

## Estimating willingness to pay for watershed restoration in Flagstaff, Arizona using dichotomous-choice contingent valuation

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Forest restoration reduces the probability of catastrophic wildfire and post-fire flooding; it therefore protects the quantity and quality of water in a restored watershed. The Four Forest Restoration Initiative (4FRI) is a landscape scale restoration initiative in Northern Arizona. 4FRI plans to restore the majority of the forested watersheds that provide the municipal water supply for the City of Flagstaff, Arizona (population 65 000). While start-up funding is available for 4FRI, funding sources for future monitoring and maintenance remain uncertain. One way to promote financial sustainability for the restoration initiative is to establish a payments system wherein Flagstaff residents pay for a portion of the costs. I present results from a contingent valuation survey estimating Flagstaff residents' willingness to pay for restoration of the Lake Mary and Upper Rio de Flag watersheds. I find the average household is willing to pay ~\$4.89 per month to contribute to forest restoration, resulting in potential annual monetary net benefits of up to \$1.3M. Thus, the results provide statistically significant evidence in favour of establishing a payments system. This survey focused solely on residents of Flagstaff, Arizona; however, the results are applicable in areas with similar ecosystems where forest restoration provides improved watershed services.

### Introduction

Ecological restoration can play a pivotal role in restoring forest health and mitigating catastrophic wildfire potential (Allen *et al.*, 2002). The Four Forest Restoration Initiative (4FRI) seeks to restore >970 000 hectares of Ponderosa pine forests across four National Forests in Arizona. Restored forests maintain a more resilient structure that encourages natural surface fire regimes, discourages tree seedling recruitment, overstocking and thus reduces 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 or restoration monitoring. Without large-scale intervention, fire suppression and rehabilitation costs will continue to grow, impeding the ability to maintain forest conditions into the future (Covington, 2000; Snider *et al.*, 2003). Costs, however, remain a significant barrier to restoration. 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 (Snider *et al.*, 2003; Berry, 2010; Wu *et al.*, 2011). Funding exists for the initial treatment for 4FRI; however, future funding for monitoring and maintenance is uncertain.

One potential way to mitigate the funding issues from 4FRI is to charge the beneficiaries of the restoration and use the payments to fund monitoring and maintenance. An essential step in devising potential payments is to estimate the potential non-market benefits of the 4FRI restoration. A large body of research exists

investigating the non-market values of catastrophic wildfire and the values of reduction in wildfire risk in high-risk areas. In addition, many researchers have estimated the non-market values of wildfires, wildfire risk and reduction. For example, Mueller *et al.* (2009) find that proximity to wildfires has a statistically significant decrease in sale price of homes using a hedonic property model. Donovan *et al.* (2007) also apply a hedonic property model to estimate the value of wildfire risk on home values. They compare house prices before and after information on wildfire risk is provided online for 35 000 homes in Colorado Springs, CO. Wildfire risk has a positive correlation with home value before the information is provided, however, afterwards there is no positive correlation. Contingent valuation (CV) methods have also been applied to estimate values of wildfire reduction (Loomis *et al.*, 2009), values for different treatment options including thinning and prescribed burning (Walker *et al.*, 2007) and prescribed fire (Kaval *et al.*, 2007). This study differs from previous because it focuses on estimating the benefits of forest restoration in a municipal watershed.

I estimate Willingness to Pay (WTP) for forest restoration in the Lake Mary and Upper Rio de Flag watersheds. The 4FRI landscape-scale restoration initiative plans to restore all of the ponderosa pine forests in the Lake Mary watershed and 11 500 acres in the Rio de Flag watershed. Both the Lake Mary and Upper Rio de Flag watersheds provide municipal water for residents of Flagstaff, Arizona. Thus, Flagstaff residents are key beneficiaries of the restoration through potential increases in the quantity and quality of their municipal water supply; Flagstaff residents will

also benefit from reduced catastrophic wildfire and consequent post-fire flood risk. This study contributes to the current body of research about the benefits of forest restoration in several ways. First, while previous studies have estimated the WTP for various types of forest restoration and wildfire risk reduction, few studies have estimated the WTP for additional water-related ecosystem services following a change in forest restoration. In addition, this study investigates residential water users' WTP in the arid Southwest, an area with a rich body of research into the science of forest restoration, yet lacking in studies estimating the non-market values of restoration. Finally, I use uncommonly applied Bayesian estimation techniques to obtain WTP.

## Methods

Non-market valuation involves estimating the value of an environmental good or service not commonly bought and sold in a market. Several non-market valuation techniques exist, and most have been applied in some manner to estimate values of forests (Riera *et al.*, 2012). The CV method is a stated preference method of non-market 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 respondents and asking whether they would vote in favour of a referenda and pay a particular randomly assigned dollar amount.

Similar studies have estimated values of non-market water-related ecosystem services using CV. 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. In addition, Mueller *et al.* (2013) find irrigators in the Verde Valley in Arizona are WTP ~\$183 per year for upstream forest restoration of the Verde watershed. While similar studies have estimated the value of water-related ecosystem services, few estimate the value of improvements in water resources following forest restoration for municipal water users.

While Maximum Likelihood estimation remains by far the most common method for estimating WTP from dichotomous-choice CV surveys, some studies have employed Bayesian estimation, including Yoo (2004), Li *et al.* (2009) and Mueller (2013). With classical Maximum Likelihood estimations of WTP, additional simulation using methods such as the Krinsky and Robb (1986) technique is required post-estimation to obtain a distribution of WTP. In contrast, the draws of WTP post-Bayesian estimation provide a distribution of WTP without any father simulation. I choose the Bayesian estimation because of its relative convenience in obtaining a distribution of WTP post-estimation.

## Data

### Sample selection, focus group and survey design

Addresses of survey respondents were obtained from the City of Flagstaff utility records. Addresses were chosen at random from the city records ensuring a spatially representative sample. A focus group was held with the Flagstaff Water Commission to test and validate the survey instrument. A draft of the survey was distributed at a monthly Water Commission meeting. Attendee's recommendations were used to guide the survey design.

Data were obtained from a dichotomous-choice CV survey of Flagstaff city residents. The survey was designed using the Dillman's Tailored Design Method (Dillman, 2007). A random sample of single-family residences was sent a signed cover letter, collared survey booklet and a return envelope. A reminder postcard was sent, and non-respondents received a second mailing of the survey booklet.

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 Figures 1 and 2). Diagrams displayed three watershed conditions: 'Current watershed condition', 'Restored Watershed Condition' and 'Watershed Condition Following Wildfire' and the hydrologic responses associated with each watershed condition. Following these diagrams were attitudinal questions about forest restoration, water supply and the WTP question. The last section included demographic questions and solicited respondent's comments. Please see the supplementary material for the full survey booklet.

The WTP question read as follows:

Suppose the City of Flagstaff is to propose a referendum requiring residential water users to pay a monthly fee on their water bill. By law, all funds would go directly to monitoring and maintaining the forest health of the Lake Mary and Upper Rio de Flag watersheds.

If the water user contribution program were to cost you an additional X \$ per month, would you vote in favor of the referenda?

where 'X' equals a random bid amount inserted into surveys. Bid amounts ranged from \$1 to \$20, weighted with higher frequencies from \$1–\$8 and lesser frequencies from \$9 to \$20. Bid amounts were selected based on suggestions from the focus group session.

## Methods

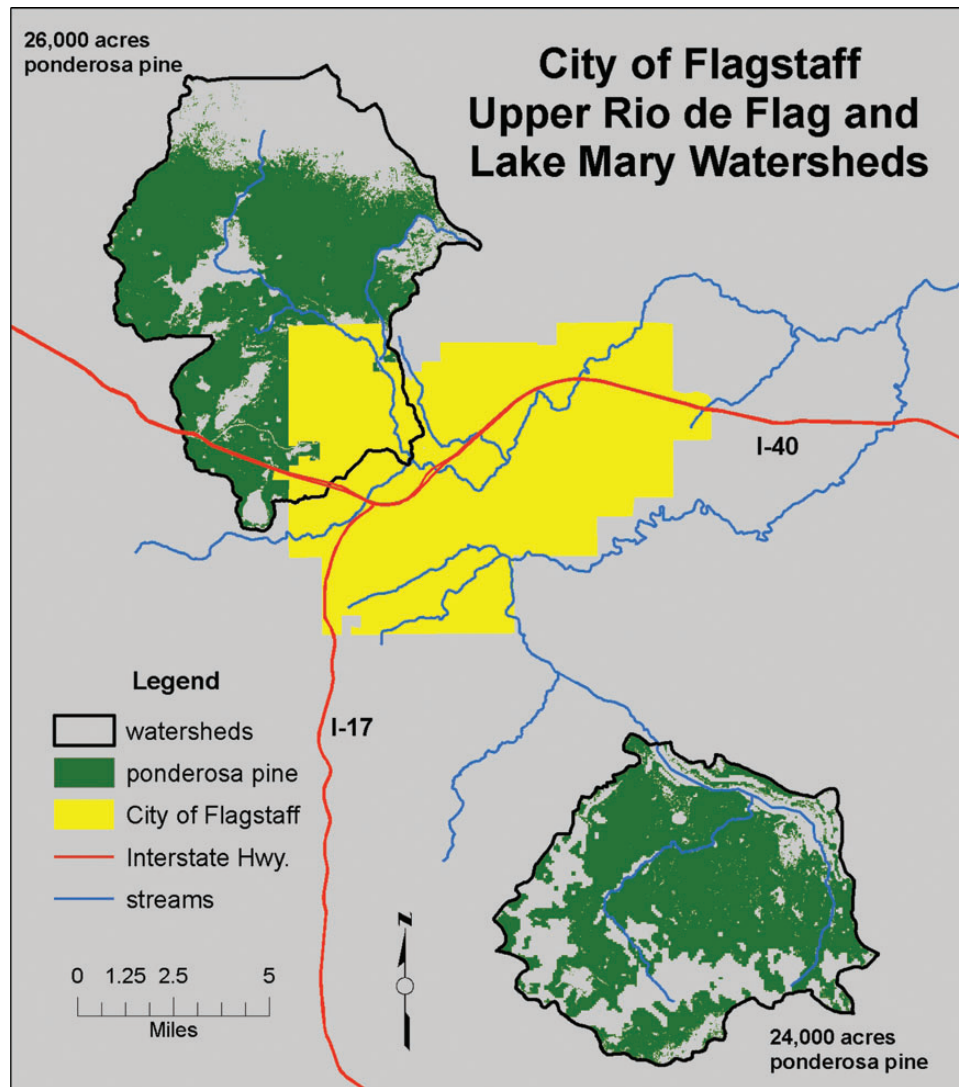
### Bayesian estimation

The WTP function is estimated 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:

$$WTP_i = x_i' \beta + \mu_i \quad (1)$$

where  $x_i'$  is a vector of explanatory variables,  $\beta$  is a vector of estimated coefficients and  $\mu_i$  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  $y_i$  represent the respondent's vote, i.e. 1 if 'yes' and 0 if 'no'. Assume  $\mu_i$  are independent and normally distributed with a mean 0 and standard deviation  $\sigma$ , 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,

$$\begin{aligned} \Pr(y_i = 1 | x_i) &= \Pr(WTP_i > Bid_i) \\ &= \Pr(x_i' \beta + \mu_i > Bid_i) \\ &= \Pr(\mu_i > Bid_i - x_i' \beta) \\ &= \Pr(z_i > (Bid_i - x_i' \beta) / \sigma) \end{aligned} \quad (2)$$



**Figure 1** Map of watershed.

where  $z_i$  is the standard normal random variable and  $\sigma$  is a variance parameter. I estimate the probit model using Bayesian estimation and Gibbs sampling (Gelfand *et al.*, 1990). I drop the initial 19 000 draws for burn-in. I use the remaining 1000 draws in the analysis. Unlike traditional Maximum Likelihood estimation techniques, because I use Markov Chain Monte Carlo methods to estimate WTP, I do not have to use additional simulation procedures to estimate WTP from the regression coefficients. WTP draws are a product of the estimation.

### Respondent certainty

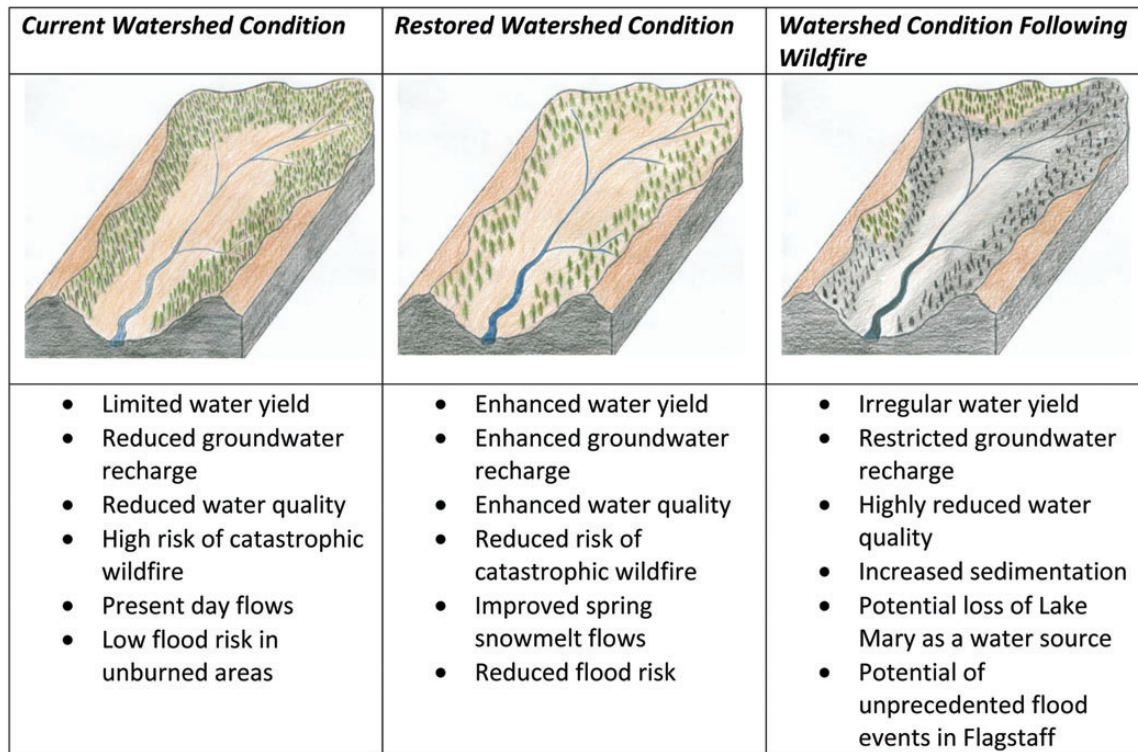
After the WTP question, respondents were asked to rank their certainty of their response on a scale of 1–10, where 1 is ‘Not at all certain’ and 10 is ‘Completely certain’. A large body of research exists on reducing hypothetical bias by using certainty responses (Champ and Bishop, 2001). Hypothetical 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 behaviour. 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 (2001) performed a split sample experiment where some respondents were asked their WTP to invest in wind energy for one year through an actual payments programme, whereas others were offered a hypothetical opportunity to invest. Champ and Bishop (2001) found evidence of hypothetical bias – the WTP of the respondents with the hypothetical opportunity was higher than those who were required to send a payment. 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, I choose to follow the approach suggested in Champ and Bishop (2001) and applied by Li *et al.* (2009).

## Results

### Response rate

A total of 490 surveys were mailed with 120 responses and 48 undeliverables, resulting in a response rate of 24 per cent. A 24 per cent response rate is similar to other CV studies using mail surveys. For example, Walker *et al.* (2007) have an average



**Figure 2** Watershed conditions diagram. (A) Current watershed condition; (B) restored watershed condition; (C) watershed condition following wildfire.

**Table 1** Summary statistics for attitudinal variables

Variable	Mean	SD	Min	Max
Wildfire	4.45	0.80	1	5
Drought	4.46	0.74	1	5
Flooding	3.23	1.16	1	5
Global Climate Change	3.55	1.34	1	5

overall response rate of ~30 per cent, and Mueller *et al.* (2013) report a response rate of 32 per cent.

**Respondent attitudes toward forest restoration**

Respondents were asked, ‘Prior to this survey, were you aware of the Four Forests Restoration Initiative?’ A total of 33 per cent of respondents were aware of the 4FRI initiative. I also asked respondents about their awareness of the link between forest restoration and watershed health. On a scale of 1–5, where 1 is ‘Not at All Aware’ and 5 is ‘Very Aware’, the mean value was 2.9. The results show that most respondents consider themselves at least ‘Somewhat Aware’ of the link between forest restoration and watershed health. The relatively low percentage of respondents aware of 4FRI provides potentially valuable information for policymakers considering public information campaigns.

Respondents were asked, ‘Considering the full range of issues you face, how important is watershed health to you? On a scale of 1 to 5, where 1 indicates “Not Important” and 5 indicates

“Extremely Important,” circle one’. The mean response was 3.97, indicating that watershed health is a high priority for respondents. Respondents were also asked, ‘Considering the full range of issues you face, how important is wildfire prevention to you? On a scale of 1 to 5, where 1 indicates “Not Important” and 5 indicates “Extremely Important,” circle one’. The mean response was 4.52, indicating that wildfire prevention has a relatively high priority within the sample.

Respondents were also asked to indicate how concerned they are about threats to the Lake Mary and Upper Rio de Flag Watersheds including:

- Catastrophic Wildfire
- Drought
- Flooding
- Global Climate Change

On a scale of 1–5, where 1 indicates ‘Not at All Concerned’ and 5 indicates ‘Extremely Concerned’, respondents are the most concerned about wildfire and drought. Table 1 shows the summary statistics for respondent concern about threats to the watersheds.

**Respondent demographics**

Fifty per cent of respondents consider themselves affiliated with the Democratic party. According to the AZ Secretary of State’s web statistics, as of April 2013, there were 71 248 registered voters in Coconino county, with 27 350 associated with the Democratic party (<http://www.azsos.gov/election/voterreg/2013-04-01.pdf>). Flagstaff, AZ, is known to have a higher percentage of democratic voters than any other municipality in Arizona. Therefore, the sample seems to be reasonable in terms of its representativeness

of political leanings. The average income within the sample is in the category \$60 000–\$79 999. According to the US Census Bureau, the median household income in 2011 dollars in Flagstaff, AZ, is 48 758, and the mean household income is 63,666 (<http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?Src=bkmk>). Thus, the population mean income falls within the same category as the sample mean income.

**Respondent certainty**

Respondents were asked, ‘On a scale of 1 to 10, with 1 being not at all certain and 10 being completely certain, how certain are you of your answer’ to the WTP question. Seventy per cent of respondents chose a Certainty level of 8 or above on their answer to the WTP question. I follow the approach outlined in [Champ and Bishop \(2001\)](#) discussed earlier and re-code responses with a certainty level of 7 or less as ‘No’ votes on the WTP question to reduce hypothetical bias.

**WTP estimates**

WTP is obtained using the parameter estimates from the probit. Following [Hanneman \(1984\)](#), WTP from a standard probit is as follows:

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

where

$$\alpha = \hat{\beta}_0 + (\hat{\beta}_1 \times \bar{X}_1) + (\hat{\beta}_2 \times \bar{X}_2) + \dots + (\hat{\beta}_{K-1} \times \bar{X}_{K-1})$$

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

- *Awareness of 4FRI*: whether or not the respondent was previously aware of the 4FRI initiative (0 = ‘No’, 1 = ‘Yes’)
- *Importance of Fire Prevention*: the relative importance of wildfire prevention (5 point Likert Scale)
- *Concern for Watershed Health*: relative concern for watershed health (5 point Likert Scale)
- *Threat of Wildfire*: concern for threat of catastrophic wildfire (5 point Likert Scale)
- *Threat of Drought*: concern for threat of drought (5 point Likert Scale)
- *Democrat*: whether the respondent is a Democrat (0 = ‘Republican or Other’, 1 = ‘Democrat’)
- *Income*: a categorical measure of respondent’s reported income (range 1–9).

Several of the attitudinal variables are highly correlated. To avoid multicollinearity, I drop *Watershed Health*, *Wildfire* and *Democrat* from the final model (See Table A1 in the supplementary material for an alternative specification.).

Regression results are reported in Table 2. The estimated coefficient on *Bid Amount* is negative and statistically significant, indicating that the higher the *Bid Amount*, the less likely the respondent is to vote ‘Yes’ on the WTP question. The estimated coefficient on *Awareness of 4FRI* is positive and statistically significant, indicating that if a respondent was previously aware of 4FRI, they are more likely to vote ‘Yes’ on the WTP question. The positive statistical

**Table 2** Bayesian probit regression results: independent variable: ‘vote’

Variable	Estimated coefficient	SD	P-level
Constant	−4.448542	1.416719	<0.0001
Bid Amount	−0.082327	0.047270	0.0370
Awareness of 4FRI	0.499746	0.333866	0.0590
Importance of Fire Prevention	0.356384	0.217535	0.0430
Threat of Drought	0.532668	0.265246	0.0270
Income	0.105354	0.070809	0.0650
Mean WTP			\$4.89

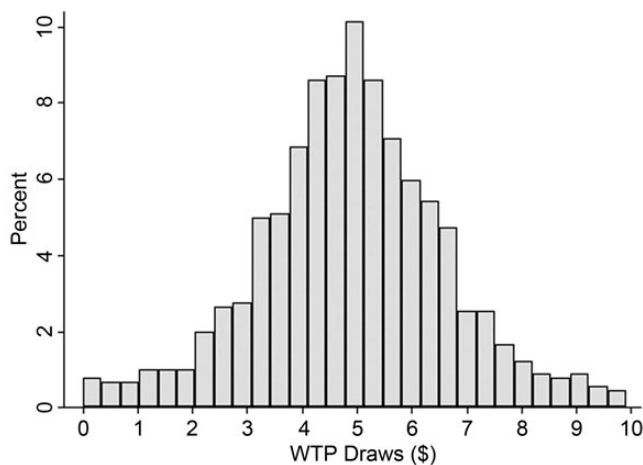
significance of the *Awareness of 4FRI* variable could have significant policy implications. The results show that respondents who are more aware are also more willing to provide financial support for the programme. As noted earlier, only 33 per cent of respondents said they were aware of the 4FRI initiative before the survey. Given the positive relationship between WTP and awareness, an information campaign could prove more effective at garnering financial and other types of public support.

The estimated coefficient on *Wildfire Prevention* is positive and statistically significant. This indicates that respondents with a high level of concern for wildfire prevention are more likely to vote ‘Yes’ on the WTP question. The estimated coefficient on *Threat of Drought* is also positive and statistically significant, showing that respondents who are relatively more concerned with drought are more likely to vote ‘Yes’ on the WTP question. The positive and statistically significant coefficients on *Wildfire Prevention* and *Threat of Drought* provide statistical evidence that respondents make the connection between forest restoration and the associated improvements in ecosystem services. Income also has a positive and statistically significant impact on WTP, showing the estimates are consistent with economic theory. All else constant, respondents with higher income are more likely to vote ‘Yes’ on the WTP question.

Based on the best statistical model, mean WTP is \$4.89 per month with a 95 per cent confidence interval of \$4.79–\$4.96. The draws from the WTP function post-Bayesian analysis are represented in Figure 3. In other words, the average respondent would be willing to pay an additional \$4.89 per month to support monitoring and maintenance of the Lake Mary and Upper Rio de Flag watersheds. Flagstaff has ~22 360 households (<http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?Src=bkmk>). If the sample accurately represents the average single-family household in Flagstaff, AZ, the average monthly benefit of watershed restoration for single-family household residents in Flagstaff is \$109 000 per month for an annual benefit of \$1.3M. More conservatively, suppose that I assume that the estimated WTP represents only 24 per cent of Flagstaff residents’ WTP for forest restoration, as obtained by the 24 per cent response rate. Even this conservative estimate represents monthly benefits of \$26 000 and annual benefits of \$315 000.

**Discussion and conclusions**

[Wunder \(2005\)](#), as cited by [Kemkes et al. \(2010\)](#), defined Payments for Ecosystem Services as ‘voluntary transactions where an



**Figure 3** Willingness to pay draws post-Bayesian estimation.

ecosystem service is bought by one or more buyers from one or more providers'. Forest restoration provides a bundle of potential ecosystem services as mentioned earlier, including the more direct benefits of potential increases in the quantity and quality of their municipal water supply and the other benefits of reduced catastrophic wildfire and post-fire flood risk. This research suggests that eliciting payments from the beneficiaries of maintaining and restoring an existing watershed in Flagstaff, AZ, may be a viable option for mitigating costs and promoting financial sustainability of the 4FRI.

Although the survey results provide evidence of a positive and statistically significant WTP for forest restoration, several areas of further research exist in this area. With additional funding, I would like to expand my sample to include multi-family residences and people living outside the municipality of Flagstaff, AZ. Downstream water users in other areas of northern Arizona will also benefit from the 4FRI restoration. Thus, the above-mentioned results provide what I believe is a conservative lower bound estimate of the benefits of forest restoration to the nearest population centre. The estimates provide policy-relevant evidence that the non-market benefits of forest restoration should be included in cost-benefit analyses, and including the non-market benefits may have significant impacts on the financial sustainability of proposed restoration programs.

Ecological restoration of forested watersheds is necessary to prevent catastrophic wildfire and maintain watershed health, especially in the ponderosa pine forests of Northern Arizona. The City of Flagstaff obtains its drinking water from the Lake Mary and Upper Rio de Flag watersheds. The 4FRI plans to restore the Lake Mary and Upper Rio de Flag watersheds; however, the funding source is uncertain. Forest maintenance provides benefits in terms of improved watershed health and residents of Flagstaff one of the largest groups of potential beneficiaries. I find an average sample WTP from of \$4.89 per month to fund monitoring and maintenance of the 4FRI restoration. The analysis shows a potential annual benefit of ~\$1.3M to Flagstaff residents for the 4FRI restoration. Thus, my results provide evidence that a potentially sustainable source for funding is through charging Flagstaff residents for forest restoration. Although this survey focused solely on residents of Flagstaff, AZ, the results are applicable to many areas in the Western and southwestern United States where

forested watersheds provide a bundle of ecosystem services, and restoration would reduce wildfire risk and improve watershed services.

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