respondents were asked their WTP to obtain the "restored watershed condition" and avoid the "watershed condition following catastrophic wildfire" as represented in Figure 2. In essence, their WTP represents their valuation of a bundle of watershed services, including the potential for higher yield and reduction of catastrophic wildfire risk. Given the volatility of climate and policy regulation in the arid Southwest, we believe it is reasonable that the irrigators were valuing a bundle of somewhat unpredictable services. If all of the increases in water yield from forest restoration were available to only the Verde River irrigators, the annual volume of water available could increase as much as 10% after restoration. Because of the inherent uncertainty involved in our bundled WTP estimates, we believe that our WTP represents a reasonable lower-bound WTP for this 10% in increased water yield for several reasons. One, even if additional water becomes available, there is no guarantee the irrigators would actually gain access to the water. Second, the availability of increased water suggests that watershed restoration has

occurred and increased water yield is paired with potential increases in water quality and reductions in wildfire risk. Thus, although our WTP estimates are not directly connected with the predicted outcomes of an exact hydrological model, we believe they are a robust estimate of potential net benefits of forested watershed restoration for irrigators within our population.

[45] Although somewhat geographically distant from upstream forested watersheds, our results indicate that downstream irrigators value upstream forests that capture and deliver water. While the WTP among irrigators may be significant, irrigation represents only half of total use of water from the Verde River. Water diverted to the greater Phoenix area from the Verde River averages approximately 93.1 million cubic meters (Y. Reinink, Salt River Project, personal communication) while irrigation in the study area accounts for only 41.8 million cubic meters annually [*Pool et al.*, 2011]. In the Verde irrigation region, all of the diversions are temporary earthen diversion dams in the channels. All of the diversions divert more than their necessary allocation to ensure adequate deliveries. Because of this, at the end of each ditch, as much as 60% of the diverted flow is returned to the river, thus much of the diverted flows are returned to the main stem Verde River. Capturing the aggregate value of additional watershed services from forest restoration among all beneficiaries would require estimation of WTP for other downstream user groups. It is likely that the value of the improved water services is positive for downstream user groups, such as municipal water, irrigation, industry, hydropower, and recreation and thus our benefits estimate represents only a small portion of the total potential benefits of watershed restoration.

[46] While wildfire was expected to be perceived as a major threat to water supply, wildfire was not a significantly greater concern to respondents than overallocation of water and drought. Although wildfire is considered by experts to be the greatest threat to watershed health throughout the region, drought and overallocation of water are prevailing concerns to irrigators. This may be due to the geographic distance between upstream forests and downstream water users.

[47] Estimating WTP of water users for water-related ecosystem services from forest restoration is important because the willingness of different water users to invest in watershed health may determine the future health of western forests and their ability to provide ample amounts of high-quality water. It must be noted that the values estimated in this study represent the views of one of several different water user groups. Future studies estimating the WTP for other water users, such as recreation, municipalities, and hydropower would contribute to the total demand for watershed services for different user types. The aggregate WTP of these other user groups, together with a robust forest products industry, may provide more than enough funding to completely offset landscape-scale restoration costs.

7. Conclusions

[48] In this study, we estimated the WTP of additional watershed services from landscape scale forest restoration. From our sample of 1137 irrigators, we found that the average annual WTP per household was $183.50 for an aggregate benefit of $400,000. We found that statistically significant predictors of WTP were respondents' awareness of forest restoration, degree of concern of water issues, overallocation, drought, annual water costs, and annual income. Our study provides evidence that downstream irrigators are willing to invest forested restoration of upstream watersheds that provide important watershed services. Policy makers and other stakeholders may be able to ensure the long-term financial sustainability of large-scale forest restoration and healthy watershed by capturing the nonmarket demand for improved watershed services.

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