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Pricing ecological services: Willingness to pay for drought mitigation from watershed protection in eastern Indonesia

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Abstract. In this study we estimate local economic values of ecological services provided by protected forest watersheds in Ruteng Park in eastern Indonesia. Our use of contingent valuation (CV) methodology for pricing drought mitigation benefits to local farmers extends previous work by deriving measures of willingness to pay in terms of incremental agricultural profits. On the basis of the theoretical and content validity of estimated models we find that CV can be used to value complex ecological services in a rural developing country setting. The estimated parameters provide policy and management information regarding the economic magnitude and spatial distribution of the value of drought mitigation.

1. Introduction

Rapid disappearance of the world's natural forest cover [*Food and Agricultural Organization* (*FAO*), 1997], despite the fact that standing tropical forests provide socially useful goods, suggests that society misallocates resources. Economists conjecture that this is partly because economic agents and policy makers receive distorted market signals and/or unreliable and incorrect information regarding the value of services from tropical forests [*Panayotou*, 1994]. Mitigation of drought conditions downstream from protected tropical forests is a good example of unpriced and undervalued service flow [*Barbier*, 1994]. *Dixon* [1997] provides a summary of other types of watershed (ecosystem) services provided by protected watersheds. In many tropical settings these services primarily contribute as inputs to agricultural production. However, the economic worth of protected watersheds is rarely quantified [*Georgiou et al*., 1997; *Dixon*, 1997]. In a recent survey of research trends in environmental and resource economics, *Deacon et al*. [1998] call for more rigorous empirical valuation of ecological assets in developing countries.

This paper takes a step toward filling this gap by applying the contingent valuation (CV) method to price ecological services provided by tropical forest watersheds of Ruteng Park, Indonesia. We modify CV methodology on two counts. First, willingness to pay (WTP) is modeled in terms of producer surplus measures in contrast to most environmental valuation that is derived from consumer welfare theory. Second, two models of behavior, perceptions and adjustment, are proposed to capture how households respond to the CV question. The study contributes empirical evidence to the debate over whether environmental quality is a luxury for rural households in developing countries [*Choe et al*., 1996]. Finally, this study also responds to a call by an Environmental Protection Agency's (EPA) Ecosystem Valuation Forum "... to identify and explore the real challenges of ecosystem valuation through practical case studies, for only through the crucible of real experience ... develop improved protocols for valuation studies" [*Bingham et al*., 1995, p. 89].

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2. Ruteng Park and the Valuation Framework

Although forests in the highest watersheds of the Manggarai region on the island of Flores had enjoyed some protection since the Dutch colonial rule, the government of Indonesia established Ruteng Park on 32,000 hectares in 1993. The primary conservation goal was to provide greater protection against deforestation threats and to initiate reforestation and land conservation that enhances watershed protection. A recent evaluation of water resources on the island of Flores finds that forests in Manggarai provide drought mitigation service by protecting streams and rivers [*Binnies and Partners*, 1994]. Three other studies support this finding. First, research by a local nongovernmental organization finds that during the previous 25-year period, streamflow has decreased in 9 out of 10 streams studied in regions of Manggarai that are experiencing deforestation [*Swiss Intercooperation*, 1996]. Second, analysis of cross-sectional variation in hydrological, topographic, and vegetation data from the 37 principal watersheds within Ruteng Park shows that [*Priyanto*, 1996, p. ix] "... reforestation has an important role to ... increase ground water replenishment and springs and river discharge during the dry period." Finally, the Manggarai people living around Ruteng Park agree that watershed protection is the primary benefit from the park because they perceive that forests protect their water supply [*Kramer et al*., 1997]. Thus, while there is substantial biophysical evidence of the drought mitigation services of Ruteng Park to the farmers downstream from the park, the economic values of this ecological service are unknown. Next we propose an adaptation of *Gregersen et al*.'s [1987] three-stage framework to estimate the economic value of this drought mitigation service.

In stage 1 the establishment of Ruteng Park produces a drought mitigation service, measured as the change in baseflow, W_1 less W_0. Baseflow is the nonepisodic residual streamflow that remains after rain leaves the hydrological system as either stormflow (runoff) or evapotranspiration. The forest hydrology literature posits that extensive tree cover maintains baseflow levels in areas with environmental characteristics similar to Ruteng, i.e., clayey and compacted soil, steep terrain, and intense rainfall [*Bruijnzeel*, 1990; *Bonell and Balek*, 1993]. The three forest hydrology studies in the Manggarai region, discussed previously, show that forests are net producers of baseflow. In stage 2, the primary economic role of baseflow is as a fixed input in agricultural production because agriculture is the predominant economic activity in the region and because the farmers who benefit from this service cannot choose levels of forest protection to generate drought mitigation. In this context, baseflow can be conceived as the part of the hydrological cycle that is useful in farming: moisture available to plants. Finally, in stage 3 the effect on agricultural production changes the economic welfare of agricultural households living around Ruteng Park. This change in welfare is a measure of the value of drought mitigation. Thus, by identifying the main production relations and economic tradeoffs and linking them to baseflow, as proposed by *Eckstein* [1958, pp. 39–40], the value of drought mitigation can be estimated as "willingness to pay" measured in terms of incremental profits resulting from the baseflow increase. Without judging their importance, all other nonecological services and goods and all costs that are related to Ruteng Park are outside the purview of this study.

Agricultural households can directly be questioned to elicit their WTP for the drought mitigation using CV surveys because the incremental profit is a compensating (or equivalent) variation measure [*Mäler et al.*, 1994]. In CV methodology, values are elicited by first describing a proposed (hypothetical) service and its market to the survey respondents and then asking them directly to state their WTP for the proposed service. Although the use of stated preference data makes this method controversial [*Portney*, 1994], there is growing evidence that if carefully implemented, it succeeds in uncovering nonmarket values even from rural households in developing countries [*Whittington*, 1998; *Carson*, 2000]. The link between WTP and profits provides the means to evaluate the validity of WTP estimates by testing the correlation between WTP and input and output prices and fixed inputs, variables that belong in a production model. Typical developing country applications have valued private and public dimensions of water quality and quantity [*Choe et al.*, 1996]. CV studies focusing on rural households' use and valuation of tropical forest are rare; *Shyamsundar and Kramer*'s [1996] application in Madagascar is among the first empirical studies in this context. More recent applications include studies by *Köhlin* [1998] and *Mekonen* [2000].

The primary reason that CV is relevant for this study is that few other valuation methods can comprehensively describe and approximate values for a complex ecosystem process. In addition, collection of valuation data through surveys allows us to simultaneously elicit beliefs and opinions that underlie preferences that determine values. The major complication with using CV is the burden on the survey designer to appropriately describe the ecological phenomena to farming households and to accurately elicit their values for the service without information and interviewer bias(es). Thus this application tests the range and scope of CV methodology by attempting to value a complex ecological service and by conducting the study in rural areas of a developing country where the culture is different from the setting of typical CV studies. As described in sections 3 and 4 the model specification must incorporate a combination of traditional production measures and household beliefs in an approach that is theoretically consistent and unique.

3. Model of Willingness to Pay for Drought Mitigation

A model of the stated WTP offers the opportunity to test a hypothesis using survey data, and therefore to validate the benefit measures based on the significance of estimated coefficients. Such validity is an important benchmark given the criticisms of the CV method. The model also allows us to identify determinants of demand for watershed protection and thus to identify management information and policy handles. Even though drought mitigation influences household well-being through production activities, we need a comprehensive household model that relates drought mitigation, profits, and utility of farming households because welfare (well-being) is characterized within a utility maximization framework. A detailed derivation of the model, which basically integrates two independently established strands of logic in the literature, is presented by *Pattanayak and Kramer* [2001]. The first set of studies show that environmental services that are production inputs can be valued using profits functions [*Freeman and Harrington*, 1990; *Point*, 1994]. The second set show that when markets are sufficiently complete, the implied separability of the production (profit) or consumption (expenditure) spheres of the household simplifies the analytical tasks for deriving welfare measures [*Thornton and Eakin*, 1992]. Therefore profit or quasi-expenditure functions can be used to value environmental services even for consumer-producer households [see, e.g., *Mäler et al.*, 1994]. Although the requirement that markets are complete may seem restrictive, statistical tests (reported by *Pattanayak and Kramer* [2001]) and descriptive evidence (discussed in section 4) clearly support the existence or smooth functioning of "more or less" complete markets. Here we present a qualitative description of the model of WTP.

Agricultural households maximize utility, which is assumed to depend on agricultural commodities (e.g., cereal) and inputs (e.g., leisure) and is conditioned by household characteristics. Utility maximization is subject to essentially two constraints. First, an agricultural production function assumes that baseflow W, which measures the background drought environment of the farm, is a fixed input. W is a weak complement to other production inputs or outputs because the demand for W is zero if there is no agricultural production. Biophysical and socioeconomic inputs also mediate the production technology. Second, the household's budget constraint ensures that expenditures are equal to the sum of the monetary equivalent of the household input endowment, agricultural profits π, and exogenous income. This sum is the "Beckerian" full income.

Figure 1 illustrates the valuation logic for a typical household that lives in the affected watersheds experiencing the drought mitigation service, or baseflow increase from W_0 to W_1. The associated increase in utility from baseline levels, $U_1 - U_0$, measures the change in household welfare attributable to a drought mitigation, and the WTP for drought mitigation is the exogenous income that can be taken away to leave the household at U_0. Because W affects utility only through the profit level and markets are perfect, $\pi_1 - \pi_0$ $(\Delta\pi)$ is a money metric of the welfare gains resulting from ΔW, other things being equal. The existence of perfect markets for key inputs and outputs (separability) is reflected by the separating hyperplane that ensures the equivalence of $\Delta\pi$ and WTP.

As illustrated in Figure 1, $\Delta\pi$ generated by drought control service measures compensating variation or WTP for this ecological service [*Mäler et al.*, 1994]. Therefore, in theory, WTP for drought mitigation can be measured by directly questioning the agricultural households by using the CV method. In practice, however, because this service is a proposal in a CV question, household stated willingness to pay WTP_S could diverge from $\Delta\pi$ for at least two reasons discussed below. *Laughland et al.* [1996] build a convincing case for the role of empirical work in analyzing divergences between theoretical and observable measures of WTP.

The first reason for the divergence is that household responses to the CV question depend on their perceptions of the service θW, which may not be equal to the proposed levels of the service ΔW. Using similar logic, *Choe et al.* [1996] reason that the difference between WTP from CV data and from travel cost data is partly because CV responses are based on perceived water quality, which is different from actual water quality (from travel cost data). A perceptions process posits that the perceived drought control service θW is reflected in the household response to the CV question. While θ is not independently identified, we contend that the WTP_S amount reflects households' combination of perceived value and perceived increase, i.e., perceived $d\pi$ multiplied by θW, they expect to receive. A second reason for the divergence between theoretical and stated WTP is that households consider the context within which this contingent service is provided and take into account other commodities and conditions, not just drought mitigation. An adjustment mechanism A by which households either discount or mark up their perceived profit increase $\Delta\pi_S(\theta)$ is similar to "nonuse" components of estimated WTP in many CV studies. In part, the adjustment is due to the public dimension of drought mitigation, given that joint private-public features are inherent to most contingent goods evaluated in CV studies [*Whittington*, 1998]. In this case the discounting could be, for example, because the farm households are not familiar with drought mitigating options or local forest hydrology conditions. Similarly, an example of a reason for a markup is the public good nature of an ecological service that benefits the entire community. Thus households adjust their WTP_S by A depending on the environmental conditions R and demographic attributes and opinions H.

In (1) we propose a linear adjustment as a first approximation of a general WTP_S function using the notation described previously and P as a vector of input and output prices that affect profitability π.

$$\begin{aligned}\mathrm{WTP}_S &= \Delta\pi_S[P, Z, \theta W] + A(R, H)\\ &= \mathrm{WTP}_S[P, Z, \theta W, R, H].\end{aligned} \tag{1}$$

Thus a household would be willing to pay no more than $\Delta\pi_S(\theta) + A$ for this service. *Whittington* [1998] cautions against the cavalier use and interpretation of stated preference values that are not bounded by respondents' ability to pay since disposable incomes are typically low in developing countries. By virtue of its derivation from and dependence on agricultural profits, the WTP_S measure in (1) reflects "ability" to pay not just "willingness" to pay.

We assume a flexible-form quadratic profit function to specify our estimating equation, and the resulting specific WTP_S is reported in (2). See *Pattanayak and Kramer* [2001] for details on the derivation of this functional form. The subscript i refers to the household.

$$\begin{aligned}\mathrm{WTP}_{Si} &= \Delta\pi_{Si} + a_0 + a_h H_i + a_r R_i + \varepsilon\\ &= \beta^*_{Wn} P_{ni} W_{0i} + a_0 + a_h H_i + a_r R_i + \varepsilon,\end{aligned} \tag{2}$$

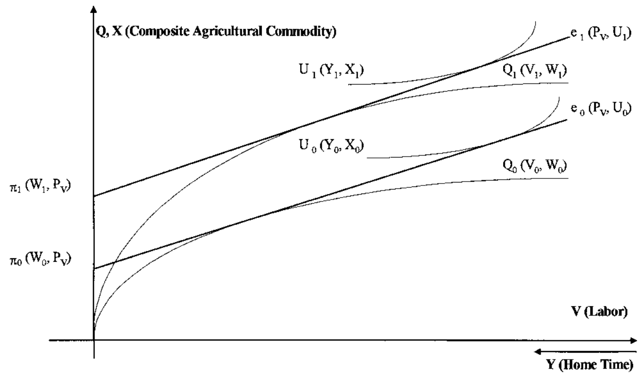

Figure 1. Benefits to representative household from drought mitigation 1.

where $\beta^*_{Wn} = \beta_{Wn}\theta$. This specification of the WTP_S function simultaneously maintains consistency with the profit function and with standard CV models [*Cameron and James*, 1987; *Hanemann et al.*, 1991] in that it includes a variety of demographic, behavioral, and environmental variables.

This study uses dichotomous choice CV questions that asked Manggarai households if they would be willing to pay proposed annual fees for drought mitigation services provided by Ruteng Park. In this format the household would agree to pay an annual fee F_i if WTP_{Si} exceeds F_i. A similar logic applies to the followup questions about WTP a higher fee F_i^U or a lower fee F_i^D corresponding to a "yes" or "no" to the first question. Even though the household response is a set of binary variables, the variation in the proposed annual fees (F_i, F_i^U, and F_i^D) allows direct estimation of WTP_{Si} as a function of P_{ni}, Z_i, R_i, H_i, and W_{0i} by using a "censored regression" approach [*Cameron and James*, 1987]. The log likelihood in (3) follows *Hanemann et al.* [1991] but modifies the WTP_{Si} structure to include θ and A_i.

$$\begin{aligned}\mathcal{L}(\beta_P, \beta_Z, \beta_w, a_r, a_h, \theta, \nu) &= \sum_i^N YY_i\\ &\cdot \log\left\{1 - \Phi\left[\frac{F_i^U - \mathrm{WTP}_{Si}(P_{ni}, Z, \theta W_i, R_i, H_i)}{\nu}\right]\right\}\\ &+ \sum_i^N YN_i \log\left\{\Phi\left[\frac{F_i^U - \mathrm{WTP}_{Si}(P_{ni}, Z, \theta W_i, R_i, H_i)}{\nu}\right]\right.\\ &\left. - \Phi\left[\frac{F_i - \mathrm{WTP}_{Si}(P_{ni}, Z, \theta W_i, R_i, H_i)}{\nu}\right]\right\}\\ &+ \sum_i^N YN_i \log\left\{\Phi\left[\frac{F_i - \mathrm{WTP}_{Si}(P_{ni}, Z, \theta W_i, R_i, H_i)}{\nu}\right]\right.\\ &\left. - \Phi\left[\frac{F_i^D - \mathrm{WTP}_{Si}(P_{ni}, Z, \theta W_i, R_i, H_i)}{\nu}\right]\right\} + \sum_i^N (NN_i)\\ &\cdot \log\left\{\Phi\left[\frac{F_i^D - \mathrm{WTP}_{Si}(P_{ni}, Z, \theta W_i, R_i, H_i)}{\nu}\right]\right\}.\end{aligned} \tag{3}$$

For the quadratic specification the likelihood function is nonlinear in the parameters, θ (perception factor), and the baseflow coefficients β_{Wn}, with these appearing as a product. We can only estimate the product of θ and β_{Wn}, given that household responses simultaneously reflect their expected baseflow increase and their valuation of marginal baseflow. The variability in the offered fee, while allowing the estimation of ν (the standard deviation of the error ε in the WTP equation), does not allow a simultaneous identification of θ. We assume the correlation of errors for the starting and followup bid to be 1 as by *Hanemann et al*. [1991]. *Alberini* [1995] has shown that this assumption causes small losses in terms of bias (estimates) in comparison to the gains in efficiency (more information), i.e., estimated WTP is reasonably close to the results from a bivariate distribution of starting and followup bids.

4. Data Collection and Description of Study Area

The models are based on household data, drawn from a socioeconomic survey conducted in the Manggarai district in 1996 as part of a larger project on the economic analysis of protected areas [*Kramer et al*., 1997]. Given that the hydrological effects of the park dissipate over geographical distance, the study area was restricted to the 48 villages (desas) from 9 counties (kecamatans) in the buffer zone of Ruteng Park that are contiguous to the protected area. Of the 13,700 farming households in the buffer zone, 500 were chosen on the basis of stratified random sampling in which the weights reflected the population density of the desas. The survey was translated into Indonesian and administered by 16 Indonesian undergraduate agronomy students who spoke the Manggarai dialect. The interviewers received 3 days of training.

The CV questions were developed with feedback from focus groups and pretests in several Manggarai households, and the interviewer training emphasized the appropriate way to ask these CV questions. CV questions were introduced with a standard description of park institutions and management to ensure that respondents received homogenous information. This was followed by several opinion questions designed to remind respondents about their environmental constraints and substitution possibilities. Drought mitigation was described in the survey as "drought control services, which is to decrease the drought conditions for your crops and improve a supply of dry season water." These services were described to result "from several planned activities by Ruteng Park including protecting existing forests, planting trees in degraded watersheds, and teaching the farmers new soil conservation measures." The amount of increased baseflow was not specified because the precise physical measure is unique to each of the 37 watersheds in the sample and because we hypothesize that household responses to the CV questions are based on their own perceptions of the service (section 3). The selected payment vehicle was a fee to be collected by park officials for protection of the park. All households in the sample were asked if they would be willing to pay an annual fee for drought control service; depending on their response, we asked a followup question for higher or lower fees. Six starting and 12 followup fees were selected from a distribution of values recovered from the pretests. Although double-bounded dichotomous choice models may be subject to biases from "yea-saying," anchoring, and correlation between fees, we adopted this format because it is statistically efficient [*Hanemann et al*., 1991; *Hanemann and Kanninen*, 2000] and because the elicitation process is familiar to respondents from a culture where bargaining is popular.

The average Manggarai household who responded to our survey has little education and wealth. They exhibit a heavy reliance on agriculture, primarily growing coffee and rice. We find that market exchange exists for the major outputs (e.g., coffee and rice) and inputs (e.g., labor) in 80–100% of the villages in our study area. Most villages had stores, credit facilities, and access to major towns. In addition, our experience in the field showed that the households were fairly well integrated into the market economy. Researchers rarely tend to use statistical tests to support market evidence. To the extent that such tests have been used in the development economics literature [*Pitt and Rosenzweig*, 1986; *Benjamin*, 1992], we follow their lead and find that the data support the existence of markets [*Pattanayak and Kramer*, 2001]. Typically, the Manggarai farm small, steep, and unirrigated parcels of land that have primarily volcanic soil. While the Manggarai region receives, on average, 2500 mm of rainfall annually, many subwatersheds frequently experience drought situations, especially during the dry season, as indicated by the fact that only ~40% of the rainfall stays in the system as baseflow.

Responses to leadin questions in the CV section of the survey revealed that households are keenly aware of and interested in their environmental conditions. Ninety-nine percent of respondents agree that "the amount of water in the springs and rivers depended on the forests"; 47% believe that "dry season water shortages" have increased in the Manggarai region over the last 10 years; 80% agree that by "spending money on irrigation systems farmers could successfully reduce drought conditions for their crops during the dry season"; and 66% felt that "plants, birds, monkeys, and other animals in the region needed special protection."

5. Results: Estimated Model of WTP

The dependent variables in the estimated WTP_S function is a set of binary responses (yes, yes; yes, no; no, yes; and no, no) to CV questions on household willingness to pay initial and followup annual fees for drought control service. The ranges of the six initial, followup low, and followup high fees are \$0.23–11.36, \$0.11–5.68, and \$0.45–22.73, respectively. In general, we observe a lower percentage of yes responses as the fees are raised across the sample, a behavioral response that is consistent with a declining aggregate demand. To some extent, response patterns to the fees are confounded by physiographic and sociodemographic differences at the household level; we expect responses to be statistically correlated with household perceptions of profitability, beliefs, and physiographic and sociodemographic features.

The specification for the WTP_S model include the following variables, with their means reported in Table 1. The set of prices P_{ni} include two main outputs (coffee and rice) and inputs (labor and fertilizer). Watershed-level baseflow W_i, measured in meters per year, is calculated from analysis of forest cover and climatic, topographic, and hydrological data by an Indonesian hydrologist collaborating on this study [*Priyanto*, 1996]. In addition, the WTP_S function includes the adjustment function A_i comprising of household attributes and opinions H_i and environmental conditions R_i. Environmental conditions include the annual rainfall and the extent of primary forest cover in their watershed. Socioeconomic characteristics include household average education level and a count of consumer durables (approximating wealth). The opinions affecting A_i include two binary responses: the possibility of mitigating droughts through investments in irrigation systems and the

Table 1. Maximum Likelihood Estimates of WTP Function $\sim N(\mu, \sigma^2)$

Variable Description	Mean	$\Delta\pi_S(\theta)$ β (*P* Value)	$\Delta\pi_S(\theta) + A$ β (*P* Value)
Incremental Stated Profit			
Baseflow, coffee price	1.83	0.64[a] (0.50)	0.40[a] (0.67)
Baseflow, rice price	0.18	30.3[a] (0.000)	20.83[a] (0.002)
Baseflow, labor price	0.92	−0.33[a] (0.86)	−0.62[a] (0.80)
Baseflow, fertilizer price	0.19	−18.4[a] (0.005)	−9.97[a] (0.15)
Adjustment Function			
Annual rainfall (1000 mm)	2.54		−2.09 (0.16)
Forest cover (fraction of watershed)	0.69		−0.93 (0.11)
Does irrigation investment mitigate droughts?	0.80		2.60 (0.006)
Have droughts increased in last 10 years?	0.46		0.26 (0.71)
Average education (years)	2.03		1.93 (0.002)
Wealth index (asset count)	0.85		0.76 (0.008)
Constant		−0.003 (1.00)	0.02 (1.00)
Standard deviation of WTP		6.50 (0.000)	6.15 (0.000)
Sample size		490	490
Likelihood ratio		25.3 (0.005)	67.5 (0.000)
Normalized pseudo R^{2}[b]		0.066	0.163

[a]Scaled by unidentified θ.
[b]Calculated using formula described by *Veall and Zimmermann* [1996].

increase in droughts over the past 10 years (1 = believe; 0 = do not believe).

Estimates of the WTP_S function, which allows us to identify determinants of demand and management information, are as follows. Because the dependent variables are binary response variables to CV questions about household WTP, we use nonlinear maximum likelihood estimation. In Table 1 we report the estimates for the double-bounded WTP function that relate to two specifications of the adjustment process. The first specification posits no adjustment of WTP_S (alternatively, the adjustment is simply constant), and the second specification allows a nonzero adjustment that is influenced by several factors. The likelihood ratio statistics and the normalized pseudo R^2, measuring overall "goodness of fit" of these models [*Veall and Zimmermann*, 1996], indicate that the second specification of the double-bounded model performs the best. We focus on the second double-bounded model ($\Delta\pi_S(\theta) + A$) in the remaining discussion because it has the highest statistical explanatory power. Note, a single-bounded model (not reported here) that uses responses to only the first offered fee generates a standard deviation of WTP_S one and half times greater than the double-bounded standard deviation, presumably because of its relative statistical inefficiency [*Hanemann and Kanninen*, 2000].

Turning to the results of our best specification Table 1 ($\Delta\pi_S(\theta) + A$), we interpret the coefficients as the marginal effect of the particular variable on household $\Delta\pi_S$ and WTP_S [*Cameron and James*, 1987]. Households expecting increases in profits through higher rice revenues are willing to pay more. Given that rice is the water-demanding crop, it is not surprising that the rice coefficient is significant in comparison with the coffee coefficient. Employing a similar interpretation, lower fertilizer costs are correlated with higher WTP (although only at a 85% significance level), whereas the labor costs are statistically uncorrelated. We conjecture that this is because households may find it easier to think of buying a service (drought mitigation) that lowers demand for a purchased input (fertilizer) rather than lowering demand for an input purchased less frequently (labor). Note that these price-baseflow parameters are scaled by the unidentified θ; thus the coefficients measure a combination of household perceptions of the baseflow increase and technological productivity (value) of marginal baseflow. We also find that the signs of all four price coefficients are consistent with the theoretical properties of quasi-expenditure functions.

For the adjustment component, various socioeconomic characteristics and environmental conditions have a statistically significant effect. The coefficient on the wealth index indicates that wealthier households are willing to pay more, perhaps because the environmental conservation is a normal good. More educated households may have a better understanding of the implications of forest protection for water supplies and of the "Park project" for community development and therefore mark up their perceived benefits. The coefficient on forest cover (though significant only at 89%) indicates that households living in watersheds with higher levels of forest cover may feel that there is no need for forest protection because they are not exposed to droughts. Thus they discount any perceived profits from drought control and are willing to pay less. For similar reasons, residents in watersheds with greater rainfall (although the coefficient is significant only at 84%) are willing to pay less. The coefficient on the binary response to the irrigation question indicates that those who believe that "irrigation investments mitigate droughts" are willing to pay more, perhaps because they are familiar with the concept of purchasing drought control.

Using the coefficients in Table 1 and the formula in (2), the mean annual stated WTP_S is \$2.79; of this, \$1.97 is the perceived increase in annual profits from drought control $\Delta\pi_S$ and \$0.82 is the adjustment A_i. These calculations are for the typical household, characterized by the sample mean value of all regressors in the statistical model (mean in Table 1). The median WTP_S of \$1.64 is lower than the mean probably due to asymmetric distribution of income and preferences for the ecological service [*Carson*, 2000]. For comparative purposes, $\Delta\pi_S$ and A for the other model in Table 1 are \$2.76 and \$−0.003, double-bounded ($\Delta\pi_S(\theta)$ in Table 1).

Sample mean and median estimates provide only central tendencies of stated values. We also tease out a spatial distribution of economic benefits by calculating WTP_S of household

Table 2. WTP for Drought Mitigation in Manggarai Counties

Kecamatan (County)	Stated WTP $\Delta\pi_s$ Median	Stated WTP $\Delta\pi_s$ Mean	Stated Adjusted WTP $\Delta\pi_s + A$ Median	Stated Adjusted WTP $\Delta\pi_s + A$ Mean
Borong[a]	0.98	1.05	0.48	0.69
Pembantu Elar[a]	1.33	1.47	2.13	2.08
Satarmese[a]	1.41	1.58	1.43	1.7
Pembantu Borong[a]	2.96	2.75	4.01	6.22
Elar	2.4	2.39	4.72	4.72
Pembantu Lambaleda	2.03	2.18	2.59	2.8
Pembantu Ruteng	1.19	1.24	2.12	2.81
Ruteng	2.4	2.33	1.82	1.77
Langke Rembong	4.23	3.32	6.42	6.22

[a]Southern counties exposed to moist southern winds.

clusters that are represented by nine Manggarai counties (kecamatan); these kecamatan are differentiated on the basis of baseflow, forest cover, and exposure to moist southerly winds. Median and mean $\Delta\pi_S$ and WTP_S in the nine kecamatan are reported in Table 2. On the basis of the rank correlations between biogeographic features and the estimated values we hypothesize a spatial pattern to the stated valuation of drought mitigation explained in terms of three biogeographic aspects. For residents of watersheds with high baseflow and forest cover we observe low $\Delta\pi_S$, presumably because of (1) the belief that additional water is technologically irrelevant, (2) actual diminishing returns of water, and/or (3) the belief that additional forest protection is unnecessary. The lower valuation of additional ecological services and forest protection by residents of counties that are relatively rich in this ecological capital is consistent with a negative demand relation. Moreover, in the wetter southern watersheds (in Borong, Pembantu Elar, and Satarmese counties) frequently exposed to moist winds from the southern seas and continually shrouded by cloud cover [*Binnies and Partners*, 1994], we observe low $\Delta\pi_S$. In these more moist watersheds, trees are less likely to compete with agricultural crops; therefore households discount the value of drought mitigation. The three biogeographic factors probably reinforce each other and influence household perceptions of both the baseflow increase and the value of marginal baseflow. In contrast to the pattern for $\Delta\pi_S$, Table 2 does not reveal a clear spatial pattern for WTP_S, that is, for $\Delta\pi_S + A$.

Because the kecamatan clusters overlap to some extent with the clusters of the data collected by different interviewer teams, it is possible that the biogeographic distribution may be confounded by the interviewing effect. Although we observe no pronounced interviewer team effects, we would recommend caution in interpreting the spatial distribution hypothesis. In CV studies of social forestry and village woodlots in India and Ethopia, *Köhlin* [1998] and *Mekonen* [2000] also find spatially distributed values.

6. Discussion of Methods and Policy Implications

Although parks in tropical countries have been envisioned as integrated conservation and development projects (ICDP) for more than a decade, few studies have attempted to quantify how conservation of tropical forests may facilitate economic development. This study attempts to fills some gaps by combining the predictions of a basic hydrological model with CV methodology to value a complex ecosystem service: drought mitigation provided by tropical forested watersheds in Ruteng Park to agrarian communities of eastern Indonesia. By exploiting the spatial variation in the current baseflow and agricultural prices, surveys of WTP can be used to approximate the household valuation of such a service. The estimated positive WTP for drought mitigation is an example of the quantification of substantive economic benefit of a large tropical forest park. The signs on statistically significant regressors that are consistent with the properties of quasi-expenditure functions lend theoretical validity to the WTP model. The estimated WTP value indicates that the potential beneficiaries do demand the drought control service, even though socioeconomic and environmental conditions influence them to adjust their valuation of the watershed protection package.

When applying the CV method to a hitherto unmeasured ecological service in a developing country setting, the risk of commodity and context misspecification is high; that is, despite the interviewer training, focus groups, and pretests the description of the contingent commodity can be less than convincing. In this study this misconception is likely to be evident either in the size of the unidentified scaling factor θ or in the value of marginal baseflow $d\pi$. *Pattanayak and Kramer*'s [2001] analysis of the role of water in agricultural production and profitability in Manggarai offers some insights regarding the implied size of θ. While spatial differences are lost at this level of aggregation, combining the mean marginal profitability of \$0.36 per mm of baseflow (reported in that paper) with the estimated stated values of \$2–\$3 (estimated here) suggests that farmers expect the baseflow levels to increase by ~6–8 mm or by 1% due to watershed protection. This perception is not at odds with the debate among tropical forest hydrologists [*Bonell and Balek*, 1993]. Given that there is uncertainty regarding the magnitude and spread of drought mitigation from forest protection, small-sized drought mitigation is credible [*Bonell and Balek*, 1993]. This compatibility of household perceptions with the hydrological assessments of the size of watershed protection offers evidence of content validity of the CV survey.

Clearly, more information on perceived baseflow increases θ would enable estimation of the size of drought mitigation, and more questions for the respondents seeking precise descriptions of expected θ should be considered. Notwithstanding their statistical performance, rudimentary measures of opinions may suffer from endogeneity problems, particularly if household opinions are motivated by the same latent preference for drought control that influences the WTP_S. One option requires identification of a well-defined drought-coping strategy of the Manggarai people, e.g., the planting of cassava, a hardy dry season species. A joint model of "area planted in cassava" and WTP_S that could rigorously address the endogeneity problem (e.g., following *Cameron and Englin* [1997]) is beyond the scope of this paper.

The models provide the following kinds of quantitative policy information. The estimated WTP_S of \$2–3 is ~10% of annual agricultural costs, 75% of annual irrigation fees, and 3% of annual food expenditures and therefore reflects credible demand for drought mitigation. Moreover, noncommercial users of water on Flores Island currently pay an average annual fee of \$24 [*Binnies and Partners*, 1994]. Taken together, this information suggests two ways by which the watershed managers can finance some of their management activities. First, given that some farmers are both familiar with water fees and willing to pay as much as 10% of their current outlay for agricultural inputs, managers may succeed in collecting annual fees for watershed protection activities. Toward this end, managers should focus collection efforts on households who have high WTP, i.e., farmers who grow rice, use fertilizers, are educated and wealthy, believe in productivity of irrigation, and live in watersheds with low forest cover and rainfall. However, such a revenue collection venture may be inequitable and politically difficult because disposable incomes are low in this region. To the extent that the annual aggregate WTP amount of $27,000 (evaluated by multiplying mean WTP of $2 by number of affected households) is a referendum of support for watershed management, it still may provide politically valuable information. Proof of an annual aggregate WTP amount of $27,000 may enable watershed managers to obtain larger shares of the public budget on the grounds that watershed management activities generate locally desirable and valuable drought mitigation service.

The spatial analysis reveals that policy makers should consider a selective approach, targeting watersheds with low levels of baseflow and forest and those in the rain shadow of the wet southern winds to fulfill the management goals to [*Indonesian Ministry of Forestry*, 1995, volume 1, p. 4] "provide conservation benefits to communities in the buffer zone" through watershed protection. Further, because the park imposes opportunity costs on the local people by curtailing their use of the forests, the computed value of drought mitigation will help park managers explain their position by making explicit the tradeoffs between the more transparent opportunity costs of forest use and the latent benefits of watershed protection. Toward this, managers are likely to find support from those with sociodemographics that are correlated with WTP_S (Table 1) and those residents in specific biogeographic clusters (section 6 and Table 2). Finally, the aggregate values constitute one element in the calculation of the net present value of the overall ICDP for Ruteng Park, which generates various other costs and benefits.

To conclude, the study develops and implements a framework for valuing drought mitigation service provided by protected tropical watersheds to Manggarai people in eastern Indonesia. This application of the CV methodology extends previous work by modeling WTP in terms of producer surplus measures and by implementing models of behavioral response to CV questions (perception and adjustment). The validity of statistically significant coefficients and content validity of the survey offer evidence that the CV methodology can be applied to complex ecological services in a rural developing country setting. The estimated economic models and the parameters provide some signals for policy makers regarding the economic magnitude and spatial distribution of the local economic value of watershed protection. They also offer management information for financing and targeting watersheds. Because of the imprecision in our economic data, indices of ecological attributes, and household opinions we do not recommend using the model estimates to predict precise values of these services. Perhaps, these results are better used to understand the nature of local demand for ecological services from tropical forests and to serve as a benchmark for further research on the magnitude of watershed protection benefits. Ultimately, the results of studies such as this may facilitate greater protection of the world's fast deteriorating tropical forest ecosystems.

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