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ANALYSIS

The economics of community watershed management: some evidence from Nicaragua

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Abstract

This paper assesses the economic value of improving local watershed services for residents of a micro-watershed in the hillsides of Nicaragua. The valuation of environmental services at the local level has been relatively understudied in the literature on environmental services. According to residents, water availability has been declining over time in the zone as a result of watershed degradation. Since the primary use of water is for domestic consumption, the contingent valuation methodology (CVM) is used to estimate the value of improving water supplies in the micro-watershed. The results suggest that the economic value that local residents place on improving the quality of natural water sources is relatively modest, approximately US$10,000 per year. The costs and benefits of several possible land management interventions for improving the water situation are discussed. Intervention is difficult to justify solely on the value of expected improvements in water quality or availability, however, further analysis of mitigation options reveals that they may be justifiable from other perspectives as part of an integrated community resource management strategy. The conclusion is that a participatory, multi-sector approach is best for identifying complementarities that can simplify management of complex systems like watersheds.

Keywords: Water; Environmental services; Contingent valuation method (CVM); Community resource management; Nicaragua

1. Introduction

Watershed degradation is an important policy issue in Central America. From reducing productivity on agricultural plots to aggravating the consequences of natural disasters like Hurricane Mitch, which devastated the region in 1998, degradation of hillside watershed resources is associated with a wide range of environmental, social, and economic problems in the region (Kaimowitz, 2000). A comparably broad range of interventions at local, regional, and national levels have been proposed, and in some cases initiated, with the goal of improving watershed services.

One key element of many watershed interventions, especially in cash-strapped developing nations, is the concept of payment for ecological services generated by specific land uses within the watershed (Tognetti, 2000; World Bank, 2002). Environmental or ecosystems services are defined as ‘‘the conditions and processes through which ecosystems sustain and fulfill human life, including the provision of food and other goods’’ (Rosegrant, 2002, p. 169). Since these services

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are often not recognized or valued in the economic sense, they may be ignored in decision making about land use. By compensating land users for the environmental services they generate (or charging them for the services they receive), policy makers hope to increase both ecosystem function and overall social welfare.

Central to implementation of such schemes is the ability to place an economic value on the environmental services. Available empirical evidence on what these values might be is mixed (Kaimowitz, 2001; Aylward, 2002; Nasi et al., 2002) and it appears that prospects for justifying significant investment in upland areas are not as bright as once thought. However, most studies have focused on downstream benefits for things like canal sedimentation or urban water supplies. Fewer studies have been done on the value of environmental services at local level, in spite of the fact that the majority of benefits related to better watershed management would likely accrue locally (Hearne, 2001).

The purpose of this paper is to assess the potential local economic benefits and costs associated with taking an environmental service approach to addressing problems of potable water availability in a micro-watershed in Nicaragua. A decline in water quality and availability was identified by the community of San Dionisio as the most important consequence of resource degradation in the micro-watershed (Vernooy, 1997; Vernooy and Espinzoza, 1997). Since the principal use of water in the watershed is domestic consumption, the contingent valuation method (CVM) is used to estimate the value of restoring local water supplies. Several land use management options have been proposed as part of a strategy for improving hydrologic function in the watershed. The possible costs of these options are assessed in light of the value of the benefits from the CVM analysis.

The remainder of the paper is organized as follows: Section 2 summarizes the evidence to date on environmental services and their economic valuation. Section 3 introduces the micro-watershed where the study was conducted, with particular emphasis on its water use and management issues. Section 4 describes the CVM study, and analyzes the results and their implications. Section 5 assesses some possible options for improving water availability, and discusses the role of local communities in their design and implementation. Section 6 summarizes and concludes.

2. Valuing watershed services

Different forms of land use can generate a variety of environmental services. Forests, for example, can regulate water flow, maintain biodiversity, and provide amenity value for residents and tourists. Wetlands can regulate water flow and maintain water quality. Pastures and forests can act as carbon sinks. In general ecosystem services fall into three categories: provision of direct benefits, regulation functions, and recreation/tourism value (Rosegrant, 2002).

Interest in ecosystem services grew out of concern that massive land use changes taking place as a result of development could have significant negative impacts on production and consumption. Since in most cases the services provided by ecosystems were not recognized, they were not valued economically, not traded in markets and not considered in land management decisions. This means that at least in theory there is an opportunity to improve welfare by finding ways to place a value on the services. More recently, it has been recognized that if implementing systems of payments for environmental services involves transfer payments from rich urban to poor rural households, they may also serve rural development objectives. This has clearly contributed to the popularity of the concept among development organizations.

Watershed services can be considered as the subset of environmental services concerned with the impact of land use change on hydrological function. This includes water quality functions such as sedimentation and contamination as well as water quantity functions relating to annual water yield, seasonal flow, or groundwater levels. Many watershed management and protection projects are initiated based on the belief that changing land use within the watershed, especially limiting or reversing changes away from natural ecosystems, can enhance water quality and quantity both locally and downstream.

In a comprehensive review of the literature on the magnitude and economic importance of land use changes in watersheds, Aylward (2002) concludes "both theory and empirical evidence suggest that it would be incorrect to assume that the hydrological externalities resulting from land use change are necessarily negative" (p. 26). He finds that "a small but growing number of studies sustain the theoretical conclusions that the net hydrological impacts of land

use change may lead to increases in economic welfare or produce only trivial losses in welfare" (p. 27). However, Aylward conditions these findings by noting the high variability among studies, both in terms of their empirical results and the quality of their data and methods. There is still much that we do not know about land use–hydrology interactions, especially over the long term. Comprehensive, multidisciplinary studies looking at water quality and impacts are required. These general conclusions are echoed by other authors in similar reviews (Kaimowitz, 2001; Nasi et al., 2002; Swallow et al., 2001).

One of the ways forwards that Aylward advocates is greater participation of stakeholders in future research on watershed management. The reasons he cites are that this will ensure that research responds to local needs, and, especially in the case of applied/adaptive research, that those results are taken up. While a great deal of participatory watershed management has been done with local communities (Hinchcliffe et al., 1999), few attempts have been made to place an economic value on local watershed services. Given that the benefits and costs of improved water management may well be local in nature (Hearne, 2001; Aylward, 2002), a sub-catchment approach may be appropriate in some cases.

Hydrological and socio-administrative units are generally not congruent, however, for sub-catchments and even small watersheds, residents are often from the same community, e.g. village, municipality, ethnic group, etc. This is clearly not always the case, and where the watershed does not coincide with any social units, community watershed management is likely to be difficult. However, where it is the case, communities may be well-placed to deal with externalities at or below the micro-watershed scale. In these cases, both the benefits and costs of internalizing an externality likely fall within a community, which means that this may be a logical level at which to address the problems.

Where site specificity is significant and where monitoring and enforcement costs to an outside entity would be high, community management may lead to more appropriate and cost effective solutions than could be devised by larger scale authorities. The origins, implications, and experiences of the approach known as community-based natural resource management have been amply documented and analyzed (Agrawal and Ostrom, 2001; Ribot, 2002; Meinzen-Dick et al., 2001; Baland and Platteau, 1996). While generally supportive of the utility and effectiveness of the approach, analyses have pointed out important lessons for improvement such as greater attention to structuring devolution of authority (Knox and Meinzen-Dick, 2001) and to understanding and supporting local organizational and negotiation processes among socially and economically differentiated stakeholders (Johnson et al., 2001; Wollenberg et al., 2001).

3. Water and watershed management in a rural micro-watershed in Nicaragua

The municipality of San Dionisio is located in the hillsides of Central America, about 165 km (3.5 h) north of Nicaragua's capital, Managua.[1] The municipality contains 144 km^2, about 80% of the micro-watershed of the Río Calico. The Río Calico is one of three micro-watersheds that make up the Río Grande de Matagalpa watershed. The total population of the municipality is about 24,000, of which 11,000 live in the urban area and the rest in 16 small communities in the surrounding hillsides (Figs. 1 and 2). In terms of income, San Dionisio is among the poorest municipalities in Nicaragua (Arcia et al., 1996). It is located in an agricultural region consisting mainly of smallholders growing maize and beans for both home consumption and the market. Because water is scarce, irrigated agricultural production in San Dionisio is prohibited. In the upper parts of the watershed, farmers grow coffee. The wealthier farmers raise cattle in extensive systems. The largest land use in the micro-watershed is natural crop–pasture association (44% of area), followed by permanent pasture (28%), coffee (14%) and gallery forest (8%) (Murillo and Osorio, 1998) (Figs. 1 and 2).

In 1994, The International Center for Tropical Agriculture (CIAT) initiated a research project on community management of watershed resources in San Dionisio. Participatory diagnoses repeatedly identified water availability and distribution as the principal natural resource management problem in the zone (Vernooy, 1997; Vernooy and Espinzoza, 1997). According to residents, both the quality and quantity of water are declining over time, a problem noted

[1] This section is based on Baltodano et al. (1997).

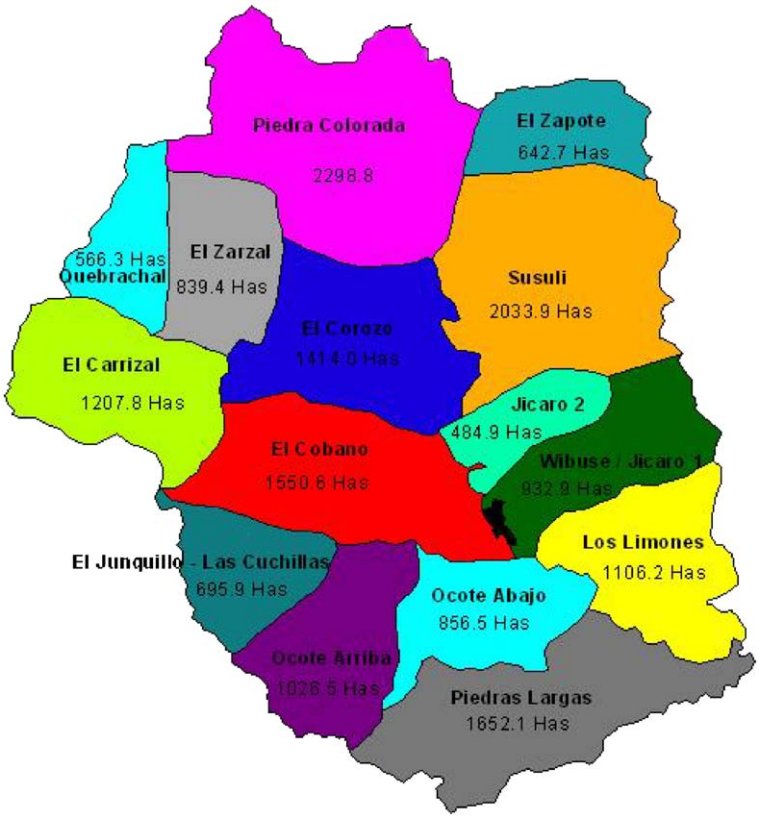

Fig. 1. The 15 communities of the Río Calico with their respective areas (in ha). The communities were identified during a 1998 participatory mapping process. Black indicates the town of San Dionisio.

elsewhere in the region (PASOLAC, 1999; Pender and Scherr, 1999). Residents blame degradation of watershed resources, principally deforestation and burning of fields, for perceived declines in the quantity of water available year round in many water sources. Water contamination associated with agro-chemicals and with agro-processing activities is also perceived to be increasing, an assertion supported by local health workers (Vernooy and Espinzoza, 1997). Unfortunately, no quantitative data are available to support these perceptions.

Residents of San Dionisio draw water from a variety of sources such as springs, wells, creeks, and rivers. By law all water sources are property of the community and open to all. However, since the land around the sources is private, access can be and often is denied in practice. Some households also have access to water from potable water projects. This water is known as "potable water" though the name refers more to the source than to the quality of the water. In 1998, there were 11 potable water projects in San Dionisio which provided water either directly to households or, to a lesser extent, to public taps in communal areas such as school yards. The projects draw water from springs. The projects were built in cooperation with government organizations or NGOs, with households providing labor in exchange for a connection to the system. Coverage is uneven; some communities have almost total coverage while others have no projects at all. Many potable water projects also suffer rationing due to dry season water shortages.

As a response to the water problems, potable water committees, known by their Spanish acronym CAPs, were created in each of the communities of the microwatershed. The committees were originally formed to manage the potable water projects, however, some have expanded their responsibilities to include broader issues of water management. In some areas,

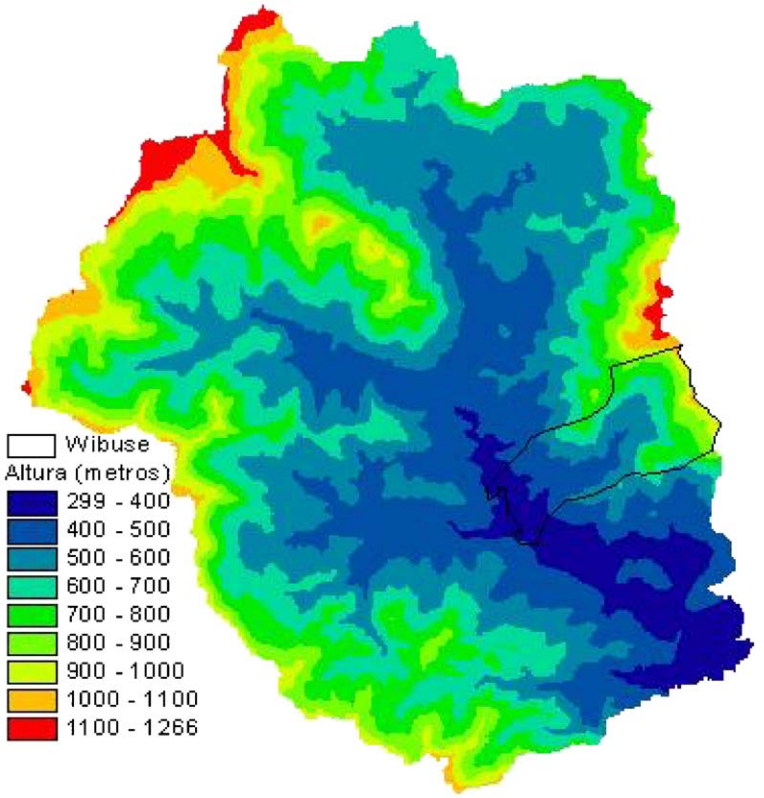

Fig. 2. Digital elevation model of the Rio Calico micro-watershed.

neighboring CAPs have created networks to facilitate joint management of water resources. There is significant variation among the CAPs in terms of the effectiveness of their management of potable water systems, however, they are considered to be the most effective local organizations in the watershed for dealing with natural resource management issues (Gottret and Westermann, 2000). Their continued existence and evolution may reflect the seriousness of the water problem in the zone. In spite of some serious political divisions, San Dionisio is a municipality with moderate to high levels of community organization. Many of the formal organizations were established in connection with development projects (ibid).

3.1. Current water use practices

To obtain basic data on water sources and water use, as well as information about water-related problems and solutions, a survey was carried out in July, 1998. A total of 153 households (approximately 15%[2]) were drawn from a sub-sample of five of the 16 communities within the micro-watershed—Susulí, El Jicaro, El Cóbano, Zapote and Wibuse. These communities were chosen because they are representative of the watershed in terms of water resources, water access, and water-related problems and conflicts (Vernooy, 1997; Vernooy and Espinzoza, 1997). Table 1 summarizes some of the information collected in the survey.

According to the survey, 76% of households had access to potable water from water projects, ranging from 98% in Susulí, a large community that is well supplied with water, to none in Wibuse. Having access to potable water did not guarantee that the

[2] Given the lack of reliable census data in the rural areas, it was necessary to estimate the number of inhabitants using key informants.

household did not use other sources, however. Twenty-eight percent of households with potable water reported experiencing rationing in the previous 12 months, lasting on average 1.3 months. During this time, households either reduced water use or sought water from other sources. Only in Susulí could households get by with just potable water systems. In other communities, households used at least one and up to three other sources of water during the year. Those who did not have access to potable water used alternative water sources year round (Table 1).

Households often use different water sources for different purposes, such as bathing, washing clothes, for drinking water, or for watering animals. Sources also varied by community, which would be expected given their different locations and ecological conditions. Wells are the most frequently used water source. Wells are also the most popular source for drinking water; 45% of drinking water sources were wells. This suggests that they are the source of the best quality water, a fact confirmed the results of survey respondents' rating of water sources.

On average, respondents reported that the quality and quantity of water from these sources was currently acceptable, however, they felt that over the past 5 years both quality and quantity had gone down. One of the main benefits of having potable water is the reduction in time and effort associated with traveling to water sources. Of the 43% of families that reported carrying water from other sources, the average time spent carrying water each day was 37 min, ranging from 4 min to 3.3 h per day. This average is equivalent to 225

Table 1
Average values of selected variables

Variable	Total	Cobano	Zapote	Susulí	Jicaro	Wibuse
Sample size	153	9	17	85	26	16
Average household size	6.47 (2.91)[+]	8.56 (4.10)	6.88 (2.39)	6.01 (2.81)	6.23 (2.3)	7.69 (3.44)
Years of education of the most educated person in the household	4.18 (2.84)	4.67 (2.78)	4.18 (2.43)	3.82 (2.45)	5.85 (3.92)	3.06 (2.24)
Percent of households who own land	80 (40)	67 (50)	76 (44)	79 (41)	85 (37)	87 (34)
Index of sources of income*,[a]	13.59 (2.58)	14.44 (1.67)	15.41 (2.58)	13.04 (2.31)	15.12 (2.52)	11.56 (1.97)
Percent with access to a potable water project	76 (0.43)	44 (53)	82 (39)	98 (15)	62 (50)	0
Number of months per year during which potable water is rationed	1.3 (2.54)	3.75 (2.5)	6.14 (3.51)	0.17 (0.7)	2.31 (1.96)	na
Number of alternative water sources used	0.79 (1.0)	1.11 (0.60)	1.53 (0.62)	0.09 (0.29)	1.54 (0.95)	2.31 (0.87)
Number of alternative drinking water sources used	0.56 (0.77)	0.89 (0.78)	1.06 (0.43)	0.07 (0.26)	1.12 (0.86)	1.56 (0.73)
Index of water quality in alternative sources**	1.32 (0.51)	1.25 (0.42)	1.29 (0.47)	2.17 (0.41)	1.14 (0.33)	1.27 (0.49)
Index of drinking water quality in alternative sources**	1.48 (0.54)	1.21 (0.39)	1.37 (0.48)	1.88 (0.64)	1.36 (0.48)	1.65 (0.57)
Index of change in water quality**	2.09 (0.43)	1.94 (0.42)	2.11 (0.33)	2.33 (0.52)	2.03 (0.41)	2.14 (0.49)
Index of change in water quality**	2.16 (0.48)	1.94 (0.68)	2.08 (0.28)	2.38 (0.52)	2.12 (0.38)	2.30 (0.56)
WTP for improved water supplies	3.95 (3.84)	11 (3.1)	0.21 (0.8)	3.14 (2.6)	7.04 (4.56)	3 (0)

[a] Since data on cash income is often difficult to obtain and not especially meaningful in a partially-monetized economy like San Dionisio, economic well being was measured using an index based on household economic activities. Previous work on local measures of poverty in the zone identified a relationship between poverty and sources of income (Ravnborg and Baltedano). According to those findings, households that earned money from livestock were generally the best off, followed by households that had basic grains and coffee. Households that only produced basic grains, were less well off than those that had coffee but better off than those that ran small businesses. Finally, day laboring was found to be the least lucrative economic activity. Because of the predominance of basic grains farmers, the index was constructed using the top two sources of income in the households. The average value of the index corresponds to a household engaged solely in basic grains production.

* Index goes between 1 and 20, with 20 representing highest income.

** The index goes between 1 and 3, with one being the best. Note: this index refers to water sources other than potable water projects.

[+] Standard deviations are in parentheses.

h a year, with a range of 24–1216. This is an underestimate of the total amount of time spent going to water sources since in many cases family members go to the water source to bath, wash clothes, or water animals without actually bringing water back to the house.

Questions about health were included in the survey because one of the potential costs of lack of clean water is illness. Doctors at the local health center reported seeing an increase in water-related health problems in recent years, and volunteered to formulate the health-related questions for this survey. They considered two types of health effects, gastrointestinal problems and skin problems.

Thirty-five percent of households reported members suffering from gastro-intestinal problems in the past 6 months, ranging from 24% in Susulí to 81% in Wibuse. Households reported that an average of 4 days per year were lost due to illness, 3 of the sick days were for adults. When asked whether drinking water gave people a stomach ache, 8% of households responded that it did. When asked whether drinking water made sick people better, worse, or had no effect on them, the average response was between improvement and no effect. In two of the communities, El Cobano and Zapote, on average people felt that drinking water aggravated illness.

Factors affecting different measures of illness were statistically analyzed in order to establish a link between water and health. While no significant relationships were found between number of sick days and water,[3] there was a significant negative relationship between incidence of diarrhea and access to potable water. No relationship was found between other water sources and incidence or gravity of illness.

According to local doctors, skin problems can also be a sign of contaminated water. Eighteen percent of households reported a stinging sensation while bathing, ranging from 12% in Susulí to 38% in Cobano, the only community that reported widespread use of water from the Calico River. Eight percent reported skin rashes from bathing, ranging from 25% in Wibuse to 4% in Susulí. Eighty-nine percent of the stinging and 65% of the rashes were reported to occur during the months of May through August. This is the rainy season, and also the start of the agricultural season when fertilizers and other agro-chemicals are used.

4. Valuing the benefits of improving water services using the contingent valuation methodology (CVM)

4.1. CVM and valuation of water services

Since the principal use of ground and surface water in San Dionisio is for domestic consumption, in this study it is valued directly as a consumption good, rather than indirectly as an input into a production process such as agriculture, agro-processing or energy production. This complicates its valuation since empirical methods are more reliable for inferring water's value than for measuring it directly. Where water markets exist, the value of changes in water quality or quantity can be estimated using data on prices and quantities from water transactions. Where such data are not available, contingent valuation may be the best alternative for valuing water as a private consumption good (Young, 1996).[4]

The CVM, in which people are asked hypothetical questions about how much something is worth to them, is not without controversy (see, for example, Mitchell and Carson, 1989; Randall et al., 1983). There are many conceptual and empirical shortcomings, however, it can be a useful first step towards approximating the value of non-market goods and services. It is particularly useful in environmental analysis, and while it has been most widely used in developed countries, its use in developing countries is also growing (Shultz, 1997).

Potable water projects have not traditionally been the focus of economic analysis, instead justifying themselves on the basis of people's right to have access to potable water (Whittington and Swarna, 1994; United Nations Millenium Development Goal #7 (http://www.un.org/milleniumgoals/)). The experience of such projects, however, has not been entirely positive. Many potable water projects are not well-main-

[3] When the independent variable was sick days and the dependent variables included household and water source characteristics, the only variable that was significant was mother's education. This variable, as expected had a negative effect, but it was not robust to different specifications.

[4] The advantages and disadvantages of the CVM will be discussed in greater detail in the following section.

tained by users and in some cases are not even used (Drangert, no date: Whittington et al., 1990a,b). In the past, the rule of thumb was that as long as the costs associated with using a water project did not exceed 5% of household income, households would have a positive demand for water from the project (Whittington and Swarna). Experience suggests that this may not be the case, and that a better understanding of household demand for water is needed.

A series of case studies of potable water projects was recently carried out in Asia, Africa and Latin America by different development agencies that support projects to improve local water supply systems (see various studies by Whittington and collaborators; World Bank Water Research Team). In several of the studies the CVMs was used to estimate the value of new water supply systems. In addition to doing statistical tests for reliability, the study authors also incorporated specific tests of the biases often suspected to invalidate the use of CVM data. Whittington et al. (1990a,b), in a study in Haiti, designed and implemented their survey instruments in order to be able to test for strategic bias, starting point bias, and hypothetical bias.[5] They found no empirical support for the existence of bias.

[5] Strategic bias occurs when a respondent feels that his or her response could actually influence a policy decision and therefore has an incentive to not answer truthfully. For example, if an individual feels that the results of the survey will be used to set actual service fees or tax levels, he or she is likely to underestimate willingness to pay (WTP). Starting point bias could occur as a result of the fact that in a bidding-game format—where respondents are offered different prices and asked if they would be willing to pay them—the initial price offered may affect the final WTP. The bidding game format is preferred over open ended question since it approximates a real economic decision in which a consumer sees the price of a good or service and makes a yes or no purchase decision (Shultz). However, there is always the danger that by initiating the question with a certain price, the interviewer is giving the respondent clues about what the "appropriate" range of WTP should be. Hypothetical bias would occur if respondents were unable to conceptualize the situation they are being asked to value in a realistic fashion. If people are not used to valuing the environment it may not be feasible for them to say what they would be willing to pay to improve environmental services. This may be especially true if the survey is being carried out in a rural area of a developing country where the economy is not fully monetized. If hypothetical bias is a problem, the results of the survey will likely be random numbers invented by the respondents to satisfy the questioner but bearing no relationship to the actual value that the respondents place on the good or service in question.

4.2. Willingness to pay for improved water supplies in San Dionisio

As part of the San Dionisio survey, respondents were asked about their willingness to pay (WTP) for improved water services using the following question, "*Imagine that it were possible to improve your most frequently used water source*, *be it potable water*, *well*, *spring*, *stream or river*. *Improving the source means that there would be more water of better quality from the same source*. *Think about how much it would be worth to you to have water from this source*". Respondents were then asked if they would be willing to pay a declining series of values per month, beginning with 15 córdobas (US$1.43 at the current exchange rate) and ending with 3 córdobas, in increments of 3 córdobas.[6] Enumerators, local residents who received training in how to implement the survey, were told to explain to respondents that the goal of the survey was to see how important the problem was to people, not to determine water charges. Much time during the training session was devoted to convincing the enumerators that this was true.

The question was phrased in a very general way, and no attempt was made to quantify how or how much water supplies would improve. This is clearly a shortcoming in terms of being able to value specific levels of change, however, it was felt that asking people to value specific quantity or quality changes would be very difficult. Rather the question was left open so that people would respond based on their own definitions of what improvements could or would occur. Given that water problems in San Dionisio are defined in relation to historical levels which are observed to be declining, encouraging people to use those past levels as benchmarks was felt to be the best way to obtain feasible and realistic estimations of what improvement could be expected to occur.

On average households were willing to pay 3.95 córdobas (US$0.38) a month for improved water

[6] Which values to use in the questions were chosen during the process of pre-testing the survey. During the pre-tests, some respondents were asked the question in an open-ended fashion while others were given ranges of possible values based on the opinion of key informants within the community.

supplies. Among the communities, the average WTP ranged from 11 córdobas in Cobano to 0.21 in Zapote (Table 1). The Zapote average is significantly lower than in other communities, even Susulí where water problems appear to be minimal. Zapote does have significant problems with water availability; potable water projects in the community suffer rationing for an average of over 6 months a year. Zapote is known as a well-organized community, and is in the process of trying to deal with its water problems. The low WTP for this community probably reflects strategic bias since, according to the surveyors, there is significant opposition in the community to solving water problems through increasing water rates.

Excluding the 17 observations from Zapote, the average WTP in the sample is 4.40 córdobas, or US$0.42 per month per household. On the level of the micro-watershed, the value of improving water quality on an annualized basis for rural households in the Rio Calico micro-watershed would be US$10,362.[7] Estimating income at the daily wage of C$30 (US$2.88), this would be 0.61% of an annual income of US$823.[8] While no other studies of improving natural water sources could be found, the literature on potable water systems reports WTP values from less than 0.5% of income to 10%, or even higher during times of drought (Whittington and Swarna, 1994). In cases where reliable alternative sources in the form of traditional wells or village pumps were available, households were willing to pay 1% or less of their income to move up one level of service, for example from traditional sources to village pumps or from village pumps to private taps. The findings for San Dionisio are towards the low end of the range of previously-cited findings.

4.3. A test of the reliability of the CVM results

To test the reliability of the results, statistical analysis was conducted of the determinants of WTP. The statistical model for examining the determinants of WTP is ordered probit, which takes into account the fact that the dependent variable, WTP, was constrained to take one of the five values offered in the survey question (Greene, 1993; Whittington et al., 1990a,b; Limdep manual). Consumer demand theory suggests demand for a good is based on its price, the price of related goods (substitutes and complements), and individual/household characteristics such as income or education. This is analogous to WTP for a good, and the same theoretical relationships would be expected to apply, with the exception of own price which is not included (Whittington et al., 1990a,b).

Theory suggests that WTP would be positively related to income and to the costs associated with using existing water services. In this case, the main cost of existing service would be time spent collecting water. While improving a water source will not make it any closer to the house, one of the main reasons that people go to distant water sources is that the nearby ones are either dry or dirty. Therefore, rehabilitating these water sources would reduce time associated with carrying water. By this same logic, women could also be expected to be willing to pay more for water improvement than men since they are the ones who do most of the water carrying work (World Bank Water Demand Research Team, 1993).

The results of the analysis of using these and other variables hypothesized to affect WTP are presented in Table 2. The two main hypothesized relationships are confirmed by the data, namely the cost of using existing sources and income. The amount of time a household currently spends carrying water is positively and significantly related to WTP. Income is positively related to WTP ($P=0.15$).

The dummy variable for sex was not significant, suggesting that women are not willing to pay more than men for improving their existing water sources. In a related study based on the same fieldwork that looked at WTP for potable water projects, women

Table 2
Determinants of WTP for improved water supplies

Dependent variable	Sign on coefficient	*P*-value
Income index	0.074	0.1447
Time spent carrying water (min/day)	0.014	0.00015
Dummy for potable water (0, no access)	−0.356	0.384
Dummy for sex of informant (0, woman)	−0.232	0.337
Dummy for Zapote (1, Zapote)	−3.102	0.0000
Number of observations	128	
Chi square (degrees of freedom)	58.32 (5)	
Significance of model	0.00000	

[7] Based on an estimate of 2056 rural households.

[8] Assuming that a person was able to find work 24 days a month, the monthly income would be C$720.

were willing to pay significantly more than men. One explanation is that in the case of potable water projects, payment was in terms of work days over a 6-month period rather than money. Some studies have found that women are more likely to commit household labor resources than cash (World Bank Water Demand Research Team, 1993).

A dummy variable for potable water was also included to control for the fact that people may feel differently about paying for the improvement of natural sources than for potable water projects. Which sign this variable should take is unclear. On one hand, people are accustomed to paying for potable water and therefore may find it easier to imagine paying more for improved service. On the other hand, people who are already paying for a service that is often not adequately provided may be disinclined to pay even more so that it can be improved. This ambiguity is reflected in the results of the analysis. The variable, equal to 1 if the household had potable water, is not significant. A dummy variable was also included to control for the apparent strategic bias in WTP in the community of Zapote. This variable, equal to one for households in Zapote, was highly negatively related to WTP, as expected.

5. Assessing some options for improving watershed services through better community resource management

The value US$10,000 can be interpreted as an estimate of the value of providing rural households in the watershed with improved water supplies in their principal water sources. The WTP measure only includes the benefits that people perceive, however. If people are unaware of benefits—as may be the case with health benefits (Whittington and Swarna, 1994)—or if there are externalities associated with water source improvement, then this estimate would underestimate the true value of the social benefits. Another shortcoming associated with WTP is that it is related to income, meaning that poorer people will always be willing to pay less than richer people, other things equal. Whittington and Swarna (1994) argue against overemphasizing the income bias, however, since empirical evidence shows that income is not the only, or even the most important, determinant of WTP.

In purely economic terms, the results of this study suggest that the value of improving existing water sources in San Dionisio is relatively modest, equivalent to a 1% increase in bean yields (Beltrán, 1999, personal communication). One option for dealing with the declining water availability would be to expand and improve the potable water systems. Deep well technologies exist to tap into larger subterranean water supplies, however, these technologies are very costly and would not appear to be justified unless they led to non-marginal changes in water availability that permitted use of water for other activities such as agriculture. Further, the fact that most existing potable water projects are not well maintained by users suggests that a high cost, technologically-based solution is not the way to go. In the survey, 80% of respondents felt that San Dionisio's water problems should be resolved via better land management rather than the construction of new water projects. Two options that farmers mentioned and that are widely promoted by government agencies and NGOs are the protection of water sources and the elimination of burning as a method of land preparation.

5.1. Protecting water sources

One way of maintaining or improving the quantity and quality of water in natural water sources is to undertake protection measures such as regular cleaning or planting and maintaining trees or other vegetative buffer zones. Information on water source protection was collected in the survey. Households reported protecting 44% of water sources.

Several options exist for increasing the protection of water sources. One would be that government (local, regional, national) mandates water source protection measures. Many governments have regulations about land use along major waterways, however, research has shown that protection of secondary water sources can also improve hydrologic function in the watershed (Ashby et al., 1999; Knapp et al., 1994). Given that water sources are technically public, it would have to be specified who would be responsible for implementation, monitoring and enforcement. Community organization could play a role in here.

Since the survey data indicate that a significant portion of the water sources are already being protected, an analysis of the determinants of protection

was carried out to get a better idea of what is currently motivating water users to spontaneously protect their water sources. For the 113 water sources for which complete data were available, a probit model was estimated with a dependent variable of whether or not the water source was protected. Independent variables included socio-economic characteristics of the household using the water source, characteristics of the water source, including what kind of source it is, whether or not it is "private",[9] and how many families use it (Table 3). The results show that there is significant variation among communities in whether or not water sources are protected (Table 3). Two, Susulí and Jicaro are significantly more likely to protect their water sources than the others. Among household characteristics, access to water from a potable water project is negatively associated with water source protection, which may mean that households that are less dependent on water from these sources are less likely to invest in their protection. Income is also negatively associated with water source protection, though the coefficient just misses significance at conventional levels ($P = 0.12$).

Table 3
Results of Probit analysis of whether or not a household protects a water source ($n = 113$)

Variable	Coefficient	*P*-value	Mean
Independent-water source protected by household			0.39
Sex of respondent (1, male; 0, female)	0.305	0.44	0.64
Number of people in the household	− 0.073	0.25	7.8
Maximum education level in household (years)	− 0.051	0.40	4.3
Membership in local association(s) (1, yes; 0, no)	− 0.111	0.76	0.30
Potable water (1, access; 0, no access)	− 0.910**	0.05	0.44
Source belongs to household (1, yes; 0, no)	1.60**	0.000	0.32
Time to source (min/day)	− 0.002	0.75	26.71
Income (index from 1 to 20)	− 0.088	0.12	13.73
Susulí	3.08	0.004	0.07
Zapote	1.18	0.224	0.19
Jicaro	2.57	0.003	0.32
Wibuse	0.44	0.508	0.33

Chi-squared = 58.56, df = 12, significance 0.000.

According to the analysis, the major determinant of water source protection is whether or not the household feels that the water source belongs to it. Water sources that belong to the household are significantly more likely to be protected than public sources or sources that belong to other households. The number of families that use a water source is not significantly associated with whether the source is protected. This suggests that the benefit of ownership is related to security of access to the water source (and possibly also products of buffer zones such as fuelwood) rather than to problems with free-riding. Households with secure access have a greater incentive to invest in water source protection, an investment whose benefits are realized over time.

These results suggest that one way to address the problem of water availability would be via access rights to water sources. Since legislation mandating open access to water sources is already in place but is unenforced, there is clearly an opportunity for community level organizations to negotiate locally acceptable agreements between land owners and water users. Examples of local organizations negotiating with government to establish local norms for land use around water sources exist (Ravnborg and Ashby, 1996). Whether this would be possible among land owners and water users is an open question. In Nicaragua, as in many countries in Latin America, land tenure has been a point of conflict for decades, and it may be difficult for landowners and water users to establish trust and reach mutually acceptable solutions regarding access rights.

The potable water committees and their nascent federation offer an opportunity for building on existing capacity in local resource management. Strengthening these groups—in particular with regard to dealing with property rights issues—is likely be much more cost effective than establishing a new organization. In the survey, 67% of the households that were familiar with the operation of CAPs supported their branching out into broader NRM activities.

The previous discussion focused only on whether households do or do not engage in conservation activities at the water sources they use. It did not address issues of productivity of conservation practi-

[9] As mentioned earlier, water sources are technically public property. However, ownership of the land around the water sources appears to confer a de facto title to the water source as well.

ces, nor externalities associated with water source conservation. Increasing the productivity of conservation activities should induce more people to engage in conservation, as well as increase the impact of conservation among those who are already doing it. There is an effort underway in San Dionisio to test the productivity of different trees species for water source protection. In an innovative system of community-managed experimental plots in the micro-watershed, residents identified trees species as an area of interest for further experimentation. The experiment currently being carried out is very small scale, involving a few water sources and about a dozen trees species. The idea is to make species widely available to local people, who will plant them and monitor the impacts.

5.2. Reduce the use of burning as a method of land preparation

Another option for improving water availability that has considerable support both in San Dionisio and elsewhere is a ban on burning fields as part of land preparation (PASOLAC, 1999; Ravnborg and Ashby, 1996). Little scientific information is available about the effects of burning on water availability, especially on the off-site effects, however, farmers frequently associated burning with reduced water availability (Ravnborg et al., 1996). There are few rigorous empirical studies of the costs associated with the costs and benefits associated with burning in the context of crop production, though burning has been shown to contribute to plot level degradation such as loss of soil, soil fertility, and reduced water penetration and retention capacity (Castro Blandón, no date).

The anti-burning campaigns that have been carried out in San Dionisio and other parts of Central America have had a moderate degree of success in reducing burning (Castro Blandón, no date; Reyes, anon). It appears that with regard to burning there are essentially two types of farmers. The first are those for whom burning is a habit that can easily be dropped when its plot-level disadvantages are pointed out. This decision involves the farmer weighing his or her individual costs and benefits, and is not a case of internalizing externalities.

The other group of farmers are those for whom burning is a critical part of the production process that cannot be profitably abandoned. Burning requires much less labor than other forms of land preparation and it reduces pest and weed infestations (Castro Blandón, no date). In some areas, especially the hillsides, crop production would be nearly impossible without burning due to weed and pest problems (Estrada, 1999, personal communication).

Campaigns carried out by governments and NGOs are successful with the first group of farmers, but are unlikely to have an impact on the second. Coercion or compensation would be required to change the behavior of this second group of farmers. While it is likely that well-organized local communities could compel farmers to heed anti-burning regulations (Ravnborg et al., 1996), the high levels of uncertainty about the off-site impact of burning on water would probably not make this cost effective.

There is evidence that burning is causing off-site problems not related to water. Burning is usually carried out in late spring, and during this time much of Central America, including major cities, is under a cloud of smoke. This has been known to cause airport closings and other problems in the region, and to contribute to air quality problems as far away as the US state of Florida. Florida is willing to invest in research and development initiatives designed to reduce burning (Sanz, 1999, personal communication), something that has been suggested in other parts of the world where burning of fields and forests is widespread (Tomich et al., 1998).

In purely economic terms, it is likely that the value of reducing smoke pollution in Florida is higher than the benefits of improving local water supplies in rural Central America. If off-site benefits such as those realized in Florida are included among the benefits associated with a reduction in burning, the economics of the decision whether or not to burn would likely change dramatically.

The role for local communities in this case would be similar to that contemplated in traditional payment for off-site environmental services, namely enforcing compliance and/or managing the monetary or other compensation that rural residents would receive for changing land use practices. A strong and representative community organization may well do this more cost effectively than other regional or local authorities. The key would be whether the monitoring and enforcement costs of local groups more than offset

the transaction costs of dealing with many local organizations.

6. Summary and discussion

This paper estimated the value of improving local water quality and quantity in Nicaragua's Río Calico micro-watershed to be approximately US$10,000 dollars per year. The estimation was done using CVM, which has been shown to be reliable for assessing the value of water for domestic consumption. While significant in the context of the poor communities in the study, US$10,000 is not an enormous sum of money, roughly equivalent to a 1% increase in bean yields in the micro-watershed (Beltrán, 1999, personal communication). That the benefits of improving local water supplies are relatively modest is consistent with the consensus emerging from both the community level studies (Mejia, no date; Merayo, no date) and watershed level analyses (Aylward, 2000; Kaimowitz, 2001).

While the magnitude of the benefits would not appear to merit costly technical or policy intervention in the near term, the high degree of uncertainty surrounding the long term impacts, especially in the face of further degradation, argue for action (Kaimowitz, 2000). In the case of San Dionisio, the scale of the problem is consistent with local level solutions since both the causes and consequences are believed to occur below the micro-watershed scale. This paper assessed two options for addressing the problems via improved land management. In both cases, the strategies are part of an integrated approach to natural resource management that would likely yield a range of benefits beyond potential impacts on water. In each case, local communities could play an important role in designing and implementing solutions.

In the case of protecting the water source, technologies such as tree planting may reduce degradation of water sources, however, there is evidence that institutional barriers—namely land tenure—may be discouraging the adoption of conservation measures. This suggests an opportunity for re-negotiation of tenure rules for the mutual benefit of landowners and water users. Since a local organization already exists and has some capacity to deal with these problems, it appears that this would be a cost-effective way to approach the problem. Since improved organizational capacity is very likely to be useful in other areas, spillover benefits may also be generated.

The other option for improving water availability was to reduce burning of fields as a form of land preparation. Burning is thought to have negative effects on water availability, however, little scientific evidence is available on which to base policy recommendations. A ban on burning for the purpose of increasing local water availability would not likely be cost effective. While its effects of water are not clear, burning is undoubtedly related to high levels of regional and international smoke pollution. Incorporating the value of reducing smoke pollution in Central America and south Florida is likely to make a ban on burning much more attractive economically. Such a ban would have to be on a very wide scale in order to be effective, and it is unlikely that local communities alone would be capable of managing it. Local organization may still play an important role, however, in both enforcement and in ensuring that benefits are appropriately distributed.

Without better information on the relationship between land use and environmental services, it will be difficult to design and implement effective interventions to improve watershed services either locally or off-site. More research is needed. Better methods to more accurately estimate economic benefits would be useful, as would more data with which to quantify the impacts of change over time. Given the high costs of collecting this data, one possible way to make progress here would be to work with the local communities. Devolution of natural resource management authority to communities means that they will need detailed and accurate information about their local conditions, something which may currently be lacking (Baland and Platteau, 1996). Participatory research and community monitoring could be valuable and low-cost methods for gathering this information both to support community management and to improve broader knowledge of the relationships between land use and watershed services.

If this participatory testing and community monitoring can be expanded, sustained, and systematized, it could yield not only local benefits but also important research results about the impact of land use on

water availability (Hearne, 2001). Critical to achieving these benefits would be building community capacity to monitoring the impacts of tree-planting practices over time. Examples of the kinds of support communities might need to do this include both organizational methodologies and biophysical indicators (Johnson et al., 2001).

In the absence of reliable information to guide decision-making, and in recognition of the fact that in many cases equity considerations weigh as heavily as economic ones, new approaches to valuation are emerging that are based on multiple criteria and multiple types of information, of which technical results are just one (O'Connor, 2000). "In a broader, adaptive or institutional approach to valuation, the objective is to establish a process that provides stakeholders with an opportunity to re-consider their values and priorities in light of new information. . .. Valuation is thus reframed as a process of negotiation and conflict resolution rather than of finding a single optimum and efficient solution" (O'Connor, 2000; Tognetti, 2001). This is consistent with recent findings that individual's attitudes and experience drive their WTP for water as much as socio-economic and ecological characteristics (Barton, 2002). Results such as those presented in this study can be considered starting points on which to base a longer-term process of participatory resource management.

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