LOCAL RESOLUTION FOR WATERSHED MANAGEMENT: THE CASE OF WATER AND LAND ALLOCATION OF COTACHI, ECUADOR.

DISSERTATION

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ABSTRACT

Various environmental trade-offs arise in the Cotacachi watershed, located in the Andes Mountains north of Quito, Ecuador. Of particular concern to the local population are the declining quality and diminished reliability of water supplies for household and agricultural uses resulting from deforestation, poor pasture management, and related problems in the upper reaches of the drainage basin.

The purpose of this study is to determine what, if anything, local people are willing to pay for the sort of watershed management that would make water supplies cleaner and less subject to interruption, and to estimate the shadow price of irrigation water for the efficient allocation of resources. Estimates of willingness-to-pay (WTP) were obtained using contingent valuation (CV), and estimates of the shadow price were obtained using a Linear Programming model (LP). Eighty households were interviewed in September 2002. Half these households are in communities below 3,200 meters elevation, which have irrigation, and the other half in communities above this elevation level, where agriculture is rain-fed. Along with questions relating to economic activities and income sources, which yielded data for the development of the LP model, the survey instrument contained referendum-style CV questions. Using the responses to CV questions, I estimated an econometric model in which WTP for water quantity and

quality improvements was the dependent variable and right-hand side variables included household earnings and the portion of income derived from off-farm employment.

The LP model yielded the shadow price of water: $0.27 per cubic meter of water in low-altitude communities and $0.26 per cubic meter of water in high-altitude settings. Econometric revealed that the majority of households, in low-altitude communities as well as high-altitude settings, are willing to pay between $1 to $3 per month (avg. 1.94) to make water supplies cleaner and more reliable – through improved watershed management, for example. This is a sizable payment relative to existing tariffs for potable and irrigation water. This study suggests that the costs of watershed management could be covered, at least in part, by capturing the local benefits of same. This has significant implications for the decentralization of water resource development in Ecuador.

Dedicated to Karen Gallagher, a constant inspiration

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FIELDS OF STUDY

Major Field: Natural Resources

Minor Field: Human Impact

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CHAPTER 1

INTRODUCTION

1.1 Problem Statement

Of all the natural resources harnessed for economic development in rural areas, none is more important than water, which directly or indirectly affects numerous human activities. The survival and growth of fish stocks, which are an important source of food, depend on the quality of rivers, lakes, and streams. Recreational swimming and boating are, of course, impossible if clean bodies of water are inaccessible. Of more fundamental importance are the quality and reliability of private, municipal, and industrial water supplies. Agriculture is a major user of water as well. As Lal (2000) points out, fresh water availability is prerequisite for sustainable development.

Because of its importance for many human activities, Heathcote (1998) contends that water should be managed properly in order to guarantee its quality and quantity. Water management should consider three important factors: 1) adequate supplies of water over time; 2) water quality maintained at levels that meet government standards and other societal water quality objectives; and 3) sufficient water for sustainable economic development over the short and long term.

Water is abundant in Ecuador, where the research for this dissertation was conducted. According to the United Nations Food and Agriculture Organization (FAO), Ecuador has annual precipitation of 591.85 Km^3/year, (the internal renewable water resource is 432 Km^3/year). The agricultural water used in 1988 was 13.96 Km^3/year and domestic water use was 2.10 Km^3/year. Due to the abundance of surface water, Ecuador has not yet exploited subterranean resources. However, the latter is sizeable. Alone, groundwater on the Pacific side of the continental divide is estimated to be 10.4 km^3/year. There is no information regarding the subterranean resources in the eastern part of Ecuador, but presumably these are even larger (FAO/AQUASTAT, 2000).

As Southgate *et al*. (1999) pointed out, water in Ecuador is not uniformly distributed. Lowland areas in the northwest and east are extremely humid and the rivers carry enough water to satisfy the demands of farms, industries and households. By contrast, rainfall is very limited and most of the precipitation occurs during a single wet season in the southwestern part of the country.

As of 1997, total irrigated are in private and public systems was 863,370 ha. However, private irrigation is small in terms of area and does not receive assistance from government agencies. As a result, private irrigation has serious problems of maintenance.

According to Southgate and Whitaker (1994) and Southgate *et al*. (1999), the private supply of water irrigation was not always as it is today. Private and community ownership was very efficient and market oriented. Water rights were regularly traded. The deterioration of the private water supply began thirty years ago with passage of the 1972 Water Law. This new law gave to the Instituto Ecuatoriano de Recursos

Hidráulicos (INERHI) a broad mandate to plan, administer, and regulate the use of all the country's water. This mandate encompassed watershed management. However, INERHI focused mainly on the design, construction and operation of its own irrigation systems. The creation of the Water Law was primarily to subsidize the use of water and to implement regulations rejecting what it was already codified in the legislation of 1936 that allowed private ownership. (Southgate and Whitaker, 1994; Southgate *et al*., 1999).

Since 1995, the national government started to transfer public irrigation systems to local representative users. However, the legal prerequisites for water markets – that is, water rights – were not established. Instead, INERHI was replaced by a Consejo Nacional de Recursos Hidráulicos (CNRH) and responsibilities for water resource development and watershed management were devolved to regional authorities, provincial and municipal governments, as well as rural communities (Southgate *et al*., 1999).

The Ecuadorian Government sought through the creation of the CNRH to decentralize the planning, construction and operation of irrigation projects. However, the newly created regional agencies have not been able to develop new projects, or even finish projects that were in construction. These modest changes are mainly a consequence of limited budgets and the economic and financial crises that Ecuador experienced in late 1990s.

Economic instability has discouraged investments of all kinds, not excepting conservation investments. Furthermore, subsidies for irrigation and potable water, which grew very large after passage of the 1972 Water Law, remain in place. These diminish the economic interests of individuals and communities in the mutually beneficial trade of water rights. By the same token, incentives for watershed management are weakened inasmuch as the "output" of that management – increased supplies of cleaner water – is depreciated by the state's policy of selling water at an artificially low price.

At least for the time being, the worst of Ecuador's macroeconomic and political crises is past, which means that full implementation is now possible of the new policies and institutional arrangements introduced in recent years. Economics has a crucial role to play this implementation. For example, instituting watershed management requires estimates of the money that downstream populations are willing to pay for improved performance of irrigation and potable water systems. In addition to demonstrating the values created by good watershed management, economics provides insights into how these values can be captured – in the form of monetary transactions between upstream and downstream communities, for example.

By no means are the issues with which Ecuador is grappling these days unique. To the contrary, the policy and institutional framework for water resource development, generally, and watershed management, specifically, is the topic of debate and concern throughout Latin America and in other parts of the developing world. Accordingly, the findings of this study are bound to be of interest far beyond Ecuador's borders.

1.2 Objectives of the Study

The policy and institutional framework for water resource development, and watershed management are the focus of many international organizations. Among them, the U.S. Agency for International Development (USAID) seeks to address these problems through a number of projects. One of these is the Sustainable Agriculture and Natural Resource Management (SANREM) Cooperative Research Support Program (CRSP), which got under way in the early 1990s. The SANREM-CRSP Andes Project in Ecuador is part of a multidisciplinary, multi-institutional project for promoting sustainable management of mountain environments around the world. The main objective of the SANREM-CRSP Andes Project is to develop information and methods in order to help local communities make long-term natural resource management decisions. An important part of the SANREM-CRSP Andes Project is to address water quality and quantity problem in local communities (Rhoades, 2000).

In keeping with the general focus of SANREM's project in Ecuador, the research reported in this dissertation focuses on water resources, with special emphasis on estimating the scarcity value of water. Of course, the scarcity value of water is affected by population growth and other trends affecting demand. Likewise, scarcity values depend on the availability of water, which is in turn determined by precipitation and other natural factors as well as by public policies.

The ultimate objective of this study is to assess the economic feasibility of soil and water conservation programs in order to know if they can be sustained in the long run. Specific research questions include:

- What agricultural practices are consistent with the efficient allocation of water and land in the region? How should water be allocated in the light of increasing demands from agricultural and nonagricultural uses?

- What water policies can lead to efficient production in irrigated areas and the availability of water for nonagricultural uses?
- How does the shadow price of irrigation water differ of the annual water irrigation fee as is currently paid?
- Are rural households willing to pay positive sums for supplies of potable and irrigation water that are cleaner, less subject to interruption, or both?
- Does the value that rural households attach to improved performance of potable water and irrigation systems vary as incomes go up or down, as information about health and other impacts of consuming polluted water is disseminated, and as communities mobilize to improve water systems and watershed management?

To answer these questions, the study estimates the optimal net value of agricultural production given environmental constrains such as water, land, and labor availability, and how implementing soil and water conservation measures in the SANREM Andes Project may help to achieve this optimum. Knowing the marginal value of water will help to estimate a potential water rights market exchange. The database collected under the auspices of SANREM and from other significant sources is used to estimate shadow prices for water, land, and labor.

Additionally, this study estimates how willingness-to-pay for improved performance of potable water, which is made possible by improved watershed management, is affected by rural development as well as the sorts of conservation initiatives that SANREM-AND facilitates.

1.3 Organization

The dissertation is organized in six chapters. Chapter II is devoted to a review of the pertinent literature regarding the use of Contingent Valuation for eliciting and measuring the benefits of improvements in quality and reliability of water systems. Furthermore, the chapter examines the linear programming model regarding the efficient allocation of resources in farming activities. Chapter III contains a description of the area of study and a summary of the SANREM-Andes project. Chapter IV develops the theoretical framework for both the contingent valuation and the LP model, and it describes the survey and sample design. In Chapter V, results of the study are presented. Chapter VI presents a discussion of the study findings and recommendations for additional research.

CHAPTER 2

LITERATURE REVIEW

Throughout the developing world, water supplies are inadequate, in terms of quantity as well as quality. Among others, Whittington *et al*. (1990a) has examined the problem of wrongful planning of water system supplies and limited availability of service for potential users. They argue that poor planning is largely the result of inadequate information about potential users, which leads to erroneous assumptions about the needs and desires of rural populations. They also suggest that local participation from the beginning of the planning process is an important part of improved planning.

According to Pretty and Shah (1997) and Savory (1999), participation in these projects should start with what people know and do well already. However, one of the problems starts with the definition of the term “participation.” This word is ambiguous because it can imply different meanings depending upon the researcher’s view and the word’s use. The World Bank’s Social Assessment Group, for instance, defines participation as “a process whereby beneficiaries influence the direction and execution of development projects rather than merely receive a share of project benefits” (Paul, 1987). Others view participation as a simple fulfillment of beneficiaries point of view through a consultation at some points during project's design and implementation. Ostrom *et al*. (1993), see organization as key in participation programs and point out that organization requires the commitment of all participants.

Although participation is a key factor in improved planning, negotiating agreements among participants is not an easy task. People may differ substantially in regard to their preferences, resources, and information, and they sometimes need to overcome obstacles that result from the potential for opportunistic behavior by participants in environments characterized by risk. In early stages, participant groups can focus on establishing agreed rules for management and decision-making. These rules can be used as a vehicle to channel information to individual members (Ostrom, 1990; Röling, 1994). These initial goals can help to build confidence and trust that grows within participant groups. Then the participant groups can focus their attention on development activities that will benefit themselves as well as the community at large. This may involve the nomination of individuals to receive specialized training, such as soil and water conservation, pest control, veterinary practice, and so on, so that they can pass knowledge back to the whole group in their new role as paraprofessionals or extension volunteers. Once confidence and trust grows with the success of group initiatives, resource bases expand and group activity can evolve to an entrepreneurial stage where common action projects are initiated (Shah and Shah, 1995; Pretty and Shah, 1997).

Over the last two decades there has been a gradual shift in attitude towards local natural resources management and participation. Community involvement has shown that an increase in participation raises the likelihood of social acceptability, particularly among the target groups that are supposed to benefit from the project (World Research Institute, 1990). Increasing stakeholder participation in the project design and implementation can, in fact, improve project success rates (Davis and Whittington, 1998). There has been an increasing number of comparative studies of development projects showing that 'participation' is one of the critical components of success. Participation has been associated with increased mobilization of stakeholder ownership of policies and projects, greater efficiency, understanding and social cohesion, more cost-effective services, greater transparency and accountability, increased empowering of the poor and disadvantaged, and strengthened capacity of people to learn and act (Reij, 1988; Ostrom, 1992; Fernandez, 1994; Bromley and Chapagain, 1994; Shah and Shah, 1994; Duram and Brown, 1999; Keohane, and Ostrom, 1996; Heathcote, 1998; Thoms and Betters, 1998; Ravnborg and Guerrero, 1999; Steelman, 1999; Rhoades, 2000).

The importance of community participation and resources management is now widely recognized, both conceptually and in terms of the role that beneficiaries and local organizations can play in the design and implementation of development projects (Moser 1989). This recognition goes hand in hand with the new global economic order, with major changes in government's roles. A sort of devolution is currently increasing around the world, with more and more responsibilities delegated to provincial and municipal levels. For the first time in many regions, local governments can make major decisions affecting local economic and social development. However, this devolution has a tradeoff mainly as local governments have the new responsibility to raise their own revenues required to fund local infrastructure, health, education and social services. The results of this devolution still have yet to be seen, but the responses of local governments to ongoing devolution will help to determine the evolution of economic welfare and of the environmental stresses over the long term.

As important as valuing local knowledge and technologies is, gathering information to enhance farmers' capacity to innovate also plays an important role in soil and water conservation. Participatory technology development adapted to local conditions is an interactive process in which the knowledge and research capacities of farmers are joined with those of scientific institutions, at the same time, as local capacities to experiment and innovate are strengthened. Farmers are encouraged to generate and evaluate indigenous technologies and to choose and adapt external ones on the basis of their own knowledge, experiences and value systems (Ostrom, 1992; Pretty and Shah, 1997).

In this process of participatory development, it is important to have a reliable and valid methodology, as well as improved planning methodology (Carson, 1998; Whittington *et al*, 1990a). Whittington *et al*. (1990a) suggest that a methodology should include a procedure for eliciting information about the value placed on different levels of service, in addition to tariffs in order to recover at least operation and maintenance cost.

2.1 The Contingent Valuation Method (CVM)

The Contingent Valuation Method (CVM) is a survey-based technique for eliciting preferences for non-marketed goods, such as environmental amenities, in a form that allows one to estimate how survey respondents trade off private consumption for a non-marketed good in monetary terms. With market goods, one can rely on price information and quantities demanded. In the case of environmental goods, quantities are fixed and price information is non-existent. When applying economic principles to decisions involving collective goods, one needs the shadow price information for all affected individuals. The attraction of contingent valuation is that it facilitates the construction of a market in which the researcher can observe an economic decision directly related to the good of interest.

The CVM is a powerful tool to use with hypothetical direct valuation that requires the active involvement of participants. Via questionnaire surveys, respondents are asked to reveal their willingness to pay (WTP) for a particular project, policy change or preservation of some resource in a hypothetical or contingent market (Carson, 1998). These values are summed for users and non-users alike and the net gains to society are estimated.

For contingent valuation to work, it is essential that three conditions hold: the non-marketed good must be well defined, the scenario must provide a plausible means of provision, and there must exist a plausible mechanism for making the trade-off between the consumption of private goods and the non-marketed good of interest (Carson, 1998).

The CVM was proposed and first used in developed countries for valuation of public goods like access to parks, clean air or water, endangered species or unobstructed views. The essential feature of public goods is that one person's consumption does not affect the amount available to the next person (although some public goods, such as recreational areas, may be subject to congestion). Clean air and public defense are classic examples of pure public goods. Once these public goods are provided, the marginal cost of an additional person using the public good is zero.

To date, however, CVM has been used in developing countries or emerging economies mainly for the valuation of publicly or privately provided goods, such as water supply and sewerage in areas currently without these services. In these cases, CVM is used as a proxy of market analysis to guide the design of systems and setting of tariff rates. An example from India of the use of contingent valuation as a proxy for market analysis for valuing publicly provided water is given by Dixon *et al*. pp. 70-72 (1994 pp. 70-72).

CV techniques involve direct questioning of consumers to determine how they would react to certain situations. Unlike market or surrogate market approaches, CVM estimates are not based on observed or presumed behavior. Instead, CVM estimates are calculated by inferring what an individual's behavior would be from the answers of the interviewed individual expressed in a survey framework. CVM techniques rest on standard neoclassical economic principles and use either Hicksian measures of consumer surplus, compensating variation (CV), or equivalent variation (EV)[1].

2.1.1 Elicitation Method

A variety of techniques have been developed and used in contingent valuation studies in order to directly elicit individual's true values for the provision of a non-market good such as environmental quality, protection of an endangered species, water provision, and sanitation, and so forth (Cho, 1996). Mitchell and Carson (1989) presented several methodologies to use CVM, and they give suggestions of which one of

[1] Compensating valuation is the amount of payment or charge in income necessary to make an individual indifferent between an initial situation and a new situation with different prices. Equivalent valuation may

these methodologies is the most appropriate to specific conditions of particular cases. Among these methodologies, three are the most popular ones:

2.1.1.1 The Open-ended Approach

In this approach, researchers ask respondents directly the monetary value they are willing to pay for a specific change in environmental quality or provision of certain public good. The open-ended question does not state or suggest any particular amount (Bishop *et al*., 1983; Walsh *et al*., 1984; Seller *et al*., 1984; Shechter, 1991; Goodwin *et al*., 1993; Kealy and Turner, 1993; Kriström, 1993; Brown *et al*., 1995; Booyle *et al*., 1996; Ready *et al*., 1996). The answers to open-ended questions are based on participants' own judgment, thus a direct estimate of their WTP. One of the disadvantages of this approach is that it is difficult for participants to decide on a maximum WTP for an environmental good, with which they may not be familiar. As a result, there is a high percentage of non-response and a large number of unbelievably high or low answers. Furthermore, it provided very low estimates of consumer surplus as well as negative values (Arrow *et al*., 1993).

2.1.1.2 The Dichotomous Choice Approach

The dichotomous choice approach has been used widely in contingent valuation studies. Two different techniques use this approach. One of them, the iterative bidding game, is modeled on the real life situation in which individuals are asked to state an auction price (Mitchell and Carson, 1989). Since an auction is familiar to respondents,

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be viewed as a change in income equal to a gain in welfare resulting form a change in price, See, Dixon *et* it would easier to respondents to understand and participate. Participants are asked whether or not they are willing to pay an initial bid. If they say “yes” then the bid is raised several times until the respondents say “no.” These “yes” or “no” responses are used in a regression model to estimate the median WTP (Cho, 1996). One of the virtues of this technique is the likelihood to capture the highest price that consumers are willing to pay. Furthermore, its simplicity and the iteration process used in this technique enable participants to fully consider the value of the environmental good (Hoehn and Randall, 1983). One of the problems to face with this technique is that the starting bid may imply something about the value of the good. According to Carson and Mitchell (1989), starting bids well above participants’ true WTP will tend to increase the revealed WTP amount, while starting bids well below participants’ true WTP will tend to decrease it.

The second technique of dichotomous choice approach is “Take-it-or-Leave-it,” which uses a large number of predetermined prices to group the expected maximum WTP of most respondents for the environmental good. With this technique, each respondent is asked to assign his or her WTP for the environmental good just once (Mitchell and Carson, 1989). This technique has several strengths. According to Mitchell and Carson (1989), this technique simplifies the respondent’s task in a fashion similar to the bidding game, without having the iterative properties of the bidding game. The respondent only has to make a judgment about a given price — a judgment performed frequently by consumers, thereby a close proxy of a real market situation. This approach also presents an incentive to a respondent to say yes if his or her WTP is greater than or equal to the price asked and to say no otherwise (Hoehn and Randall, 1987).

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al. p. 75.

The take-it-or-leave-it approach has several disadvantages. It is inefficient compared to other elicitation methods because it needs many more observations for the same level of statistical precision in sample WTP estimates. The reason for this is that this approach obtains only a discrete indicator of the maximum WTP. Mitchell and Carson (1989) suggest that the most serious problem with the take-it-or-leave-it approach is that one must make assumptions about how to parametrically specify either the valuation function or the indirect utility function to obtain the mean WTP. In recent times, a double-bounded approach has been introduced to overcome these difficulties. In the take-it-or-leave-it approach with follow-up, respondents are asked if they are willing to pay for an initial bid, and then they are asked one follow-up higher (or lower) bid randomly chosen from a pre-specified bid depending on whether the response to the first bid is 'yes' or 'no'. This technique is statistically more efficient than the simple take-it-or-leave-it approach, but all other problems that take-it-or-leave-it has still hold (Kanninen, 1993; Haab, 1998).

2.1.1.3 The Payment Card

Mitchell and Carson (1984) developed this technique as an alternative to the bidding game. They wanted to keep the properties of the direct questions approach while increasing the response rates for the WTP questions. They obtained this by asking the respondents to circle a number from a payment card or checklist with a series of numbers ranging from zero to some large amount. According to them, this approach avoids the need to provide a single starting point bid; at the same time, it offers to the respondent a meaningful context for his or her bid. Then the true WTP lies in the interval between respondent's answer and the next higher value. One of the advantages of this technique is to lessen the respondents' difficulty in providing a WTP answer, which can result in decreasing the number of non-responses to WTP questions. Furthermore, it does not require a large sample to have a statistically significant WTP, as needed for the dichotomous choice method (Mitchell and Carson, 1984; Jordan and Elnagheeb, 1993).

However, this approach presents difficulties. Cameron and Huppert (1989) suggest that the proper range of values used on the payment card or checklist present problems because it can be influenced by the survey designer and by the estimation method in the data analysis. They argue that the size of the intervals displayed in the payment card raise a problem too. The finer the intervals are, the more difficult it becomes for respondents to decide which interval contains their actual WTP. Wider intervals would make their decisions easier, but there would be an important loss of information to be estimated. Mitchell and Carson (1989) admitted that the payment card is potentially vulnerable to biases associated with the ranges on the cards and the criteria used to determine these ranges.

Despite the difficulties found in using this approach, it has been widely applied in theoretical and empirical studies (Loehman and De, 1982; Booyle and Bishop, 1988; Cameron and Huppert, 1989; Halstead *et al*., 1991; Jordan and Elnagheeb, 1993). Jordan and Elnagheeb (1993), using Monte Carlo experiments, compared the parameter and WTP estimates from the dichotomous choice method and the payment card. They found that the latter had a parameter closer to the true population parameters than its counterpart from the referendum method. Furthermore, they found that the parameter estimates from the payment card were also more efficient than those from the dichotomous choice method.

Recently, most scholarly discussion has focused on theoretical foundations, measurement, validation and calibration of CVM (Forsythe *et al*., 1994; Alberini, 1995; Kanninen, 1995; Ajzen *et al*., 1996; Chen and Randall, 1997; Haab and McConnell, 1997; Loomis *et al*., 1997; Cameron and Quiggin, 1998; Carson, 1998; Carson *et al*., 1998; Haab, 1998; Halvorsen and Sælensminde, 1998; Tolley and Fabian, 1998; Mansfield, 1999; Kerr, 2000; Cooper, 2002). However, since environmental resources are not sold in markets, this poses complications in its application. First, there are no observations on actual transactions from which researchers can infer individual preferences. Second, the utility consumers associate with these resources goes beyond direct use value (Mitchell and Carson, 1989).

Nevertheless, CVM present difficulties for a researcher. Often, it is difficult to explain to government officials, community leaders and interviewers the objectives of the study. The concepts of total economic value[2] and maximum willingness to pay (or minimum compensation that a respondent is willing to accept) can be difficult for the researcher to translate and for some non-economists to understand. Problems can arise when the researcher explains the extension of the hypothetical market. A hypothetical situation may not be real for respondents and responses might not reflect their true value of the hypothetical good or service. These difficulties represent the biases that CVM has to overcome.

2.1.2 Biases in Contingent Valuation Surveys

There are mainly three types of biases in contingent valuation surveys that often are mentioned in the literature: strategic bias, biases that misrepresent responses; starting point bias, biases that give some sort of indication of the value; and hypothetical bias, misrepresentation of the hypothetical market scenario. Mitchell and Carson (1989) also added the improper sampling design or execution of the survey and improper benefit aggregation as a source of bias. This section reviews these three main sources of biases and presents some of the actions to deal with them.

2.1.2.1 The Strategic Bias

The strategic bias may arise when an individual thinks that he or she may influence an investment or policy decision by not answering the interviewer's questions truthfully. Such strategic behavior may appear as a "free rider" problem, when the respondent thinks that he or she will enjoy the service regardless of whether he or she pays for it because someone else will ultimately pay for the service. On the other hand, if he or she believes that a government agency has already made the decision to install the service (e.g. public water stand posts in the community) and he or she believes that the purpose of the survey is for the agency to determine the amount people who will pay for the service in order to assess charges, the individual will have the incentive to understate his or her true willingness to pay (Mitchell and Carson, 1989; Whittington *et al*., 1990a; Schulze *et al*., 1996). As a result, to influence the outcome of a particular project, the respondents can provide values that are artificially high or low.

[2] The economic value of environmental assets can be broken down into a set of component parts. See David

Mitchell and Carson (1989) suggest that a well-designed survey providing the respondents a credible, more realistic and carefully designed hypothetical market will minimize the possibility of strategic bias. They argue that strategic behavior is not a significant problem for CV studies because the "free riding" problem is more an exception, not necessarily the rule. It is more important to deal with the possibility of meaningless values.

2.1.2.2 The Starting Point Bias

The starting point bias arises when the interviewer starts the questioning at an initial bid. A respondent who is unsure of an appropriate answer and wants to please the interviewer may interpret this initial process as a clue to the "correct" bid affecting his or her willingness to pay. This interpretation provides a meaningless value because it does not reflect respondents' true willingness to pay. Several studies have shown that this bias exists and that it can be important in terms of the outcome of the study (Rowe *et al.*, 1980; Brookshire and Crocker, 1981; Whitehead *et al.*, 1995). The bidding game and take-it-or-leave-it technique are the most predisposed to confront this problem. These techniques challenge respondents directly with a proposed amount or value; the respondent needs to accept it or reject it.

A solution to these types of problems could be the use of payment cards. Payment cards, as Mitchell and Carson (1989) pointed out, diminish the respondents' inconvenience to supply a WTP response. In addition to the payment card, another solution is to use a randomly chosen starting point (this will reduce the researcher starting

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W. Pearce. 1993. Economic Values and the Natural World. The MIT Press, Cambridge MA. pp 15-22.

point biases) which covers a pre-tested plausible range of WTP, and begins with a relatively large increase (or decline) and finishes with a smaller increase (or decline) to elicit respondents true WTP.

2.1.2.3 The Hypothetical Bias

The hypothetical bias may arise from two reasons. First, the respondent may not understand or correctly perceive the characteristics of the environmental good being described by the interviewer such as air quality, conservation of tropical forests, or preservation of endangered species that respondents may be willing to pay. This problem arises because it may be difficult for people to perceive the change in the quality of the environmental service (e.g. changes in the concentration of carbon dioxide or dissolved oxygen in the atmosphere). This may not be a particular problem in rural areas because it may be difficult for people to perceive such environmental changes and the hypothetical scenario may be too abstract for the respondents (Mitchell and Carson, 1989).

Whittington *et al*. (1990a) note, particularly in the context of developing countries, that individuals will not take contingent valuation questions seriously and will simply respond by giving whatever answer come to their mind. This is one of the reasons why many economists and survey researchers have been skeptical about the ability to conduct CVM surveys in developing countries. However, the hypothetical scenario of CVM may not be that abstract in developing countries, as it has been argued. It may be all too real, as Whittington *et al*. point out, if the donor organizations and government agencies that provide funding to the CVM surveys judge the results credible. These findings will likely be used in policy decisions. Contingent elicit values for private goods (such as improved water supply) are expected to exhibit greater reliability and predictive validity than those elicited for pubic goods. Whittington *et al*. (1990a) found in several studies with Third World countries that response rates for CVM are typically very high and respondents are often quite receptive to listening and considering the questions posed.

Second, hypothetical biases also arise as a result of the type of payment used in a hypothetical market, and arise when respondents do not suffer any cost from an inaccurate response to CV questions or they are not familiar with the method of payment. There are several forms of payment in hypothetical markets such as utility bills (Jordan and Elnagheeb, 1993); taxes (Whitehead *et al*., 1995); user fees (Halstead *et al*., 1991), and higher prices. Mitchell and Carson (1989) suggested that the selection of payment depends on the connection with the commodity or amenity to be valued. This payment should be viewed by the respondent as a real one, not subject to cheating or lying (Cho, 1996).

Other difficulties of using CVM arise with the interpretation of respondents' answers to abstract and hypothetical questions. Despite the limitations, the CVM is particularly useful in two settings. In the first situation, when one wants to estimate the willingness to pay for improvements in concrete social services like potable water supply, sewage disposal, or solid waste collection. In these cases the objective of the CVM survey is easy to identify, and respondents have a good idea of what they are being asked to value. In the second situation, researchers try to estimate and identify the willingness to pay by individuals and societies to protect or preserve ill-defined or very difficult to value benefits of no marketed good and services such as the valuation of biodiversity or preserving natural areas. When the benefits are grouped in categories such as existence values, bequest values, or option values, the CVM is about the only way that economists can estimate the willingness to pay to protect and preserve environmental goods (Carson, 1998). Carson (1998) suggests that a survey provides one means by which a respondent can obtain information about a good, and the choice offered in the survey provides an incentive to process that information[3].

Despite the limitations and problems, empirical studies using CV method have been used in several different areas ranging from health issues (Weaver *et al*., 1996); air and noise pollution control (Alberini *et al*., 1997; Kumar and Rao, 2001); recycling (Guagnano, 2001); energy accessibility and availability (Bose and Shukla, 2001); environmental conservation and restoration (Maxwell, 1994; Bromley, 1995; Lohr and Park, 1995; Blomquist and Whitehead, 1998; Reiser and Shechter, 1999; Loomis *et al*., 2000); recreation and tourism (Goodwin *et al*., 1993; Smith *et al*., 1997) creation and conservation of national parks and reserves (Scarpa *et al*., 2000) endangered species preservation and policy (MacMillan, *et al*., 2001); and government policies provisions (McLeod *et al*., 1994). Nonetheless, as Whittington et al. (1990b) pointed out, CV studies with water may be the more significant ones, not only in terms of "reality" of the hypothetical scenario of the study, but also due to the implications and expectations that may arise in rural and urban areas in different regions around the world where large financial inputs and human resources are being devoted to improve water supply (Raje *et al*., 2002).

[3] Carson (1998) argues that in a contingent valuation survey, respondents are not required to have perfect information set. Consumers in private goods markets routinely make decisions on incomplete information.

Empirical studies have shown the importance of CVM with water issues, and researchers have used it to measure the value of household water quality improvements in rural and urban areas. In these studies, different approaches and techniques were used. For example Whittington *et al*. (1990a) used CVM to estimate the WTP for water services in Southern Haiti. They used the bidding game approach during the study. They found that consumers were willing to pay for public standposts for drinking water an average of US$1.08 per month when the starting point bid was at US$ 0.40, US$1.20 per month when the starting bid was at US$ 1.00, and US$1.14 when the starting point bid was at US$1.40. Furthermore, they found that in cases of private connections for drinking water, consumers were willing to pay an average of US$ 1.34 per month when the start bid was at US$ 1.00, US$ 1.48 per month when the start bid was at US$ 2.00, and US$ 1.42 when the start bid was at US$ 3.00. A similar study was conducted by Whittington *et al*. (1991) in Onitsha, Nigeria. In this particular study, they wanted to estimate WTP for water by consumers in the area. As in the Southern Haiti study, they used the bidding game approach and found that a little more than 40 percent of the sample was willing to pay between US$ 0.11 and to US$ 0.23 per month.

In another study addressing water quality, Le Goffe (1995) wanted to estimate the demand for natural assets in France; he used CVM to estimate consumers' WTP for improved water salubrity and protection of aquatic ecosystems from eutrophication. This study was carried out in Brest, France in 1993, and used an 'open-ended' approach. A Tobit model was used to analyze the relationship between WTP and the independent variables. Barton (2002) used CVM in a study to estimate consumers' WTP for

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He adds that nothing in neoclassical economic theory requires consumers to be perfectly informed, only improvements in coastal water quality in two towns along the Pacific Coast of Costa Rica. He used a "double bounded" dichotomous choice approach, and found that conservative estimates of WTP across the sites were 2.5 to 3.2 percent of stated income.

In a study of willingness to pay for irrigation water, Bate and Dubourg (1997) used CVM to perform a 'net-back' analysis on irrigation water demand in the East Anglia region of the United Kingdom. They used the analysis to predict the effects of imposing a price-based allocation for irrigation water. This net-back model was used before estimating farmers' willingness to pay for the irrigation water, both with and without subsidies. Of the crops analyzed in their study, only potatoes proved to be profitable once the subsidies were removed. Potatoes presented a WTP of £880.04/ha for irrigation water. The opportunity cost of irrigation water was estimated to be £72.00/ha, thus a potato production would continue even if an efficient price for irrigation water were charged.

In studies focusing on water scarcity, Reddy (1999) used CVM to estimate willingness and ability to pay in six villages in a water-scarce region of Rajasthan State in Western India. The water use function was estimated using ordinary least square method, and the bidding game approach was used for the WTP questions. He found that villagers were willing to pay between Rs. 17/month up to Rs. 26/month. Reddy also found a correlation between scarcity of water and economic conditions with willingness to pay. Villages with higher scarcity of water and better economic conditions were willing to pay more for access to water than those villages with less scarcity and worse economic conditions. Raje *et al*. (2002) used CVM to estimate consumers' WTP for urban water

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that they make rational decisions based on the information set they possess.

supply services in India. They used a dichotomous choice--open ended approach. They used a logistic regression to analyze the relationship of WTP with the independent variables, and found that few consumers were willing to pay more than the initial bid of Rp 4.00 per cubic meter. Koss and Khawaja (2001) used a CVM to estimate how much consumers were willing to pay to avoid the occurrence of water shortages in Southern California. They used a 'double bounded' dichotomous choice model, and found that consumers are willing to pay as little as $11.67/month to avoid a 50 percent risk of shortage during the next 10 years, and as much as $16.92/month to avoid a 50 percent risk of shortage during the next 20 years.

2.2 The Linear Programming (LP) Approach

In a CVM study of the value of water or any other natural resource, participants are questioned directly about WTP. Other approaches to valuation are more indirect. For example, a linear programming of a representative farm can be developed and shadow prices analyzed to determine how much a resource like water is worth to farmers.

Linear programming (LP) represents one of the most significant additions of statistical and economic methodology of the middle 1900s[4]. It is a flexible and powerful tool of economic analysis that can be applied in most cases in which one is confronted with a choice of procedures or techniques and there is some standard (e.g. maximizing

[4] The development of linear programming began during the 1940s with the need of the military establishment to make efficient and timely decisions in planning, procurement, scheduling and deployment. See, Quirino Paris. 1991. An Economic Interpretation of Linear Programming. Ames: Iowa State University Press. 337 p.

profits or minimizing cost) for choosing an optimal mix of activities subject to constraints on available resources.

The development of LP and the simplex method[5] for solving LPs changed the outlook about the formulation of large-scale problems and about their solution. Linear programming is the most widely used mathematical programming method, and it seems that there is not a real limit on the size of problems that can be solved in a reasonable time and with an affordable cost[6].

Mathematical programming models long have been used by economists to analyze agricultural economies and to examine natural resource issues. When the geographic scope of analysis is national or regional, non-linear formulations are sometimes required, to reflect inverse relationships between the prices of goods and services and consumption levels as well as positive relationships between input prices and the use of inputs. However, when the geographic scope of a study is limited, then a LP model, which rests on the assumption of perfectly elastic demand for output and perfectly elastic input supplies, is suitable (Paris, 1991). The handful of communities that comprise the setting for this research certainly can be regarded as small relative to Ecuadorian markets for agricultural commodities, labor, and other goods, services, and factors of production. Accordingly, it is appropriate to elaborate a LP, as opposed to a more complex model in which the assumption of perfect elasticity is relaxed.

Any LP consists of an objective function, a matrix of coefficients describing production, as well as fixed endowments of various resources (Paris, 1991). The

[5] The simplex method is an algorithm for efficiently computing numerical solutions to linear programming problems, was developed by George Dantzig in 1947. See, Dennis P. Dykstra. 1984. Mathematical

objective is the net value of agricultural production and, so, the objective function comprises a linear function of production levels for various crops as well as employment levels for various inputs. These production and employment levels are the variables that are identified during a run of the LP. The objective-function coefficients of these variables are their respective market prices, which are treated as fixed because of the assumption of perfect elasticity. The linear objective is to be maximized subject to a series of linear equations reflecting the inputs required to produce various crops as well as the natural resources (i.e., land and water) available for agricultural production in various communities. In terms of vectors and matrices the problem may be state as follows (Van de Panne, 1975):

$$Max \qquad f = p'x \tag{2.1}$$

$$\text{subject to} \qquad \begin{aligned} Ax &\le b, \\ x &\ge 0. \end{aligned} \tag{2.2}$$

where A is the m $\times$ n of the coefficients of the variables in the system,

$$a = \begin{bmatrix} a_{11}a_{12}\cdots a_{1n} \\ a_{21}a_{22}\cdots a_{2n} \\ \vdots \\ a_{m1}a_{m2}\cdots a_{m} \end{bmatrix}, \tag{2.3}$$

and b is column of m elements containing the constant term coefficients,

$$b = \begin{bmatrix} b_1 \\ b_2 \\ \vdots \\ b_m \end{bmatrix}, \tag{2.4}$$

Programming for Natural Resource Management. McGraw Hill Series in Forest Resources. McGraw-Hill Book Company, New York.

while x is the column vector of n x-variables,

$$x = \begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_n \end{bmatrix}. \qquad (2.5)$$

Once the model is operational, it can be used to evaluate the consequences of public policy changes, improvements in natural resource management, and changes in general economic conditions. For example, separate LPs can be created for a sample of the communities where SANREM is active. Running these LP models separately and individually will simulate current conditions. A combined LP – one in which resources like water are automatically transferred among communities, if the aggregate net gains from doing so are positive – can then be run to simulate the impacts of water law reform.

Any LP run contains a report of shadow prices for all resource endowments. These represent a benchmark for evaluating, say, watershed management initiatives that succeed in alleviating shortages of irrigation water. The LP user can also carry out sensitivity analysis, specifying different resource endowments for example. By the same token, it would be interesting to investigate the shadow prices of community labor, comparing these for example with wages earned in nearby floricultural enterprises and other agribusinesses. If a major discrepancy is found, it would make sense to re-run the LP model with diminished labor endowments so that community-level consequences of increased labor mobility can be examined.

Shadow prices can be used by donor organizations to allocate their financial funding efficiently for each community. It can allow the donors to know the price of

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[6] D.P. Dykstra. 1984, p. 15.

irrigation water to be paid by the householders in order to optimize the expected return from the project. It will also determine where, in terms of location and activity, the water should be allocated to maximize the returns. The latter benefit of a LP model is also valid for individual householders or recipients of donor program's investment.

Policy-makers, with the assistance of donor organizations and the participation of local communities, could establish tradable property rights for water. For most commodities and inputs, allocation by means of markets has been the favored solution of economists and international organizations such as the World Bank and International Monetary Fund[7]. Establishment of tradable property rights could play an important role in improving the efficiency, equity, and sustainability of water use[8].

The benefits of these types of policies will be, among others, the empowerment of water users by requiring their consent to any reallocation of water and compensation for any water transferred. If well-defined rights are established, the water users could invest in water-saving technology knowing that they would benefit from the investment. It will also induce water users to consider the full opportunity cost of water, including its value in alternative uses, thus providing incentives to efficiently use water and to gain additional income through the sale of saved water. A system of tradable water rights would provide incentives for water users to take into account the external costs imposed by their water use, reducing the pressure to degrade resources. Finally,

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[7] Coase (1960) formalized this contention, showing that market allocation will be efficient, given well defined and nonattenuated initial property rights and zero transaction costs. See, R. H. Coase. 1960. The Problem of Social Cost. *The Journal of Law & Economics*. Vol 3, pp. 1-44. The assumption of zero transaction costs does not hold true for water rights, where information, transportation, and enforcement costs may be in fact higher than in most input markets.

[8] Mark W. Rosegrant, and Hans P. Biswanger. 1994. Markets in Tradable Water Rights: Potential for Efficiency Gains in Developing Country Water Resource Allocation. World Development, Vol 22 No 11 pp. 1613-1625.

allocation of water through tradable rights provides a maximum flexibility in responding to changes in crop prices and water values as demand patterns and comparative advantage change. Once responses to changes of prices and values are set, the diversification of cropping may proceed[9].

However, the use of LP models in the analysis of agricultural projects is not free of difficulties. According to Gittinger (1982), the LP model is a more complex methodology that requires more formal input-output data than simple budgeting does, and it also has serious methodological limitation in the analysis. For instance, the LP model has problems dealing with risk. Sources of risk and uncertainty, such as the variability of soils between farms, water availability in different areas of the farm, and other farm-level variations, are usually nor reflected very well in a LP model.

Despite these difficulties, empirical studies have shown that LP is a reliable tool to determine the efficient use of natural resources. The LP model has been used in forestry and most recently with studies of water allocation. Llewelyn and Williams (1996) used a linear programming model to estimate technical efficiencies of irrigation water systems in Indonesia. The LP model helped to determine the excessive amount of inputs that farmers were using. This inefficient use of inputs may be due to past subsidization programs and policies implemented by the Government of Indonesia.

In another study, Pannell and Nordblom (1998) used a LP model to estimate the impacts of risk aversion on farm management practices. The risk aversion was modeled within the farm's utility function. They found that farmers could reduce their

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[9] Rosegrant and Biswanger, 1994, p 1614-1615.

risk by adopting suitable management practices without making large sacrifices in expected income.

In a Spanish study, Berbel and Gómez-Limón (2000) used a LP model to measure irrigation water in rural communities around Sevilla and Valencia. They wanted to know if water pricing would be an effective instrument for controlling water overuse. The results showed that water pricing was not an effective instrument because water consumption did not fall until prices reached a very high level, at which farm point income and agricultural labor would be negatively affected.

In a study conducted by Haouari and Azaiez (2001) a LP model was proposed to determine the optimal cropping patterns under water deficit conditions. They developed this model using hypothetical data. Their model consisted of a multi-phase decision process, which allowed the selection of the most profitable crops, as well as the optimal area and efficient allocation of water.

In a study in a setting where water is scarce, Salman *et al*. (2001) used a LP model to analyze the seasonal allocation of irrigation water and their impact on agricultural production and income in the Jordan Valley. The model was designed to serve as a decision-making tool for policy makers at the district and regional level. They found that the model closely approximates the actual responses of consumers to water price increases. As a result, the model can be used to determine the inter-seasonal allocation of water in regions where water is scarce.

In a similar study in Jordan, Doppler et al. (2002) found a potential of a substantial return from agriculture if there is an implementation of different cropping patterns and water allocation. They used a LP model to estimate solutions for maximizing and minimizing gross margins, and found that the risk associated with gross margins is quite elastic in terms of the demand for water.

Data requirements for estimating the above contingent valuation and linear programming methodologies include household socioeconomic characteristics, characteristics of all sources in the choice set, and the choice decisions. The choice decisions include the source of water and the quantity of water demanded by a household from that source. However, it is extremely difficult to collect reliable information on the quantity of water demanded in a field because water containers of different sizes are commonly used in the rural areas to collect water and the water is carried out from the containers by different persons in a household for different purposes and at different times. Additionally, consumers may have little idea about the volume of water used.

The estimation of volumes of water used in a household is a difficult task even for experts interviewing and carrying out socioeconomic surveys (Mu, 1988). In a situation where people do not know how much water is used and a new water system is installed, it would be impossible to ask how much water they would consume in the future. As a result, it is very unlikely that reliable information regarding water consumption can be obtained from a survey. This is why a demand curve of water is not included in the present study. The present study focuses instead on the optimal farming patterns of subsistence agriculture with and without irrigation water, how much consumers are willing to pay for improving the reliability, and the quality of current drinking water supply systems.

CHAPTER 3

THE STUDY AREA

Cotacachi is located at 0°22'00" N latitude and 78°20'10" W longitude, in the southeastern part of the province of Imbabura, Ecuador (Figure 3.1). It is 64.6 miles northwest of Quito and immediately southeast of the Cotacachi-Cayapas Ecological Reserve, which is protected due to an incredibly rich biodiversity. This area shows evidence of having one of the highest levels of endemism (i.e. the presence of species found nowhere else) of any protected site in the world. In fact, 20 percent of endemic species of plants of Ecuador are located here (Ecociencia, 2002). The Cotacachi-Cayapas Ecological Reserve has been designated as an international biodiversity hot spot. This area distinguishes itself for having a variety of life zones including the hydrological critical high zone páramo at almost 5000 meters above sea level (masl).

The peasant communities involved in this study are located between 2,800 masl to 3,800 masl of the Ambi watershed system, which is in the upper part of the Mira River drainage basin (Figure 3.2). The area has an average of 1308 mm of rainfall, with a dry season running from June to September. The mean temperature is 18°C, with low readings averaging 10-12°C during the rainy season between October and May. The

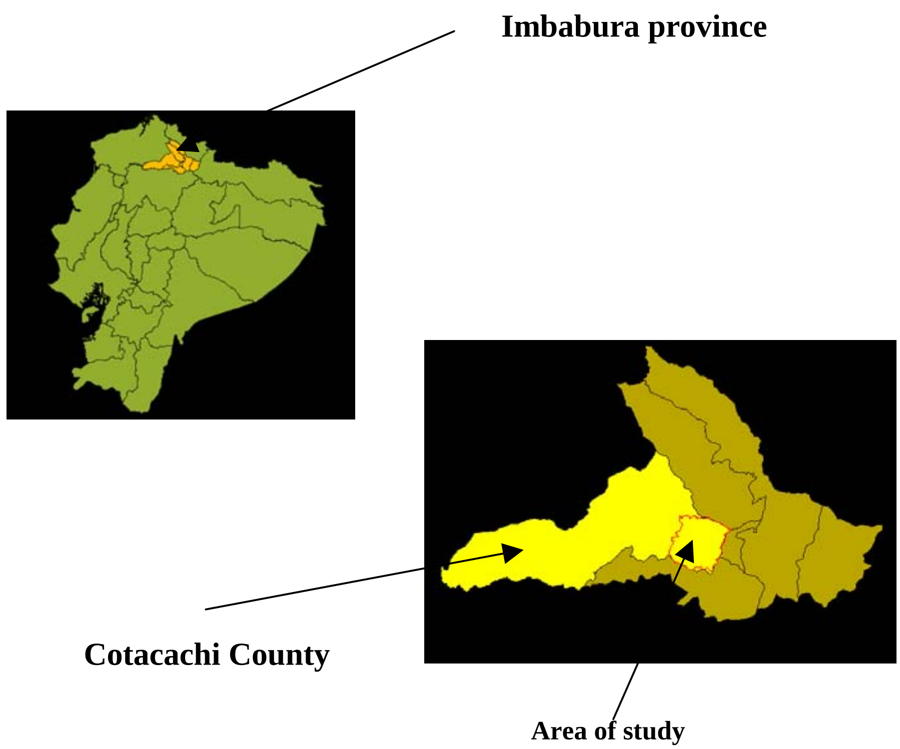

Figure 3.1. Area of Study (Source: SANREM-CRSP Andes Project)

difference in altitude clearly separates the peasant communities that have access to irrigation water and those that do not. The latter groups are generally at higher elevations, where there are also frost risks.

The Ambi River watershed system is a functional unit established by physical relationships where upstream land use can incite a chain of environmental problems affecting downstream areas. Furthermore, this watershed system holds multiple, interconnected natural resources such as soil, water and vegetation. Impacts on one

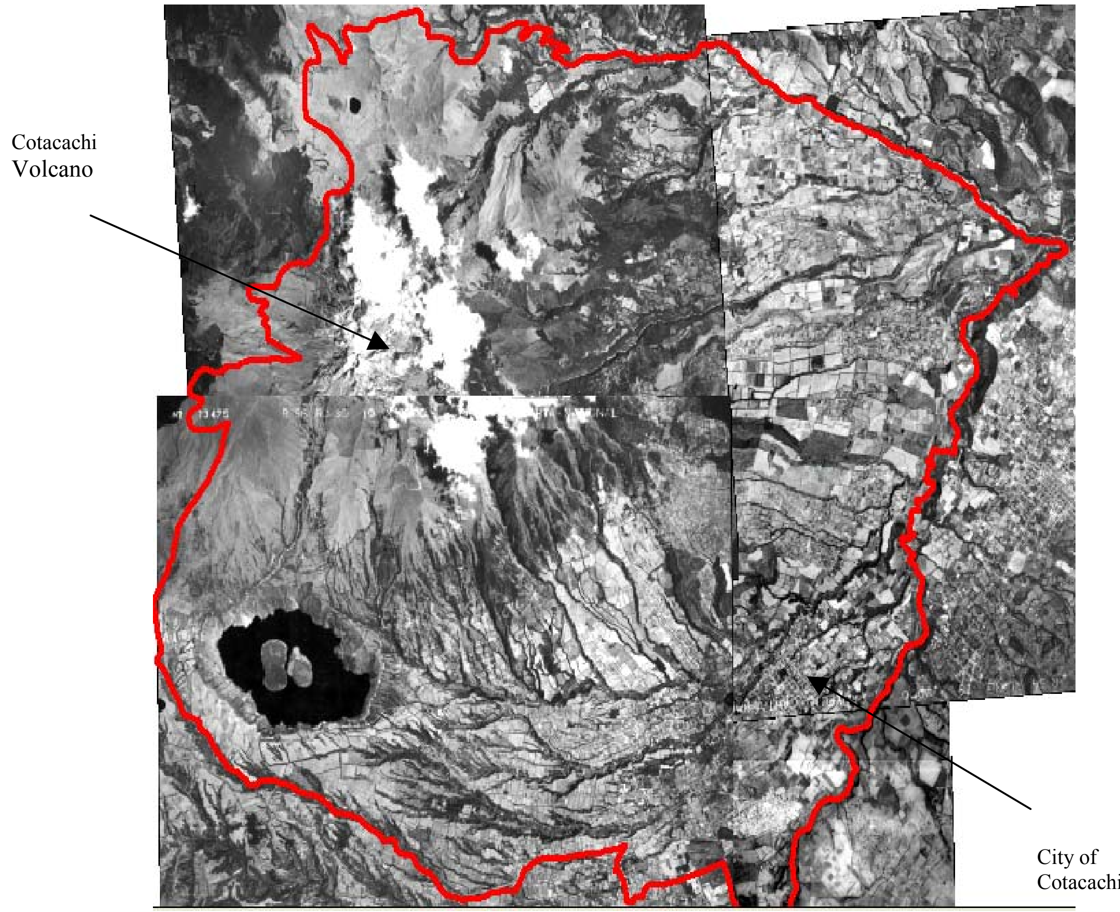

Figure 3.2. Aerial Photography of the Area of Study and upper Ambi watershed (Source: SANREM-CRSP Andes Project)

resource invariably affect the status of others. Soils in upland settings are typically fragile in structure, and are easily eroded once permanent cover is disturbed or removed. Slopes tend to be very steep, which facilitates the erosion process and limits land-use capacity. Soils types in the area of study are Eutroneps-Vitroneps-Inceptisoles; typically the soils have good to excessive drainage, are slightly acidic, have low erosion levels, and are of medium-high to high fertility. Productivity loss may not be noticeable until the topsoil has been depleted and the infertile subsoil exposed, as has been suggested by Lal (2000). Conversely, soils in lowlands are shallow and fragile, and are very erosive yet fertile. Downstream lands are the recipients of excess sedimentation, unregulated storm flows, and reduction of downstream flow due to upstream diversion of water into irrigation systems.

The Ambi watershed and the areas drained by its upper tributaries, such as the Pichaví River and the Arrayanes, Chilcapamba, and Morochos gorges, have environmental services that are threatened by urban expansion, a growing floral exports industry, and poor quality pasture lands. At each contour slice of this watershed system, examples of sustainable and unsustainable land use practices can be found.

3.1 Human Communities

Human adaptation to the diverse Andean agro-ecological zones has resulted in vertical arrangements of production regimes, population movements, and human settlements. Indigenous Quechua-speaking populations dominate the highlands of this area. The communities of Cotacachi were chosen to participate in this study partially due to their dependence on mountain springs with no treatment to supply their needs of safe drinking water and irrigation. The Indian communities practice traditional agriculture and depend on artisanal crafts and labor migration while the town people are merchants. Forty-one indigenous communities are located at elevations above the town of Cotacachi. All of these belong to the campesino organization named the Union Organizaciones de Campesinos de Cotacachi (UNORCAC).

UNORCAC was created in 1977 and legally established in 1980. The main objective of this organization is to improve socio-economic conditions for its indigenous and campesino members. UNORCAC implements programs, projects, and activities with the participation of communities. They work in the areas of health, environment, education, communication, and the construction of community infrastructure (water, roads, and electricity). They also provide training programs in socio-organizational skills, agricultural and livestock management, cultural revitalization, sports and recreation. The organization of UNORCAC is very structured and systematic. The General Assembly is the highest hierarchical branch and it is here where general resolutions and decisions take place. The UNORCAC has an Executive Council that carries out the decisions and resolutions of the General Assembly. The Executive Committee is the administrative branch of the organization and its responsibility is to monitor, evaluate and follow up the implementation of plans and programs in which UNORCAC is involved.

In essence, UNORCAC plays the role of a big advisory committee and consultative group that channels most of the international aid through different projects to the communities, which are very organized and participative. Each community manages its own water and other resources and has general meetings to discuss issues regarding the use and allocation of aid and resources. In each meeting, community members try to reach a consensus over what steps they might take to achieve a specific goal. Majority rule is also an option to settle the most difficult issues, but they use consensus first before imposing any measure or rule on anyone.

The communities have established several rules regarding resource use and participation. In terms of drinking water accessibility and use, communities first agree to have access, and then they establish the mechanisms of how members can have access to the drinking water system. All potential beneficiaries of the water system agree to build the systems, including channels, pipes, and connection to each participant household. The communities have three different ways that members can participate in the construction of the system. First, members can provide labor when the system arrives to their communities. Second, if members cannot help in the construction, they hire outside labor to help in the construction and pay wages and other compensation. Third, if a member cannot provide labor, they can provide food and beverages for all members that are building the system. Additionally, communities have implemented a series of penalties imposed on any member who violates these predetermined rules, penalties that can involve forbidding the right of using a particular common resource such as water.

At present, agriculture dominates the lives of the communities in the area. The main crops are potato, barley and quinoa (a protein-rich grain indigenous to the Andes) in the upper part of the watershed system, and maize, beans, and pasture in the lowlands. Recently, big farms around the area are increasingly turning to export floriculture (i.e. cut flower production) and a shift is taking place on small farms to crops like onions and cabbage, which are sold in the local markets. Environmental problems perceived by local people include deforestation, water quality and quantity deterioration, and declining agricultural productivity.

3.2 International Support for Water Resource Development

The global community of nations through the United Nations' Global Mountain Initiative Chapter 13, Agenda 21, has recognized the importance of watershed management. Recent literature has shown an increasing number of examples of watershed management by local communities. It is now well documented that for several thousand years farmers have conserved soil and water to sustain agricultural production in many varied contexts. Rural communities in several locations around the world have established their own arrangements for containing natural resource conflicts that, left unsolved, would diminish agricultural output. There is now emerging evidence that regenerative and resource-conserving technologies and practices can bring both environmental and economic benefits for farmers and communities (Ostrom, 1990, 1992; Hinchcliffe *et al*., 1995; Shaxson, 1996; Pretty and Shah, 1997). Successful projects share several common elements, including giving farmers a central role in the innovation and adaptation of resource-conserving technologies.

An example of a project with this feature is the Sustainable Agriculture and Natural Resource Management (SANREM) Cooperative Research Support Program (CRSP), which got under way in the early 1990s. The SANREM-CRSP is supported by the U.S. Agency for International Development (USAID), which funds participatory ventures that can address environmental problems. The SANREM-CRSP Andes Project in Ecuador is part of a multidisciplinary, multi-institutional project for promoting sustainable management of mountain environments around the world. The main objective of the SANREM-CRSP Andes Project is to develop information and methods in order to help local communities make long-term natural resource management decisions.

However, the success of collective action programs for the conservation and sustainable management of watershed systems will depend upon incentives that landholders will receive. An important part of the SANREM-CRSP Andes Project is to address water quality and quantity problem in local communities.

Between 1999 and 2000, the SANREM-CRSP Andes Project carried out a study to find out the level of bacteriological contamination of the upper Ambi River watershed system as part of the water quality analysis component of the project. SANREM-CRSP scientists from Auburn University and the Pontificia Universidad Católica del Ecuador collected samples from the majority of communities affiliated with UNORCAC. More than three hundred samples were collected and analyzed. Of these, more than 34 percent revealed contamination of E. coli at levels that are unhealthy for human consumption (Duncan and Ruiz-Córdova, 2001). They suggest that this contamination is located in the watershed.

The communities of Cotacachi have access to drinking water from three riverbeds. One of the sources of drinkable water was developed with support from SWISAID (Switzerland). This project, named Cambugan, started in 1997 and was designed to provide water for domestic consumption for six communities with 490 families. The six communities and UNORCAC agreed to assume part of the cost of installing pipes lines and maintaining the system. The members of communities that participate in this project built more than 42 km of water pipelines and connections to individual households committing itself to provide labor to the project. In other words, members of each community would commit themselves to the construction of the water pipelines, or providing meals and drinks to workers when they work in their community, or providing outside labor and its cost, covering the wages and other forms of compensation to these workers. If a household of any community participating in this project did not provide any form of labor described, it would not have access to the drinkable water system.

Households also agreed to pay a fee in order to maintain the system. As of 1997, households were paying 9,000 Sucres/month (former Ecuadorian currency) or about 0.30 dollars for 150 liters per second (l/s) of water. Beyond that level, 750 Sucres or about 0.03 dollars were charged for each 15 l/s of additional water. On January 9, 2000 the Ecuadorian government announced the intention to adopt the U.S. dollar as legal tender and it was approved by the congress on Mar 13, 2000[10]. As a result of the dollarization[11] process, the communities needed to adjust their fees for water use. The communities agreed to increase the fee to one dollar/month for the amount of water pre-established and 0.15 dollars per 15 l/s for additional water households might use over the limit. However, only communities that were part of the Cambugan project have adjusted water fees to the dollarization process. The other two programs remain with the original values of 0.30 dollars for 150 g/s of water and 0.03 dollars for each 15 l/s over the limit.

The programs have run successfully regarding the construction and maintenance of the system. Unfortunately, as SANREM-CRSP scientists have proved, the quality of water is poor and households have raised concerns about the quantity as

[10] By the time of the announcement of dollarization, Ecuador was in a deep depression, with GDP shrinking by an estimated 7 percent, the value of the Sucre dropped by 67 percent, and the country failed to pay part of its $6.5 billion in Brady and Eurobond debt, shocking investors worldwide.

[11] The term “dollarization” is shorthand for the use of any foreign currency by another country for all financial transactions, except the need of the coins. It typically arises under conditions of high inflation or hyperinflation when the high cost of using domestic currency for transactions prompts the public to look for available alternatives. See, IMF Staff Country Report No. 00/125. International Monetary Fund, Washington D.C.

well. In this sense, this study seeks to estimate how much households would be willing to pay to improve the quality and quantity of their drinkable water, as well as irrigation water. The WTP estimates are needed for the evaluation of investments that will make ware supplies cleaner and more reliable.

CHAPTER 4

DATA COLLECTION AND DATA SUMMARY

In keeping with the general focus of SANREM-CRSP's project in Ecuador, the primary goal of the socio-economic survey conducted in rural communities around Cotacachi was to collect the data needed to answer research questions and to test hypotheses.

The communities involved in this study are participating in SANREM-CRSP's Andes project. As indicated in the previous chapter, communities depend on untreated spring water to supply household as well as irrigation needs. Concerns about the quality of drinking water are serious. Likewise, the availability of water for irrigation is diminishing. These negative changes are generally perceived to have taken place in recent decades, as population density has increased and watersheds have deteriorated.

The database collected under the auspices of SANREM-CRSP Andes project as well as the socio-economic survey carried out for this study have been used to analyze and estimate the marginal value of water, land, and labor of the communities of the Cotacachi region. The insights gained from this analysis will help to strengthen local institutions, such as UNORCAC, so that communities are better able to organize cooperative initiatives aimed at protecting watersheds and maintaining water quality. To achieve this, a structured questionnaire containing seven sections was designed. After the design of the questionnaire, a household sample was identified for all communities involved in the SANREM-CRSP Andes project. Once the household sample was determined, a pre-test of the questionnaire took place in order to reduce possible bias and misunderstandings, followed by the survey per se of the households involved in this research. An account of all these steps in the research process is contained in this chapter, which concludes with a description of the data collected in the survey.

4.1 Questionnaire Structure

The questionnaire (Appendix) was designed in a structured manner based on information from three different sources. One of these was the International Forestry Resources and Institutions (IFRI) Research Program at Indiana University, which combines careful study of socioeconomic, institutional, and biological factors in a long-term, comparative program of research (Ostrom, 1998). Data collection of this research program encompasses biophysical measures of forest conditions, climatic and soil conditions, demographic information, and economic indicators, as well as details about institutions affecting use of forest resources. The second source of information was the Rural Finance Program of the Agriculture, Environment and Resource Economics of The Ohio State University. This program has been working for several years in El Salvador and other Latin American countries and examines the outreach and sustainability of rural and micro finance programs and interactions among financial, labor and land markets. The last source of information was the Laboratories for Population Statistics of The University of North Carolina, Chapel Hill. This laboratory designed a structured questionnaire mainly to answer demographic and migration factors that affect the use of land (Bilsborrow et al., 1982).

The questionnaire consisted of seven sections dealing with demographic and social-economic aspects of the household. These include basic demographic, occupational, and educational data for the family members; family income and prices of outputs and inputs; labor availability and wages; income from agricultural or non-agricultural activities and credit availability; social capital, through participation on community's meetings; and household's willingness to pay for potable water and irrigation water.

The first section (questions 1 through 8) contains questions relating to demographic information, such as family size, age, sex, marital status, and education profile of each member of the household. Additionally, this section collects data on distance from the household to its closest market, as well as the most important market for the household. It also asks what type of transportation a household's member use and the time needed to get to that primary market. Finally, this section cross-examines the source of income and occupation for each adult member of the household. This information is used to determine age distribution and educational attainment, which are important in terms of social capital. Furthermore, it helps to determine the source of income per family and the opportunity cost of reaching the market.

The second section (questions 9 through 20) focuses mainly on household agricultural production. If a household has more than one parcel of land (questions 21 through 33), parcel-specific questions are repeated as many times as necessary. The section cross-examines land ownership, physical characteristics of household land and a farmer's perception of soil quality. It also includes questions about what is the main source of water to irrigate household land, as well as household members' participation in the construction and maintenance of irrigation channels (but only if farmers have access to irrigation water, otherwise these questions were skipped). The section also includes questions regarding plowing type and frequency. Finally, the section asks about the type of crops that each household grows, as well as yearly yields, and how much of production is sold and the price received for the transaction. The data collected in this section helps to determine land use, source of agricultural revenues, land ownership, and community participation, which is an important as part of social capital.

The third section (questions 34 through 41) focuses on agricultural inputs and outputs. As part of agricultural inputs, the section asks about the amount of fertilizers, seeds and pesticides used on the land. Also collected is information on minor annual production, the portion sold, and prices. Additionally, this section deals with animal production. It cross-examines what type of animals the farmer has, quantity of each sort of animal, animal sales, as well as animal expenses, such as veterinary cost, feed, and additional expenses for animal productivity. It also asks about animal sub-products that farmers obtain and their commercialization; products, prices, and quantity commercialized. As in the second section, this section helps to determine household income, and other production activities.

The fourth section (questions 42 through 47) focuses mainly on labor availability and cross-examines how many agricultural workers the household hires in each crop season and at what wage. It does not include family labor, which is assumed to be involved in the household economic activities. This section also asks how many hours of this extra labor are used, and what compensation (e.g. meals) workers receive other than salary. In the case that there is no hiring of extra labor, questions about participation in community “mingas” are asked so that the opportunity cost of labor for each household can be estimated. This section also cross-examines how many hours of different types of plowing sources (animal, mechanical, or human) are rented and the cost. If household members themselves engage in plowing, their time is included in the opportunity cost of this activity. Additionally, in this section seasonal agricultural activities are determined, such as plowing, sowing and harvest.

The fifth section (questions 48 through 53) deals with household income. It cross-examines sources of income from agriculture and other activities, as well as the amount per month that household members receive from their activities. It also includes the household’s access to credit, sources of credit, and the purposes for which this credit was requested. Additionally, this section asks about technological acquisitions for agricultural or livestock activities. This section allows for estimation of the additional household income that comes from activities other than agriculture and livestock rising.

The sixth section (questions 54 through 61) examines community participation, as indicated by involvement in community activities and institutions. It cross-examines for how long household members have been participating in community meetings and activities, and if household members hold or have held leadership or executive positions. This section has questions regarding the time and frequency of community meetings, as well as household participation and perception of other members' participation. This section allows for estimation of community participation and helps to answer one of the research questions, that is, whether community participation affects the allocation of water and land in the community.

Finally, the seventh section (questions 62 through 79) contains questions needed to collect information on various aspects of water supplies and use. The contingent valuation method (CVM) was used in this section to collect information by asking the respondent directly how much he would be willing to pay (WTP) for improved water supply and quality in the context of a hypothetical market situation. The use of CVM in the valuation of rural drinking water is well established in the literature (Mitchell and Carson, 1989; Whittington et al., 1990; Reddy, 1995a, 1999b). In other studies, CVM was used to estimate the respondents' WTP for access to drinking water. In contrast, in this study CVM is being use to evaluate WTP for a change in water quality due to improvements in drinking water systems that currently are not filtered. There is not market in the region yielding information for evaluating these improvements. Additionally, existing water markets are highly distorted by subsidies and other government policies. This means that prices are a poor measure of WTP.

Before asking household WTP questions, this section asks about the household's perception of water issues such as availability, quality, and participation in the construction and maintenance of drinking water pipes and irrigation channels. This helps to avoid any bias regarding the hypothetical situation of WTP, as well as the strategic bias if the household thinks that its answers may influence policy and hence may avoid giving true answers. Using household perception of water issues helps to get a WTP that truthfully reflects the respondent's intentions.

After establishing a household's perceptions of community water problems, questions about household WTP followed after a statement establishing the hypothetical situation of a project to improve water supply and quality. The statement is as follows:

> *"I am going to ask you several questions to know if you or another adult member of your household would be willing to support a project to construct and improve current pipe water system and irrigation channels, Your name and information will not be shared with anyone, and your answers will be completely confidential and will not be associated with your name or the name of any other member of your household.*
>
> *This part of the questionnaire seeks to know how important water is for you and other members of your household. This would help a donor organization to know the level of participation of your community would have if a project to improve water quality and supply would take place. Furthermore, it would help the donor organization to know how members of the community would be willing to cover part of the cost of construction, maintenance, and operation of this project. This project would improve the quality of water from the current system, and its supply along the year. Furthermore, it would also eliminate any waste of irrigation water by using concrete channels and metal gates for water distribution for each member of the community.*

Members of your own community, who would be elected, would be in charge of the management of these new systems for potable and irrigation water. To achieve this, the donor organization would like to know how much are you willing to pay for these projects to guarantee their success.

However, it is very important for the donor organization that you answer this questions truthfully in order to decide whether or not implement these projects"

After this statement, WTP questions follow with a starting point of 1, 3, or 5 dollars per month for a potable water project and 10, 30 or 50 dollars per year as an annual fee for an irrigation project. These predetermined bids were randomly selected for each household and a dichotomous answer (yes/no) were provided as alternatives for the household. After the initial bid, and if the household is willing to pay that bid, the bid is raised by one dollar and the household is asked again if it is willing or not to pay for the new bid. Once the survey respondent decides if it is willing or not to pay for this new bid, he will be asked how much is the maximum amount that he is willing to pay. If the household is not willing to pay the initial bid, the bid is reduced by half and the household is asked again if he is willing to pay for the new bid. Then, the questionnaire proceeds to ask how much is the minimum amount the respondent is willing to pay.

In order to improve the reliability of WTP estimates, due caution was taken. As Whittington et al. (1990) point out, the main biases that may affect CVM estimates include strategic behavior, hypothetical behavior, and starting point biases. The first two biases did not arise because households were very familiar with water and its associated problems. Having different starting point bids for each household that were selected randomly eliminated the starting point bias. An important advantage in this region is the fact that all communities are familiar with water markets and very familiar with water prices.

4.2 Sample Selection

Originally eight communities were selected from the area where the SANREM-CRSP Andes project is currently taken place. These communities were stratified according to altitude; those above 3,200 meters above sea level (masl) and those below 3,200 masl. This altitude makes an important difference for agriculture. As a rule, communities below 3,200 masl have access to irrigation water, while those above this altitude do not. In addition, frost risks are greater at higher altitudes. Of the original eight communities, five were above 3,200 masl. Two communities below this altitude, which have not been involved in the SANREM-CRSP, were added in order to have equal numbers with and without irrigation water.

A random sample of households was identified in each of the ten communities. Each member of the community was given a digital number and then randomly selected. Once the household sample was selected, access to drinking water was specified for each household, as well as its seasonal availability and quality.

Detailed household-level information was collected from 80 randomly selected households spread over the 10 communities in the area. Information was gathered with the help of structured questionnaires at the household level, as well as crosschecks on the data obtained from various informal interviews with local leaders, officials of the UNORCAC, and participants in local markets.

4.3 Pre-testing the Questionnaire and the Survey

Prior to carrying out the survey, a field pre-test was held with three different families of communities not involved in the study. These families were relatively young and the adults all have elementary school diplomas. Additionally, members of UNORCAC as well as SANREM promoters, who are directly involved in different projects in each community, gave valuable comments and suggestions for the survey. The pretest of the questionnaire took place between December 7 and 10, 2001. The main changes in the original questionnaire had to do with language, in the sense of using words simpler to understand, as well as names of products that are familiar to participants. During this time, officials of UNORCAC were concerned about questions about land ownership. As a result of their concerns, a statement was added verbally in each interview explaining that these questions would not affect in any way current land tenants. Furthermore, assurance was given that names and addresses of participants will disappear once the analysis starts.

The 80 households randomly selected from the ten communities participating in this research were surveyed between September 1st and 25th, 2002. Interviews were conducted throughout the day with one adult member of each household. The interviews were made person to person with the assistance of one member of SANREM-CRSP's local staff, which was particularly important to ease the interview because households in the region have been bombarded recently with surveys and census forms from local and national agencies and NGO's.

Three additional families were pre-tested days before the survey took place. These additional families were added because questions about participants' willingness to pay for improvements of potable and irrigation water were not ready during the first pretest. As a result of these pretests and comments of UNORCAC and SANREM personnel, necessary changes were made in the questionnaire, changes that it made easier for each participant to be interviewed and limited the questionnaire's biases.

During the interviews, several problems arose with some questions regarding the use of water, particularly those that estimate the amount of water used in different activities such as cooking, bathing, and the washing of clothes. This problem was not noticed during the pretest. Asking participants how many buckets of water they use for each activity, and then establishing an approximate percent of water use solved the problem.

Additional problems were encountered with participation of randomly selected households. Specifically, in one of the biggest communities in terms of population, most of the randomly selected household did not want to participate. As a result, two extra communities were added to the eight originally selected to complement the study sample. Members of these two new communities were selected randomly as in the other communities. Despite this problem, the survey was conducted successfully.

4.4 Survey Results

The questionnaire used in the survey was designed to measure household annual income per capita (*INC*) as a variable that depends on other factors of production, including use of land and water. For each household, on-farm and off-farm activities were recorded and saved as part of annual income (Table 4.1). Income per capita is seen as a function of wealth (asset holding such as land ownership is seen as part of household wealth), other production activities, market participation, and community participation.

The communities of Cotacachi have experienced rapid population growth in the last 30 years. Average family size (*FAMILY*) is 6 members (std. Dev. 2.2118), two more than the average size of families in Ecuador according to the last census (INEC, 2002). This variable is important because each member participates in household

Household activities	Mean	std. Dev.	minimum	maximum	Proportion of sample population
Farm production	125.89	276.69	0	1,400.00	0.35
Herd production	110.91	216.77	0	1,410.00	0.51
Dairy products	215.31	568.08	0	3,650.00	0.33
Textiles sales	361.2	1407.55	0	9,600.00	0.21
External family assistance	4.65	29.24	0	192.00	0.03
Off-farm labor	870.3	715.21	0	3,600.00	0.79
Groceries store	57	276.01	0	2,160.00	0.06

Table 4.1. Sources of annual income (U.S. dollars) in the Cotacachi Communities

economic activities, and then is expected to have an impact on household annual income.

Land is an important measure of wealth and an important factor of production and thus has a direct impact on household annual income. The size of farms (*FARM*) averages 3.03 ha per household (std. Dev. 4.3646). The details of land distribution of selected households are summarized in Table 4.2.

Communities	**No of HH**	**No of sample HH**	**Marginal (0-0.5 ha)**	**Small (0.5-1ha)**	**Semi-Medium (1-5 ha)**	**Medium (5-10 ha)**	**Large (> 10 ha)**	**Community area (ha)**	**Mean**	**Std. Dev.**
Upland non-irrigation										
Arrayanes	32	12	0	3	9	0	0	80	2.68	2.42
Italqui	64	8	1	3	4	0	0	120	1.67	1.19
Morochos	120	17	5	3	8	1	0	300	1.69	1.59
Topo Grande	120	6	0	1	5	0	0	200	2.61	1.41
Ugshapungo	20	6	0	0	1	1	4	200	12.96	7.04
Lowland irrigation										
Chilcapamba[1]	80	7	1	1	5	0	0	120	1.59	0.79
Piavi San Pedro	32	5	2	2	1	0	0	20	0.62	0.38
Santa Barbara	25	6	1	1	3	0	0	25	1.86	1.58
Morales Churupa	30	7	1	2	3	0	1	30	2.65	4.35
Turuco	32	6	0	1	3	1	1	40	5.73	7.23

[1] Chilcapamba is in the transition zone between upland and lowland; therefore there are some households with irrigation water, and some without irrigation water. In the sample, only two households did not have irrigation.

Table 4.2. Land size and distribution

In the majority of communities, differences in farm size are significant. Also it seems that population growth has led over time to the subdivision of land; as a result there has been a decline in household wealth. The majority of all households in almost all selected communities belong to the category of small and semi-medium farms (between 1- 5 ha of land). In two communities, Morochos and Piavi-San Pedro, one third of the sample belongs to marginal category (less than 1 ha of land) in terms of land ownership. In only one community, Ugshapungo, the majority of households have more than 10 ha each.

Education (*EDUIND*) is also an important household asset, a fundamental indication of human capital. It is expected to have an impact on household annual income directly. As members of each household have better education, then they should have better access to better-paid jobs, which raises family income. Education in the communities of this study shows a pattern similar to that of other rural regions in Ecuador (Pichón and Bilsborrow, 1992; Rodríguez, 1995). Approximately 27 percent of the sample population does not have any education, approximately two members of each household are illiterate (mean 1.7631, std. Dev. 1.1044), and another 35 percent did not go beyond elementary school, which means that approximately two members of each household had at least elementary education (mean 1.7631, std. Dev. 2.0927). There is a high percentage of children who drop out at this level of education to join the family labor pool. Together, these two categories include more than 50 percent of the sample population. An important part of the sample population is “No attending” category, they are children who are not at school years yet and represent approximately 19 percent of population of this study. Only 3 percent of the sample population gets a university diploma and approximately 7 percent has high or middle high school education. The mean and standard deviation of education level of each household are summarized in Table 4.3.

Agriculture dominates the lives of the population in the area. The main crops are maize (cornpro), beans (beanpro), potatoes (potapro), and peas (peaspro) in the highlands. Other important crops in the region are lima beans (limapro), lupine beans (lupinepro), wheat (wheatpro), and quinoa (quinpro). Recently, a small shift has been taking place on small farms to onions, cabbage, and other annual crops, which can be sold for cash. Nevertheless, maize, beans, and peas are still the main crops of Cotacachi communities. Approximately 93 percent of households plant and harvest

Education level	Proportion		
	Sample population	Upland population	Lowland Population
No school	0.27	0.33	0.18
No attending	0.19	0.22	0.14
Elementary school	0.35	0.36	0.34
Junior high school	0.07	0.05	0.11
High school	0.08	0.03	0.16
University	0.03	0.02	0.06
Profession or technical school	0.01	0.01	0.01

Table 4.3. Education level in Cotacachi Communities

corn, mainly for their own consumption. Beans are the second most important crop for these communities, planted by approximately 71 percent of total households. Peas are also important, which a little more than 50 percent of households harvest for their own consumption. The mean, standard deviation, and variance of crops yield per family are summarized in Table 4.4.

Crops	**Entire sample**		**Upland**		**Lowland**		**No of**	**Proportion of sample**
	mean	**std. dev.**	**mean**	**std. dev.**	**mean**	**std. dev.**	**HH**	**raising crop**
Beans (bag 100 pounds)	1.36	1.48	1.42	1.33	1.26	1.78	57	0.71
Barley (bag 100 pounds)	7.49	12.21	10.33	14.48	2.21	1.58	20	0.25
Corn (bag 100 pounds)	13.29	21.34	11.80	11.87	15.80	31.59	75	0.94
Potato (bag 100 pounds)	25.774	51.824	36.3841	61.86	5.52	5.98	32	0.4
Lima bean (bag 100 pounds)	6.51	14.14	9.21	16.54	0.44	0.24	13	0.16
Melloco (bag 100 pounds)	6.44	4.46	6.44	4.46	N/A	N/A	4	0.05
Oca (bags 100 pounds)	5.44	3.80	5.44	3.80	N/A	N/A	4	0.05
Wheat (bag 100 pounds)	4.21	7.87	5.72	10.32	2.21	1.85	14	0.18
Lupine bean (bag 100 pounds)	2.1656	4.3174	1.376	1.8511	4.9857	8.4097	32	0.4
Peas (bag 100 pounds)	0.83	1.09	0.55	0.52	1.33	1.51	42	0.53
Lentils (bag 100 pounds)	2.21	3.50	0.25	0.00	3	3.95	7	0.09
Quinoa (bag 100 pounds)	0.65	0.78	0.45	0.26	1.63	1.94	12	0.15
Carrot (bag 100 pounds)	1.5	0.71	N/A	N/A	1.5	0.71	2	0.03
Peet (bag 100 pounds)	N/A	N/A	N/A	N/A	2	N/A	1	0.0125
Zambo (units)	36.67	20.62	38.75	21.00	20	N/A	9	0.11
Lettuce (units)	190	141.77	300	N/A	135	148.49	3	0.04
Cabbage (units)	147.5	143.61	160	197.99	135	148.49	4	0.05
Tomato Tree (units)	275	160.47	275	160.44	N/A	N/A	6	0.08
Strawberry (box)	N/A	N/A	N/A	N/A	2.07	N/A	1	0.013
Avocado (units)	N/A	N/A	N/A	N/A	4000	N/A	1	0.013
Tomato (units))	N/A	N/A	250	N/A	N/A	N/A	1	0.013

Table 4.4. Crops Yield and Proportion of the Sample Raising Crop

Agricultural yield depends on two key factors: soil fertility (fertility) and soil erodibility. The latter is measured as a cost of soils erosion, which is estimated through the Universal Soils Loss Equation (USLE). Estimated soil loss is linked later to crop yield, and the cost of soil loss then is estimated by multiplying yield reductions by local crop prices (Bishop and Allen, 1989).

Crop yield has an impact on household annual income in two ways: from direct sales to marketplace, producing direct revenues for households. This variable (croprofit) gives us in dollars how much of the harvested crop is sold. Secondly, farmers use part of their harvest for their own consumption (consfam) and use as seeds (ownseeds) for the next harvesting season, which is measured as an opportunity cost for the farmer.

The animal stock of each household was measured as number in existence, trade, loss, and for consumption. Trade of the stock (aniprofit) provides direct revenues to households, but also sub products of animals (daiprofit) provide revenues, which are part of the gross income of households (grossprofit). Other production activities are also part of households' gross income; some families dedicate part of their time to produce and market different types of textiles varying from wool huts to hammocks. These products are sold mainly in Otavalo, a city that is the main marketplace for the region's products. A summary of mean and standard deviation of the household annual income of the ten communities participating in this study, as well as the percentage of that income from agricultural activities and off-farm activities is the Table 4.5.

Immigration also plays an important role in families' annual income. As the economic situation in rural areas becomes constricted, adult members of communities'

Community	Household Income		% from	% from
	Mean	std. dev.	Farming	Off-farm
Up-land without irrigation				
Arrayanes	777.42	485.00	23.00	77.00
Italquí	1278.94	1473.89	11.00	89.00
Morochos	990.47	601.71	10.00	90.00
Topo Grande	1018.84	770.86	15.00	85.00
Ugshapungo	3058.77	3036.08	69.00	31.00
Lowland with irrigation				
Chilcapamba	880.41	1199.67	29.00	71.00
Piavi San Pedro	2201.74	1728.36	34.00	57.00
Santa Barbara	1446.51	1439.64	34.00	66.00
Morales Chupa	2123.86	3286.92	9.00	91.00
Turucó	746.06	442.79	46	54.00
Entire Sample	**1325.73**	**1612.09**	**24.28**	**75.18**

Table 4.5. Household Income and sources of income of the Cotacachi Communities

families migrate to bigger cities as the demand for labor increases in those areas. As a result, most of the adult members of each household are laborers on bigger farms or work in construction in cities such as Quito or Otavalo. Approximately 25 percent of the economically active members of households in each community have full or part time off-farm work (Table 4.6). Actually, this off-farm work provides to the majority of communities' families the biggest part of their annual income.

The costs for production activities are included in one big variable (totalcost). Total cost includes agricultural inputs such as fertilizers, pesticides, and seeds, as well as labor for land preparing, plowing and harvesting. The mean and standard deviation of all these cost are summarized in the Table 4.7, as well as the mean

Communities	No of sample HH	Sample Population	off-farm Labor	Proportion Sample population	Mean	Std. Dev.
Up-land without irrigation						
Arrayanes	12	72	23	0.3194	1.92	1.31
Italqui	8	48	16	0.33	2	0.93
Morochos	17	106	30	0.28	1.76	0.97
Topo Grande	6	23	8	0.35	1.33	0.52
Ugshapungo	6	39	10	0.26	1.67	1.51
Lowland with irrigation						
Chilcapamba	7	42	9	0.21	1.28	0.76
Piavi San Pedro	5	29	10	0.35	2	1.58
Santa Barbara	6	31	7	0.23	1.17	1.18
Morales Churupa	7	38	11	0.29	1.57	1.13
Turuco	6	15	3	0.20	0.5	0.55

Table 4.6. Proportion of non-agricultural activities in the Cotacachi Communities

and standard deviation of upland and lowland communities. In all these communities, there is community participation in agricultural activities as well as other community activities called "minga" in which members of a household receive the help of other members of his community during the main agricultural seasonal activities. This is paid with lunch and labor to the neighbors that help in these activities. The "minga" is measured as opportunity cost and is part of the total cost of agricultural activities. Plowing as a separate cost includes renting mechanical plowing, animal plowing (yunta) and human plowing measured as an opportunity cost. On the other hand, maintaining and feeding the stock also comprises a cost for household. Part of the harvesting is dedicated to feed household animals and measured as opportunity cost.

Input expenses	Sample Population		Upland Population		Lowland Population	
	Mean	Std dev.	Mean	Std dev.	Mean	Std dev.
Fertilizer natural ($/year)	7.512	46.13	3.58	15.23	14.41	74.24
Fertilizer commercial ($/year)	13.10	56.31	16.09	65.95	7.86	33.68
Pesticides ($/year)	9.35	36.89	10.47	40.46	7.38	30.19
Seeds commercial ($/year)	7.68	56.07	0.57	1.99	0.50	2.32
Plowing tractor ($/year)	30.43	60.09	24.29	34.81	41.22	88.52
Plowing yunta ($/year)	87.30	84.24	74.87	80.67	109.16	87.32
Plowing opp. cost ($/year)	20.95	52.81	29.57	62.68	5.76	21.90
Labor wages ($/year)	125.92	128.65	119.94	142.44	136.42	104.17
Labor opp. cost ($/year)	53.75	68.49	53.57	67.05	54.07	72.16
Veterinary expenses ($/year)	16.30	25.09	15.28	27.16	18.08	21.27
Feed animal ($/year)	47.14	67.44	28.71	48.73	79.55	82.97
Feed opp. Cost ($/year)	15.25	34.46	23.92	40.80	0.00	0.00
Other animal expenses	3.53	10.54	2.72	8.02	4.94	13.97
Drinking water cost ($/year)	9.75	7.08	8.33	4.87	12.25	9.43
Irrigation cost ($/year)	0.56	1.25	0.00	0.00	1.55	1.68
Total expenses ($/year)	**562.77**	**460.00**	**571.02**	**501. 30**	**548.26**	**384.62**

Table 4.7. Inputs and cost in the Upland and Lowland communities of Cotacachi

Community participation (*PARTIND*) is assumed to have an impact on individual benefits. Community participation is defined in this study as activities related to farming. Activities that members of each household get involved with in the community such as, mingas for construction of drinking and irrigation water systems, regular meetings of the community to elect new directories or present the annual report of directory, mingas to assist other farmers with the preparation, plowing, planting and harvesting of the farm. This study did not include all participation activities that members of each community can get involved with, such as UNORCAC's general assembly, meetings regarding new projects for implementation of new small business, religious meetings, festivities, mingas to help build houses, and meetings to improve education, health, and other issues that may affect all communities members. A detailed description of the participation index use in this study is presented in Section 4.7. The participation index uses a rate of participation (0-1) mainly of agriculture-related activities from the survey, as well as a perception of participation that each household's member has of himself within the community. It also includes participation of elected representatives and executive officers, which would give us an idea of voluntary participation and how many times they were elected. Finally, *PARTIND* also includes the number of years that each household's member has been participating in community meetings and activities. The mean and standard deviation for the sample population as well as for upland and lowland communities are summarized in Table 4.8.

4.5 Variables definition

The data collected in the survey were used to estimate the relationship between household annual income per capita and the household's willingness to pay for improvements in drinking water and irrigation water systems. As part of the research hypothesis and questions, this relationship could only be answered once household income was estimated, which depends on several other variables that the questionnaire was precise to raise. Each section of the questionnaire, as it was presented in the last

Community Participation	Sample Population		Upland Population		Lowland Population	
	Mean	Std dev.	Mean	Std dev.	Mean	Std dev.
leadership (voluntary)	0.68	0.47	0.67	0.48	0.69	0.47
years/leadership	1.00	0.99	0.98	1.01	1.03	0.98
Participation years	19.31	9.02	20.12	7.99	17.88	10.59
Participation perception	0.80	0.78	0.08	0.18	0.72	0.21
Index participation	**0.36**	**0.13**	**0.37**	**0.11**	**0.34**	**0.15**

Table 4.8. Community Participation of Upland and Lowland of Cotacachi Communities

section, helped to determine each of the variables on which household annual income depend.

Household income is defined as the sum of the net value of all economic activities in which a household is engaged. Net value is obtained based on the revenues obtained from the economic activities less the cost involved in each activity.

Yield is the agricultural crops yield measured in quintals (sacks of 100 pounds) obtained by a household during a cropping season. Yields, inputs and crop choices were determined by interviews from the socio-economic survey.

Land is the amount of land dedicated to agricultural crops or livestock. It measures in hectares (ha) the amount of land owned by household, as well as the amount of land rented to increase its productivity. Soil fertility (fertility) and soil erodability are key factors in agricultural production and their effect was taken into account through their effect on household agricultural yield.

Participation is defined as all activities that members of each household get involved with in the community, and is supposed to have an impact on the household annual income (Robison et al., 2000; Robison et al., 2002). They use a rate 0-1 for activity including religious meetings, volunteer work, voting, neighborhood meetings regarding education, and development. They add this and get a sum of all these activities in an index that is uses as explanatory variable of income. A detailed explanation of the participation index used in this study is later described in the Section 4.7

EDUIND is an index of human capital. The numerator of the index reflects the actual number of years of education received by each economically active household member. The denominator reflects the maximum potential number of years of education the same people could receive.

The variables defined here were important to estimate the relationship between household annual income and the household's willingness to pay for improvements in drinking water and irrigation water systems, as well as to design a LP model that estimated the efficient allocation of farmer's resources. As part of the research hypothesis and questions, this relationship could only be answered once the household annual income was estimated, which depends on several other variables that addressed by the questionnaire. Any possible bias for using this direct approach was carefully addressed first by raising awareness of household perception of resources' importance, and by using a resource that is familiar to the household. Each section of the questionnaire helped to determine each of the variables that net income depends on.

The next two sections will explain the models of this study, the LP model and the simple regression in detail and the variables used in each model.

4.6 Linear Programming model definitions

The main objective of the LP model is to maximize the net gross margin of two representative farms of Cotacachi. This maximization can suggest to farmers how they can allocate their resources efficiently. However, in Cotacachi most of the farmers are dedicated to subsistence farming in order to meet minimal consumption needs. Subsistence farming has many sources of risk, with the LP model does not contemplate, such as variation in the prices of inputs and outputs and the assurance of at least attaining the minimum consumption need of the household. Contrary to subsistence agriculture, the LP model assumes that prices are fixed and sources of risk are inexistent.

As indicated in Table 4.4, four crops dominate subsistence farming in the study area. Two of these, corn and beans, are typically raised together in the same field during the rainy season, which begins in October and concludes in May. Peas are a dry season crop. The fourth crop, potatoes, are planted at the same time as corn and beans, but takes less time to mature (approximately three months), and are planted both during the rainy season and dry season. To capture key trade-offs among the cropping options – corn-beans, potatoes, and peas – use of land during the rainy season is distinguished from use of the same land during the dry season.

Along with crop production, a subsistence farm can raise livestock. One option is to raise hogs, buying small animals and selling fattened pigs. Another is to engage in dairying, with milk as well as calves being marketed.

Besides land, water is an important input to agricultural production – especially during the dry season. Labor used for crop and livestock production is provided by household members, who can also work off the farm, and neighbors, who customarily are compensated with agricultural products. Fertilizer and other inputs are available, though not widely used, with the exception of custom plowing.

Along with agricultural activities, the LP model includes activities corresponding to buying and selling commodities, the hiring of labor, the purchase of water (if the community in which the farm is located has irrigation), and working off-farm. Transfer rows correspond to resources limitations, labor (self-employed and hired), as well as commodities that the farm can produce.

4.6.1 Variables

In the LP model of subsistence farming in Cotacachi, the maximand is agricultural gross margin, which is the difference between the value of agricultural output and the cost of variable agricultural inputs. Sumpsi *et al*. (1997) and Berbel and Sánchez-Limón (2000) point out that this gross margin is a good measure of farm profits. In this model the maximand amounts to:

$$NGM = f_{ocr} + f_{oli} + f_{oho} + a_{off} X_{off} + X_k - (1 + a_k) X_k \qquad (4.1.)$$

where *NGM* is the net gross margin and is the objective function of the LP model and depends on objective function activities of the farm, off-farm work, and capital. f_{ocr} is the function of crops production; f_{oli} is the function of livestock production; f_{oho} is the function of hogs production, $a_{off}X_{off}$ is the off-farming job of household head, a_{off} is the farmer wage per day and X_{off} is the number of days dedicated to this activity; and $X_k-(1+a_k)X_k$ is the capital availability for farmers.

The crop function can be defined as follows:

$$f_{ocr} = \sum_{j=1}^{n} a_{sj} X_{sj} X_{Lj} - a_{bj} X_{bj} - Y_w - a_{Lj} X_{Lj} - a_{rent} X_{Lrent} - la_j \qquad (4.1.1)$$

where a_{sj} is the price per quintal of crop j, X_{sj} is the yield per hectare of crop j; X_{Lj} is the amount of land dedicated to farming; a_{bj} is the price per quintal of product j that is bought for minimum consumption requirement of the household; X_{bj} is the amount in quintals of product i that is bought for minimum consumption requirement of the household; Y_w is the price per year of irrigation water that is paid by the farmer, Y_w is fixed cost and it is reduced from *NGM* once the latest is estimated; a_{Lj} is the production cost per hectare of crop j; a_{rent} is the cost in dollars to rent one hectare of land; X_{Lrent} is the amount of land that the farmer rent; la_j is the cost in dollars of hiring extra labor.

$J=1$ is corn, $J=2$ is beans, $J=3$ is potatoes, and $J=4$ is peas.

The agricultural activities j_{1-4} on the farm can be defined as follows:

X_{s1} *Sell corn* amount of corn sold in the market. The yield sold is measured in quintals and its price is determined from the socio-economic survey based on prices that householders received for their crop.

S_{s2} *Sell beans* amount of beans sold in the market. The yield sold is measured in quintals and its price is determined from the socio-economic survey based on prices that householders received for their crop.

X_{s3} *Sell potato* amount of potato sold in the market. The yield sold is measured in quintals and its price is determined from the socio-economic survey based on prices that householders received for their crop.

X_{s4} *Sell peas* amount of peas sold in the market. The yield sold is measured in quintals and its price is determined from the socio-economic survey based on prices that householders received for their crop.

$X_{L1\text{-}2}$ *Corn-bean yield* is the amount of land dedicated to corn-beans rotation.

X_{L3} *Potatoes yield* is the amount of land dedicated to potatoes production.

X_{L4} *Peas yield* is the amount of land dedicated to peas production.

X_{b1} *Corn purchase* is the activity of buying corn instead of growing it. It is measured in quintals of corn bought and its price a_{b1} is estimated from the SICA[12] market index for the province of Imbabura, and from interviews in local markets.

X_{b2} *Beans purchase* is the activity of buying beans instead of growing them. It is measured in quintals of beans bought and its price a_{b2} is estimated from the SICA market index for the province of Imbabura, and from interviews in local markets.

X_{b3} *Potato purchase* is the activity of buying potatoes instead of growing them. It is measured in quintals of potato bought and its price a_{b3} is estimated from the SICA market index for the province of Imbabura, and from interviews in local markets.

X_{b4} *Peas purchase* is the activity of buying peas instead of growing them. It is measured in quintals of peas bought and its price a_{b4} is estimated from the SICA market index for the province of Imbabura, and from interviews in local markets.

X_{ww} *Water wet season* is the amount of water required by the farm to crop *j* during the rainy season. The price is zero in the model, so the total amount of water required per area unit can be estimated.

X_{wd} *Water dry season* is the amount of water required by the farm to crop *j* during the rainy season. The price is zero in the model, so the total amount of water required per area unit can be estimated.

$X_{la1\text{-}2}$ *Hire labor corn-beans* is the non-family labor available for the farmer to raise corn and beans. The labor can be hired during land

[12] Servicio de Información Agropecuaria del Ministerio de Agricultura y Ganaderia del Ecuador (SICA).

preparation, seedling season, and harvesting season. The cost of hiring labor is paid off with a percentage of crop yields, as well as with an exchange of labor.

X_{la3} *Hire labor potatoes* is the non-family labor available for the farmer to raise potatoes. The labor can be hired during land preparation, seedling season, and harvesting season. The cost of hiring labor is paid off with a percentage of crop yields, as well as with an exchange of labor.

$X_{FL1\text{-}2}$ *Dependent labor C-B* is the dependent labor required to crop corn and beans.

X_{FL3} *Dependent labor potato* is the dependent labor required to crop potatoes.

X_{FL4} *Dependent labor peas* is the dependent labor required to crop peas.

$X_{FLH1\text{-}2}$ *Head labor C-B* is the head of household labor required to crop corn and beans.

X_{FLH3} *Head labor potatoes* is the dependent labor required to crop potatoes.

X_{FLH4} *Head labor peas* is the dependent labor required to crop peas.

As is described in the objective function $f_{ocr1\text{-}4}$, the farmer faces a decision to buy or sell and it is going to depend on a critical value. This critical value is the minimum land required for crop *j* by the farmer for consumption divided by the yield per hectare of each crop *j*. This critical value can be expressed as follows:

Servicio Mensual a Nivel Consumidor. Proyecto SICA-Banco Mundial, 2001-2003.

$$X_{L\min j} = \frac{Y_{cj}}{X_{sj}} \qquad (4.1.1.1)$$

where j_1 is corn, j_2 is beans, j_3 is potato, j_4 is peas. Y_{cj} is minimum yield required for crop j for consumption purposes, and x_{sj} is the yield per hectare.

$$Land^{*}_{critj} = Land_{ownj} - Land_{\min j} \qquad (4.1.1.2)$$

where $Land_{critj}*$ is the critical land required for each crop j that the farmer uses for consumption. If the yield minus the consumption is greater than or equal to cero, the farmer can decide to sell ($a_{sj}X_{sj}$-Y_{cj}) any excess over the critical yield ($Y_{cj}*$). If the consumption minus yield is less than or equal to zero, the farmer can decide to buy any shortage (Y_{cj}-$a_{cj}X_{sj}$) of crop j to complete the critical yield ($Y_{cj}*$). This particular farmer's decision can be expressed as follows:

$$X_{sj} = \begin{cases} 0 & for \quad Land^{*}_{j} < 0 \\ a_{sj}X_{sj} - Y_{cj} & for \quad h^{*}_{j} \geq 0 \end{cases} \qquad (4.1.1.3)$$

$$X_{cj} = \begin{cases} Y_{cj} - a_{cj}X_{sj} & for \quad Land^{*}_{j} < 0 \\ 0 & for \quad Land^{*}_{j} \geq 0 \end{cases} \qquad (4.1.1.4)$$

where X_{sj} is the amount in land dedicated to crop j that is expected to sell; X_{sj} is the amount land in hectares dedicated of crop j; $a_{sj}X_{sj}$-Y_j is the yield of crop j expected to sell, and Y_j-$a_{sj}X_{sj}$ is the yield of crop j expected to buy.

The objective function of livestock can be defined as follows:

$$f_{oli} = a_{lis} X_{li} X_{lid} + \quad a_{mi} a_y X_{li} - a_{lic} X_{li} \qquad (4.1.3)$$

where a_{lis} is the price of one unit of cattle sold at the second year, X_{li} is the amount of cattle units, X_{lid} is the cattle survival units, it is estimated a 0.85 survival rate. a_{mi} is the price for one unit of milk measures in cattle, ay is the amount of milk per cattle unit. Furthermore, a_{lic} is the cost to maintain one cattle unit

The objective function of hogs involves the farmer buying one suckling pig at the beginning of the year and selling it after fattening at the end of the year. The function can be defined as follows:

$$f_{oho} = a_{ohos} X_{ho} X_{hod} - a_{hoc} X_{ho} \qquad (4.1.2)$$

where a_{ohos} is the price per hog; X_{ho} is the number of hogs; X_{hod} is the hogs survival rate, which is estimated 0.95 survival rate. a_{hoc} is the cost of raising a hog, which includes the price of buying the suckling pig, vaccines and other veterinary cost, and the cost of feeding them.

The head of the household can decide to work outside of the farm, mainly as labor for other farms, construction, or for local and government agencies. This function can be expressed as follows:

$$a_{off} X_{off} \qquad (4.1.4)$$

where a_{off} is the salary compensated for day of work, and X_{off} is the number of days dedicated to the off-farm work. The off-farm work is defined in the LP model as follows:

X_{off} Off-farm work is the availability of the head of the household to work off side of the farm as labor for other farms or in the construction or manufacturing industry. He receives a salary in dollars per day.

Furthermore, *Rent-in* is the additional land depending on the requirements of the economic activities of the farm. This additional land will be allocated to the activity that generates the highest or maximum value. The additional land can be expressed as follows:

$$a_{Lrent} X_{Lrent} \qquad (4.1.5)$$

where a_{Lrent} is the cost to rent additional land, and X_{Lrent} is the amount of land measured in hectares rented.

Finally, *Borrow* is the amount of capital cash flow that a household can obtain by lending from a commercial, governmental agency, or local lending cooperatives. The farmer has access to capital depending on the requirements of the economic activities of the farm. This additional capital land will be allocated to the activity that generates the highest or maximum value. The additional capital can be expressed as follows:

$$X_k = (1 + a_k)Y_k \qquad (4.1.6)$$

where a_k is the cost additional capital (commercial interest rate), and X_k is the amount of capital that farmer can access.

4.6.2 Constraints

All constraints are specified according to the limitations for the production activities settled up in the activities. The list of constrains is as follows:

4.6.2.1 Crop Yield

It measures the amount quintals (bags of 100 pounds) yielded per hectare (ha) and it requires a minimum output for each crop included Yc_j (critical yield) in the objective function. This minimum required is for consumption purposes of the household; it is expressed as upper and lower bound constraint. These upper and lower bound constraint are usually required to fulfill social obligations such as production of minimum food requirements. Food requirement constraints are usually a lower bound of a model and can be expressed in general form as follows:

$$\sum_j a_{cj} \geq Y_{cj}^* \quad \text{for selected } j. \qquad (4.2)$$

A farm's crop output can be either sold or consumed. It is also possible to buy the crops in the closest market. Additionally, part of crop output would be allocated to pay labor hired for each crop. The lower bound requirement can be redefined as follows:

$$\sum_j a_{cj} \leq -Y_{cj}^* \quad \text{for selected } j. \qquad (4.2.1)$$

The lower bound requirement for household consumption can be defined for each crop of the model. The model-cropping pattern should ascertain the supply of minimum quantities of food commodities for the household. These can be expressed as follows:

Corn requirement:

$$\sum a_{c1} \leq -Y_{c1}^* \quad \text{index } j \text{ for corn crops only} \qquad (4.2.1.2)$$

Beans requirement:

$$\sum_{j} a_{c2} \leq -Y_{c2}^{*} \quad \text{index } j \text{ for bean crops only} \qquad (4.2.1.3)$$

Potatoes requirement:

$$\sum_{j} a_{c3} \leq -Y_{c3}^{*} \quad \text{index } j \text{ for potato crops only} \qquad (4.2.1.4)$$

Peas requirement:

$$\sum_{j} a_{c4} \leq -Y_{c4}^{*} \quad \text{index } j \text{ for peas crops only} \qquad (4.2.1.5)$$

4.6.2.2 Land

Land is the total cultivated area in hectares that is available to the farmer. Land includes the amount of land owned by the farmer and the land available to rent for farm's economic activities. There is a limit of hectares that the farmer can rent and also a limit of hectares that he can own. The farmer must decide what crops or combination of them that he would dedicate because crops are competing for the land available. He also must decide if he is going to grow anything at all because agriculture is also competing with livestock for available land.

Land during the rainy season (*land wet season*) can be used for the rotation of corn and beans as well as potatoes production. Land during the dry season (*land dry season*) is used for either potato or peas. In the model, it is assumed that one hectare of land can sustain a herd of six cows, six calves, or a combination of both.

Mathematically, the land constraint, both *land wet season* and *land dry season*, can be defined as the area allocated to different crops in each season is utmost equal to the total cultivable area of the household:

$$\sum_{j} a_{Lj} \leq Y_{Lown}, \forall j. \qquad (4.3)$$

The LP model ascertains how the total area can be allocated among agricultural activities in order to maximize the gross margin. Each constraint can be expressed as follows:

Land wet season requirement:

$$\sum a_{wLj} \leq Y_{wLown}, \forall j \quad \text{index } j \text{ for rain season crops only} \qquad (4.3.1)$$

Land dry season requirement:

$$\sum_{j} a_{dLj} \leq Y_{dLown}, \forall j. \quad \text{index } i \text{ for dry season crops only} \qquad (4.3.2)$$

4.6.2.3 Water

There is a limited amount of water available for agricultural activities. It is estimated from the amount of rain that is received in both seasons, rainy and dry season, as well as the amount of irrigated water that each farmer is allowed to use after paying an annual fee of $1.20 per growing season. Farmers irrigate their land every three weeks or so, with no variation in the fixed annual cost. The amount of mm of rain that falls during the growing season is transformed into cubic meters of water per season per hectare. Additionally, each crop has a water requirement, which has been transformed to cubic meters per hectare per growing season. In the case of irrigated land, both the cubic meters of water required for each crop and the amount of water available are multiplied by the number of days that the land is irrigated in each season. In the case of non-irrigated land, the farmer cannot buy water. This could limit his output.

Water was divided between wet season availability, approximately 8 months (243 days), and dry season 4 months (122 days). The amount of water available for the farmer in the dry season is zero, in practical terms because evaporation is extremely high. This is particular important in non-irrigated land because the farmer has not access to any other sources of water.

Water wet season limit measures the amount of water required by the corn-beans rotation and potatoes in cubic meters per hectare per growing season. The value is estimated from the crop water requirement coefficient that is in liters per second per hectare per year (0.65 for corn and beans, and 0.89 for potato) and transformed to cubic meters per hectare per growing season. First, the water requirement coefficient is divided by 1000 to standardize in cubic meters and then multiplied by 3600 minutes and by 24 hours to get a value of cubic meters per hectare per day. The latest value is multiplied times the number of irrigated days that a farmer can access. The final value is the amount of water required in cubic meters by each crop per hectare per growing season (1,364.69 and 1,868.6 for corn-beans and potatoes respectively).

The amount of water available for the farmer has a limit that is also expressed in cubic meters per hectare per growing season. It was estimated from the amount of rain received in each season less the evaporation, which is in mm. This value is divided by 1000 to standardize in meters and multiply by 1 hectare, which gives the amount of rainwater available in cubic meters. Then, it is multiplied by the amount of days that a crop is irrigated. The final value is the amount of water available for each crop in cubic meters per hectare per growing season. In irrigated land, farmers can buy water for an annual fee of $1.20 per growing season (fixed cost).

Mathematically, *water wet season* can be defined as the water demand of all crops during the growing season cannot exceed the water available for that particular season:

$$\sum_{j} a_{wwj} \leq Y_{ww}, \forall j. \qquad (4.4.1)$$

Water dry season measures the amount of water required by potato and peas in cubic meters per hectare per growing season. The value is estimated from the crop water requirement coefficient that is in liters per second per hectare per year (0.89 for potatoes, and 0.69 for peas) and transform to cubic meters per hectare per growing season. As in the water wet season constraint, the water requirement coefficient is divided by 1000 to standardize in cubic meters and then multiply by 3600 minutes and by 24 hours to get a value of cubic meters per hectare per day. The latest value is multiplied times the number of irrigated days that a farmer can access during the dry season. The final value is the amount of water required in cubic meters by each crop per hectare per growing season (938.13 and 727.36 for potatoes and peas respectively).

The amount of water available for the farmer has a limit that is also expressed in cubic meters per hectare per growing season. It was estimated from the amount of rain received in each season less the evaporation, which is in mm. This value is divided by 1000 to standardize in meters and multiply by 1 hectare, which gives the amount of rainwater available in cubic meters. Then, it is multiplied by the amount of days that a crop is irrigated. The final value is the amount of water available for each crop in cubic meters per hectare per growing season. In non-irrigated land, farmers cannot access to more water than this limit.

Mathematically, water dry season can be defined as the water demand of all crops during the growing season cannot exceed the water available for that particular season:

$$\sum_j a_{wdj} \leq Y_{wd}, \forall j. \qquad (4.4.2)$$

4.6.2.4 Capital

Capital is the amount of cash inflows and outflows for the economic activity of the farm. It has a limit and depends upon the amount of money that the head of the household gets from the off-farm employment. It can be defined as follows:

$$\sum\left(a_{koutj}, a_{kinj}\right) \leq Y_{kj}, \forall j \qquad (4.5)$$

where a_{kinj} is capital cash inflows, a_{koutj} is capital cash outflows and Y_{Kj} is the capital available in the household.

4.6.2.5 Labor

Labor measures the number of man-labor days available for economic activities. Each week, the head of the household can dedicate 1 man-labor day for crop activities and 5 labor-days for the off-farm work, which generally is labor for bigger farms or construction. As a result the head can only dedicate one man-labor day per week to the farm. This restriction can be expressed as follows:

$$\sum_{j} a_{FLhej} \leq Y_{FLhej} \qquad (4.6)$$

where a_{FLhej} is the amount of man-labor days that the head can dedicate to crop j, Y_{FLhe} is the limit of 40 labor-days available each year for the head of the household, which is added to the total amount of man-labor days of the family. The head of household labor can be allocated to corn-beans, potato, or peas production.

Dependent labor is provided by the wife of the head and their children aged 15 or higher who still live in the house. Dependent labor can be used either to farm or raise animals and it is assumed that they choose the most economic efficient activity for the household. Additionally to dependent labor, the household can hire labor for any of the economic activities they are involved. This limitation can be expressed as:

$$\sum_j a_{FLj}, \quad a_{laj} \leq Y_{FL} \qquad (4.6.1)$$

where a_{FLj} is the amount man-labor days of dependent labor dedicated to crop j, a_{laj} is the additional labor that can be hired, and Y_{FL} is the amount of dependent man-labor days available. The dependent labor can be allocated to corn-beans, potato, peas production, or raising hogs and cattle.

4.6.2.6 Transfer allocation constraints

Hard corn transfer is the amount of hard corn that can be purchased in the market to feed farm's hogs. This restriction can be expressed as follows:

$$\sum a_{hrho} \leq 0 \qquad (4.7)$$

where a_{hrho} is the amount of hard corn purchased to feed one hog. This limitation depends upon the amount of hogs that the farmer may decide to have, if the farmer decide not to have a hog, the amount of card corn purchased would be zero. This farmer decision can be expressed as follows:

$$a_{hrcoj}\begin{cases} 0 & if \quad X_{ho} \le 0 \\ a_{hrhooc} + a_{hrho} \ge 0 & if \quad X_{ho} \ge 0 \end{cases} \tag{4.7.1}$$

Hogs unit sale is the amount of hogs units that are available to sell. The farmer might decide to buy a sucking hog, raising it for a year and then sell it. The constraint assumes that the survival likelihood of a hog unit is 95 percent. The number of hogs per household is determined by the socio-economic survey in each household. This restraint can be expressed as:

$$\sum a_{ho} + a_{sho} \le 0 \tag{4.8}$$

where a_{ho} is the units of hogs in the farm, and a_{sho} is the number of hogs sell in the market.

Milk is the amount of liters that the farmers can obtain from one cattle unit. It is measured in liters per day. The milk can be sold at 0.25 dollars per liter. This constraint can be expressed as follows:

$$\sum a_y + a_{mi} \le 0 \tag{4.9}$$

where a_y is the amount of mill measured in liters per one cattle unit, and a_{mi} is the amount of liters of milk sold in the market.

Cattle unit sale is the amount of cattle units are available to sell. The constraint assumes that the survival likelihood of one cattle unit is 85 percent. The number of cattle units per household is determined by the socio-economic survey in each household. This restraint can be expressed as:

$$\sum_i a_{li} + a_{lis} \leq 0 \qquad (4.10)$$

where a_{mt} is the amount of cattle units that are being raised in the farm, and a_{smt} is the amount of cattle units available to sell in the market.

4.6.2.7 Off-farm work requirement

As it was stated before, the head of the household dedicate 5 labor-days for the off-farm work, which generally is labor for bigger farms or construction labor. This requirement is expressed as follows:

$$a_{off} = Y_{off} \qquad (4.11)$$

where a_{off} is the number of man-labor days dedicated to the off-farm work, and Y_{off} is the limit of man labor days of off-farm work.

4.6.2.8 Loan capital constraint

The farm has a limit of 1,200.00 dollars capital available, this constraint can be expresses as follows:

$$a_{Xk} \leq Y_k \tag{4.12}$$

where a_{Xk} is the amount of capital required by the farm, and Y_k is the limit of capital available to the farm.

4.6.2.9 Land rent limit

The farm has a limit in the amount of additional land available that can be rented. The restraint can be expressed as follows:

$$a_{Lrent} \leq Y_{Lrent} \tag{4.13}$$

where a_{Lrent} is the additional land required by the farmer, and Y_{Lrent} is the amount of extra land available for the farmer.

4.7 Regression model definition

An individual's consumption of a good or service is a function of its price, the prices of complementary and substitute goods, the individual's income and his or her preferences, which reflect personal characteristics. Likewise, the highest or maximum value that a respondent is willing to pay for the improvement of some good or service is a function of prices and his or her income and preferences.

In order to estimate the respondents' willingness to pay for improvements of spring water systems in Cotacachi, this study used the dichotomous with a follow-up approach, as described in the second chapter. According to Haab and McConnell (2002), the basic model for dichotomous choice responses is the random utility model. Accordingly, the indirect utility function for respondent *j* can be written as:

$$u_{ij} = u_i\left(y_j, z_j, \varepsilon_{ij}\right) \qquad (4.14)$$

where $i = 1$ is the condition that prevails when a CVM is carried out, and the final state is $i = 0$. y_j is the income, $\boldsymbol{z}_j$ is a m-dimensional vector of the household characteristics, and $\boldsymbol{\varepsilon}_{ij}$ is the error term (Haab and McConnell, 2002).

It is assumed in this study that households are endowed with family labor and land, which are used to maximize the net present value of expected utility (Coxhead *et al*., 2000). The household objective function can be defined as:

$$Max\int EUdt \qquad (4.15)$$

which households maximize subject to conditions outlined below. Following Coxhead et al. (2000), the expected utility of equation (4.15) is constructed in terms of profit and its variance:

$$EU = U(E(\pi), Var(\pi)) \tag{4.16}$$

The conventional assumption is that $\partial U/\partial E(\pi) > 0$ and $\partial U/\partial(Var(\pi)) \leq 0$. Uncertainty has to two main sources, prices and production. Production uncertainty arises both from the characteristics of the land and family endowments, and from external events such as weather, risk of frost, diseases, and pests. Household annual income per capita can be defined as:

$$INC_i = f(WEALTH, DIST, FAMILY, EDUIND, PARTIND, \varepsilon) \tag{4.17}$$

where *WEALTH* is a proxy of household wealth (asset holding such as land ownership is seen as part of household wealth) and *DIST* measures the distance in minutes from the household to the closest paved road (a proxy for the household access to the urban market and jobs). *FAMILY* is the number of members of the household who live in it and participate directly or indirectly in production activities. *EDUIND* is the stock of education of household labor force employed during the year, *PARTIND* is community participation, and $\boldsymbol{\varepsilon}$ represents the error term.

A problem arises in a system of simultaneous equation, which is part of this study. The estimate of income was used also as an exogenous variable in the equation used to estimate maximum willingness to pay for drinking water improvements, which is described later on. A correlation exists between household income per capita (*INC*) and the $\boldsymbol{\varepsilon}$ of the second equation. To avoid this correlation problem, a predicted (fitted) value of income is used instead. Then, the equation (4.17) is modified as follows:

$$INC_i^* = f(WEALTH, DIST, FAMILY, EDUIND, PARTIND, \varepsilon) \qquad (4.17.1)$$

Land ownership is measured as a proxy of wealth *WEALTH*. It can be defined as:

$$WEALTH_i = q_i \varphi \qquad (4.17.2)$$

where $\boldsymbol{q}$ is the quantity of land, measured in hectares, owned by household $\boldsymbol{i}$, and $\boldsymbol{\varphi}$ is the shadow price of land in the area.

DIST is the measure of the time that takes for any member of the household to reach the closest paved road. This gives a proxy to measure household access to urban market where farmer can trade their yields and acquire the inputs needed, as well as the opportunity to access off-farming jobs.

Participation *PARTIND* is defined as all activities, which members of each household get involved with in the community, and is supposed to have an impact on the household annual income per capita *INC* (Robison et al., 2000; Robison et al., 2002). Community participation is defined as:

$$PARTIND_i = \sum \left(\phi \delta_i \left[\left({}^{t_i}\!/_{8} \right) \right], \phi \left({}^{m_i}\!/_{T} \right), \phi \lambda_i \right) \qquad (4.17.3)$$

where δ_i is defined as the leadership of household member i as elected officials (a proxy of voluntary participation); t_i is the time spent as elected officials of individual i; m_i is the total time of participation years of individual i; T is the time since the community organization was formed; λ_i is the participation perception rate of individual i; and $\O$ is the participation weight.

This simple model of participation included a dichotomous option: voluntary participation is 1 and non-participation is 0. The leadership and voluntary participation (δ_i) is weighted multiplying by the time (t_i) that an individual occupied an elected office. Thus, the model made an important difference between voluntary participation and non-participation. At the same time, the model did not weight to a large extent the time of leadership, meaning that there is not a big difference between an individual with one year of voluntary participation with other with 8 years of participation. The time of leadership and voluntary participation is divided by 8 because in the country the rule of law allows two consecutive re-election of four years term to the elected representative or executive office. In the area of study, the term in the elected representative or executive office of any member is one year, thus 8 years of consecutive re-election terms seems reasonable enough as a limit time of public service.

In the literature, researchers emphasize that voluntary participation is key in community participation and social capital. However, these studies do not consider significantly other types of participation. For example, the election of president, mayors, or other public executive office holders in many countries such as Ecuador is an obligation. People have to vote as national duty otherwise they would be penalized. Clearly a non-voluntary participation (λ_i) is very important to be taken in account. In irrigation water systems in rural areas of many third world countries, for example, the construction and maintenance of the system is not a free-will participation. Users of these systems must participate in these activities because the risk and cost of no participation is substantial. As is pointed out earlier, participation in the building and maintaining of drinking and irrigation water systems in Cotacachi determines if a household will have access or not to the system. Thus, the cost of non-participation for a household is significant.

In the simple model, non-voluntary participation is included. Non-voluntary participation is not weighted equally in the model. Neither are years of participation ($\boldsymbol{m_i}$). In the simple model, the participation weight $\boldsymbol{\emptyset}$ of voluntary/leadership participation ($\boldsymbol{\delta_i}$) is 2.3 times higher than the time of participation ($\boldsymbol{m_i}$), and 3.5 times higher than non-voluntary participation ($\boldsymbol{\lambda_i}$). The weights need to show a difference that can be statistically significant, and the weights lower than those included in this study were not statistically different. The general descriptive statistics of the regression variables are summarized in the Table 4.9.

The second part of the equation is the estimation of households' willingness to pay for improving drinking water systems. The household willingness to pay can be defined as a function of the expected household per capita square income $INC^{*2}{}_i$ and the error term $\boldsymbol{\varepsilon}$. The equation can be defined as follows:

$$MAX_j = f(INC_j^{*2}, WEALTH, DIST, FAMILY.EDUIND, PARTIND, \varepsilon) \qquad (4.18)$$

Variable	Mean	Std. Dev.	Skewness	Minimum	Maximum
WEALTH	114.73	163.23	2.86	5.83	923.40
DIST	42.19	18.03	0.93	15	90
FAMILY	5.54	2.34	-0.01	1	11
EDUIND	0.17	0.15	1.48	0.00	0.70
PARTIND	0.36	0.13	0.13	0.02	0.75

Table 4.9 Descriptive statistics of main variables

where MAX_i is the maximum amount of money that the respondent is willing to pay for improvements in the spring water systems, INC^{*2}_i is the predicted per capita square income, and $\boldsymbol{\varepsilon}$ is the error term.

Additionally, the dichotomous with a follow-up approach gives 0 or 1 answers following with a maximum WTP. Therefore, it is necessary to know if there is a relationship between the maximum WTP and the randomly selected starting point bid for each household. The hypothesis is that the starting point bid may affect the final willingness to pay bid. Thus, the initial dichotomous bid is a function of the starting point bid and the other explanatory variables, the correspondent equation can be written as follows:

$$WTPINI_j = f\left(INC^*_j, BID, WEALTH, DIST, FAMILY, EDUIND, PARTIND, \varepsilon\right) \quad (4.20)$$

where INC^*_i is the predicted per capita income, *BID* is the initial randomly selected starting point bid for each household, *WEALTH* is a proxy of household wealth (asset holding such as land ownership is seen as part of household wealth), *DIST* measures the distance in minutes from the household to the closest paved road, a proxy for the household access to the urban market and jobs. *FAMILY* is the number of members of the household who live in it and participate directly or indirectly in production activities. *EDUIND* is the stock of education of household labor force employed during the year, *PARTIND* is community participation and ε is the error term.

CHAPTER 5

RESULTS

The main objective of LP modeling and the CVM analysis in this study is to estimate the value of water. With estimates of these values, policy proposals can be developed to improve living standards of households and to conserve natural resources. The shadow prices obtained from the LP model provide guidance for the development of water for agricultural uses. Likewise, CVM estimates of WTP are important criteria for the design of improvements in drinking water systems.

5.1 Water and land allocation

The LP model was run in two different settings, one a farm with irrigation water and the other a farm without irrigation water. Additionally, one of the economic activities included in the model was removed to create a more realistic model, one that corresponds to farming realities in the Cotacachi reflected in the survey. Initially, the study included cattle and hogs competing for land with the other economic activities. However, farmers in Cotacachi generally use community land as a source of forage, along with their own fields. The LP model's land constraint was modified to reflect this practice, which obviously reduces the opportunity cost of livestock production internalized by the farm family.

5.1.1 Standard LP model without irrigation

The standard LP model results compared with survey information are summarized in the Table 5.1. The model suggested that a non-irrigated farm should combine farming and dairying because this would yield the highest net returns, $6,752.57 per year.

The farmers should dedicate the entire area their land (4.95 ha) to the corn-beans rotation during the rainy season and only part of their land (1.93 ha) to peas during the dry season. The corn-beans rotation features a higher net return than growing potatoes does. The standard LP model does not have a constraint regarding consumption by the family. The model's result is that the family should satisfy all its needs through purchases in the closest market and that all production should be sold. However, the survey results shows that the average farmer does not sell any of his production, which means that all crop produced in this farm is consumed by the family. Additionally, the average farmer uses 1.28 ha for the corn-bean rotation, 2.5 ha for potatoes, and 0.305 ha for peas.

Since farming is profitable, LP analysis suggests that farmers should use their land for this activity and none for dairying, since as already mentioned community land is the source of forage. The standard LP model suggests that farmers should keep six cattle and produce 3,645 liters of milk per year. In contrast, average yearly milk production is 607.5 liter per farm. Another result is that six cattle are sold every two years, while survey results indicate that only one unit is sold biennially. Additionally, farmers should

	LP solution	Survey results
Objective function Solution	6,752.57	668.25
Net gross margin	6,522.03	467.25
Objective function variables		
Corn sell	280.3125	0
Beans sell	23.322	0
Potato sell	0	0
Peas sell	22.8055	0
Land area for corn-bean rotation	14.95	1.28[1]
Land area for peas production	10.05	0.305[1]
Corn purchase	0	0
Beans purchase	0	0
Potatoes purchase	0	0
Peas purchase	0	0
Hard corn purchase	0	36
Hogs (units)	0	1
Cattle (units)	6	6
Hogs sell	0	0
Dairy production	3,645	607.5
Cattle sell (units @ 2 yrs)	5	1
Water requirement wet season	19,732.2856	669.8
Water requirement dry season	5,175.4530	-169.1
Labor for corn-beans rotation	0	6
Labor for potato	0	6
Family labor for corn-beans	179.4	12
Family labor for potatoes	0	12
Family labor for peas	82.6	12
Family labor for livestock	72	12
Head labor for corn-beans	0	1
Head labor for potatoes	0	1
Head labor for peas	0	1
Off-farm work (man-days)	5	5
Land rent	9.999	0
Capital loans	0	0

[1]From the survey results corn-beans are crop in 1.28 ha, potatoes are crop on 2.5 ha and peas on 0.305 ha.

Table 5.1 Standard LP solution for non-irrigated land compared to survey results use 72 man-labor days to raise their herd according to the LP model, compared to 12 labor days actually used according to survey results. Furthermore, the LP model does not have any hogs in its solution, in contrast to the survey results that had 1 hog bought at the beginning of the year and for which the farmer bought 36 quintals of hard corn for feed.

LP analysis suggests that no outside labor should be hired because all labor can be performed by household members. If workers were hired, they would have to be compensated with crops. Contrary to the LP model, the survey results show that the average farm hires 6 man-labor days for the corn-beans rotation and potato production while peas are produced exclusively with family labor. The LP model also suggested using 179.4 labor days for the corn-beans rotation and 82.6 for pea production compared to 12 labor days that are actually used according to the survey results.

Water availability indicates the amount of rainfall during the rainy and dry season. As stated in the last chapter, the measure of water availability for the farm is measured in cubic meters per hectare per cropping season. The LP model solution showed 1,319.88 cubic meters per hectare of water as the minimum requirement to fulfill the crop needs for water during the rainy season; this requirement is partially fulfilled by the rainfall. The minimum requirement during the dry season is 514.14 cubic meters of water per hectare, which is not met by precipitation. These levels are estimated from what crops actually need in the area of study. Survey results show only the estimated water needs and availability for the crops in both seasons. Finally, farmers do not rent additional land or request additional capital in either the LP model or survey results.

There are some differences between the standard LP model and the survey results, which suggests that the farmers may not be using their sources efficiently. The maximum net profit from the survey results was $467.25 per year, in contrast with the standard LP model solution of $6,974.75 per year (Table 5.1).

5.1.2 LP model without irrigation with production constraints

Results for the constrained LP model with non-irrigated land, in which a minimum consumption requirement is added in order to satisfy household needs and farmers cannot rent additional land, are compared with survey information and summarized in the Table 5.2. As with the unconstrained model, LP analysis suggests that the non-irrigated farm should combine both farming and dairying because this would yield the highest net returns.

This LP model had two production constraints added to the standard LP model. One of these constraints forced the farm to produce the least possible amount of each crop to satisfy minimum consumption requirements of each farm household. The second constraint is that these crops must be produced on farm's own land. Imposing these two constraints reduces the net gross margin by approximately 54 percent. The Table 5.2 also shows the minimum of consumption requirements. In the survey results, the typical farmer uses 1.28 hectares for the corn-beans rotation, 2.5 ha for potatoes (not shown in the Table 5.2), and 0.305 ha for peas.

In the constrained LP model, it is found that farmers should dedicate their own land (4.95 of hectare) to the corn-beans rotation and peas production. Yet, this time, part of the corn and beans, and peas produced on the farm should be consumed by the household. The farm family's entire supply of potatoes should be bought, not produced.

	LP solution	Survey results
Objective function Solution	3,527.79	668.25
Net gross margin	3,327.26	467.71
Objective function variables		
Corn sell	90.8525	0
Beans sell	5.842	0
Potato sell	0	0
Peas sell	14.3365	0
Land area for corn-bean rotation	4.95	1.28[1]
Land for peas production	4.95	0.305[1]
Corn purchase	0	0
Beans purchase	0	0
Potato purchase	1.92	0
Peas purchase	0	0
Hard corn purchase	0	36
Hogs (units)	0	1
Cattle (units)	6	6
Hogs sell	0	0
Dairy production	3,645	607.5
Cattle sell (units @ 2 yrs)	5	1
Water requirement wet season	6,085.4056	669.8
Water requirement dry season	3,769.3102	-169.1
Labor for corn-beans rotation	0	6
Labor for potato	0	6
Family labor for corn-beans	59.4	12
Family labor for potatoes	0	12
Family labor for peas	59.4	12
Family labor for livestock	0	12
Head labor for corn-beans	0	1
Head labor for potatoes	0	1
Head labor for peas	0	1
Off-farm work (man-days)	5	5
Capital loans	0	0

[1]From the survey results corn-beans are crop in 1.28 ha, potatoes are crop on 2.5 ha and peas on 0.305 ha.

Table 5.2 LP solution for non-irrigated land with constraints compared to survey results

The constrained LP model for the non-irrigated farm suggests that both farming and dairying are profitable activities. In this model, farmers do not rent extra land because of the constraints and they use community pastures for their herds. The number of animal units or the amount of milk to be produced did not change in this LP model. Neither did the number of family labor days.

Contrary to what the constrained LP model for the non-irrigated farm suggests, survey results indicate that the typical farmer uses his entire land for farming and that most of the production is consumed by the household, used to pay the extra labor hired, and saved as seeds for the next cropping season. Also, there are some differences between the standard LP model and the survey results, but the constrained LP model reflects more accurately what is found in the average farm according to survey results. These differences suggest that farmers may not be using their resources efficiently. The maximum net profit from the survey results is $467.71 per farm, in contrast with the constrained LP model solution of $3,507.26 (Table 5.2).

5.1.3 Standard LP model with irrigation

The standard LP model with irrigation results is compared with survey information and summarized in Table 5.3. As in the other two models without irrigation, the model suggested that irrigated farm should combine both farming and dairying because this would yield the highest net returns.

According to LP analysis, farmers should dedicate their land (3.06 hectares) to the corn-beans rotation during the rainy season and peas production during the dry

	LP solution	Survey results
Objective function Solution	5,949.5441	872.63
Net gross margin	5,820.0141	763.90
Objective function variables		
Corn sell	235.08	10[1]
Beans sell	91.42	4[1]
Potato sell	0	0
Peas sell	52.733	0
Land area for corn-bean rotation	13.06	1
Land area for peas production	5.273	0.40
Corn purchase	0	0
Beans purchase	0	0
Potatoes purchase	0	0
Peas purchase	0	0
Hard corn purchase	0	12
Hogs (units)	0	1
Cattle (units)	5	5
Hogs sell	0	1
Dairy production	2,733.75	546.75
Cattle sell (units @ 2 yrs)	4	1
Water requirement wet season	17,153.0253	669.8
Water requirement dry season	4,004.4755	-169.1
Labor for corn-beans rotation	0	12
Labor for potato	0	12
Family labor for corn-beans	195.9	15
Family labor for potato	0	15
Family labor for peas	79.1	15
Family labor for livestock	60	12
Off-farm work (man-days)	5	5
Land rent	10	0
Capital loans	0	0

[1] Corn-beans rotation is crop in 1ha Potatoes are crop on 1 ha and peas on 0.40 ha.

Table 5.3 Standard LP solution for irrigated land compared to survey results

season. The rotation and peas production features a higher net return than growing potatoes does. The standard LP for irrigated land model did not have constraints regarding consumption by the family or land available to rent; as a result, the model assumes that all production should be marketed and additional land should be rented. The survey results show that the typical farmer sells part of his production: 10 quintals of corn and 4 of beans were sold. Additionally, the farmer uses 1 ha for the corn-bean rotation, 1 ha for potatoes, and 0.40 ha for peas.

Since dairying is profitable, farmers should use community land, as the model assumes it, in order to manage their herds. The standard LP model suggests that farmers should use all their cattle to produce milk (2,734 liters); it assumed that the entire herd could produce milk. This contrast with what the survey results show: 546.75 liters per year of milk production. The standard LP model also indicates that farmers should sell the entire herd (4 units total at the end of the second year). The survey results show that one unit is sold. Additionally, farmers should use 60 man labor days to raise their herd, compared to 12 labor days actually used according to survey results. Furthermore, the LP model does not have any hogs in its solution, in contrast to the survey results that have 1 hog bought at beginning and sold at the end of the year after being fed 12 quintals of hard corn.

The unconstrained LP model with irrigation suggests that farmers should not hire any labor because there are enough person-days of labor within the household to carry out all agricultural activities. The main reason for this is the fact that the farmer has to pay the extra labor with crops, and the household has enough labor days to devote to farming. Contrary to the LP model, survey results show that the average farm hires 12 labor days for the corn-beans rotation and potatoes production, while pea production uses exclusively family labor. The LP model also suggests using 195.9 labor days for the corn-beans rotation compared to 15 labor days that are actually used according to survey results, and 79.1 labor days for peas production compared to 15 labor days from the survey results.

Water availability corresponds to the amount of rainfall during the rainy and dry season. As is stated in the last chapter, the measure of water availability for the farm is measured in cubic meters per hectare per cropping season. The LP model solution showed a value of 17,153.025 cubic meters (1,313.48 cubic meters per hectare) of water and represents the amount of water that the entire farms needs to crop during the rainy and is partially fulfilled by the amount of rainfall available during the cropping season. The value of 4004.48 cubic meters (759.68 cubic meters of water per hectare) indicates the amount of minimum water requirements for crops during the dry season, which is purchased to fulfill crops' water needs. The survey result shows only the estimated minimum water availability for the crops in both seasons. The standard LP model for irrigated land suggests that 10 ha of additional land in order to maximize net returns. Contrary to the LP model, survey results show that farmers do not rent additional land. Finally, in both the standard LP model and survey results, farmers do not borrow additional capital.

There are some differences between the standard LP model and the survey results, which suggest that the farmers may not be using their resources efficiently. The maximum net profit from the survey results is $763.90 per year, in contrast with the standard LP model solution of $5,820.01 (Table 5.3).

5.1.4 LP model with irrigation with production constraints

Results for the constrained LP model with irrigated land, which includes the minimum consumption requirements in order to fulfill household needs and a limitation on the amount of land available, are compared with survey information and summarized in the Table 5.4. As with the unconstrained model with irrigation and the two models without irrigation, the model suggests again that the irrigated farm should combine both farming and dairying because this would yield the highest net returns.

This LP model had production constraints added to the standard LP model. One of these constraints forced the model to produce the least possible amount of each crop to satisfy minimum consumption requirements of the farm household. Additionally, the second constraint limits the amount of land available. In particular, farmers are forced to use only their own land for crop production. The results of the survey change significantly. In this constrained model, farmers can use only their own land, which reduces their net gross margin by approximately 42 percent. Table 5.4 also shows the minimum consumption requirements. In the survey results, the average farmer uses 1 hectare for the corn-beans rotation, 1 ha for potatoes, and 0.40 ha for peas.

In this LP model, it is found that farmers should dedicate their land (3.06 ha) to the corn-beans rotation during the rainy season and the same area to pea production during the dry season. Yet, this time, the household should consume part of the corn and beans and peas produced on the farm. To satisfy the minimum consumption requirements, the model suggests that entire supply of potatoes should be bought, not produced.

	LP solution	Survey results
Objective function Solution	2,553.2148	872.63
Net gross margin	2,437.1408	763.90
Objective function variables		
Corn sell	53.66	10[1]
Beans sell	20	4[1]
Potatoes sell	0	0[1]
Peas sell	28.66	0[1]
Land area for corn-bean rotation	3.06	1
Land area for peas production	3.06	0.40
Corn purchase	0	0
Beans purchase	0	0
Potatoes purchase	1.75	0
Peas purchase	0	0
Hard corn purchase	0	12
Hogs (units)	0	1
Cattle (units)	5	5
Hogs sell	0	1
Dairy production	2,733.75	546.75
Cattle sell (units @ 2 yrs)	4.25	1
Water requirement wet season	3,506.1453	669.8
Water requirement dry season	2,394.6845	-169.1
Labor for corn-beans rotation	0	12
Labor for potato	0	12
Family labor for corn-beans	45.9	15
Family labor for potatoes	0	15
Family labor for peas	45.9	15
Family labor for livestock	60	12
Head labor for corn-beans	0	1
Head labor for potatoes	0	1
Head labor for peas	0	1
Off-farm work (man-days)	5	5
Land rent	0[2]	0
Capital loans	0	0

[1] Corn and Potatoes are crop on 1 ha respectively and peas on 0.40 ha. [2] The model assumes that there is not land available to rent.

Table 5.4 LP solution for non-irrigated land with constraints compared to survey results

The constrained LP model with irrigation suggests that the combination of farming and dairying is the most profitable activity. In this model, farmers are using community pastures. The number of animal units and the amount of milk to be production did not change in this LP model. Neither did the number of family labor days. The number of family labor days dedicated to the herd did not increase either, as was the case with the model without irrigation. Contrary to what this constrained LP model suggests, survey results indicate that the average farmer uses his entire land for farming and that crop output is consumed by the household, used to pay the extra labor hired, and saved as seeds for the next cropping season. Also there are some differences between the standard LP model and the survey results, but this constrained LP model reflects more accurately what is found in the average farm according to survey results. These differences suggest that farmers are not using their resources efficiently. The maximum net profit from the survey results is $763.90 per year, in contrast with the constrained LP model solution of $2,437.14 (Table 5.4).

5.1.5 General LP Results

The conditions of the two representative farms, with and without irrigation, illustrate the general conditions of the majority of farmers in the study area. However, the results of the LP analysis differ a lot from agricultural practices, as revealed in the survey. In the latter, traditional agriculture is very important. Farmers in the area of study engage in subsistence agriculture, with output used almost entirely for consumption. In this kind of farming, there is not much investment. Farmers do not use fertilizers to enrich and protect the soil or insecticides to eliminate pests; neither do they use commercial seeds that can produce more per area, and do not use other crops that could produce more revenues with a relatively low cost. There is a risk-coping issue that LP models do not address, but that is important for farmers in the area. Basically, farmers concentrate their efforts on their traditional crops such as corn, beans, potatoes and peas to satisfy minimum consumption requirements year after year.

Another constraint can be added to the LP models, a constraint that makes the herd compete for the land available on the farm that is currently planted to crops. This would represent an alternative to the current practice of using community land to pasture livestock. Under this alternative condition, maximum profits from the LP model would be reduced significantly, a reduction of approximately 70% on non-irrigated land and 80% on irrigated land. Based on information provided by the Ministry of Agriculture, it is necessary to have two hectares of natural pasture per animal. In the area of study, in some cases cattle compete with crops for available land. As a result farmers dedicate part of their land just to have natural pasture. Yet, in other cases, like the two representative farms that set the conditions for the LP models, cattle graze on community land. This reduces the cost of raising cattle for the livestock owner. When cattle compete for land with crops, the model suggests that livestock production is unprofitable. Instead, raising crops is profitable activity for the farmer.

The shadow price for irrigated land is US$58.80 per hectare. In contrast, the shadow price of non-irrigated land is lower US$48.6 per hectare. This difference relates to the higher crop yields and agricultural net returns in irrigated fields. Another reason why irrigated land is worth more is that it is closer to urban areas than non-irrigated land. Also, there has been more subdivisions of irrigated land in irrigated districts. Average farm size in communities with irrigated land is 2.58 ha, compared to an average of 3.29 in non-irrigated settings. Subdivision reflects population density, which correlates with demand for real state.

An important reason for using the LP model in this study was to obtain a measure of the shadow price of water. In both representative farms, without and with irrigated land, the LP model yielded those values (Table 5.5). The shadow price in both representative farms is estimated after obtaining the amount of water required for each crop with the optimal solution. Then, two additional constraints are added to the model and forcing a restriction in the amount of water estimated by the model.

Shadow prices of water show how undervalued is the resource in the region. The values obtained by the LP model are in cubic meters, which contrast to what is actually paid by farmers. The values for non-irrigated and irrigated farms during the rainy season are very similar. It reflects the amount of water available during the season,

Constraints	Shadow price Irrigated land	Shadow price Non-irrigated land
Land wet season (ha) Solution	58.8	48.6
Land dry season (ha) Solution	0	0
Water wet season limit Solution	0.273219	0.26
Water dry season limit Solution	0.11	0.02

Table 5.5 Shadow prices of land and water

and also the productivity of both farms. Contrary, during the dry season the values of both lands differ drastically. It may reflect the limit of water in both lands, which is more profoundly apparent with non-irrigated land.

The $1.20 per growing season paid by the farmer is largely a result of heavy government subsidies explained in Chapter one. Farmers with irrigation should pay approximately $0.83 per cubic meter of water per hectare. With these subsidies, no conservation program for water can be sustainable.

Capital is not binding in either farm, irrigated or non-irrigated. It is interesting that farmers in both settings do not request any loan from available sources, even with a line of credit of US$1,200.00. Similarly, farmers from both versions do the LP model, without and with irrigation, do not apply for loans even having a line of credit available to them.

The LP model assumes that crops are produces with the farm's own cash flow obtained from commodity sales as well as off-farm work. Additionally, the nature of subsistence farming with very few inputs purchased and labor supplied mainly by the family, makes reasonable to think that once the system is in place, the cashflow from crop sales the year before (t) can be used to supply inputs in current year (t+1).

Land dry season, which is defined as the amount of land available during the dry season, is not binding either. The model suggests using only 0.5 ha of farmers' own land and the rest of land should be rented. Limited availability of family labor is a binding constraint. However, fewer than the 40 days per year that the household head could dedicate to agriculture are actually used. This reflects the option that he has of working off farm for a little less than $3.00 per day.

5.2 Improving spring water systems

A sample of 120 households from 10 different communities of the study area was selected for surveying. However, one community, containing approximately 30 households of the original sample refused to participate in the study, although six of thse 30 eventually agreed to be included in the sample. Along with this problem, funding and time constraints also played a role in the limitation of the sample. Consequently, only 80 of the households were part of the final survey in this study.

The primary objective of using CVM in this study was to determine consumers' willingness to pay for improvements in the existing drinking water systems. The 80 households interviewed were used in the estimations of this section. All these households are connected to the community spring water supply system. The questionnaire used in the survey was specifically designed to measure households' WTP.

Survey responses from both non-irrigated land and irrigated land were combined and the discrete continuous models were estimated. Ordinary least squares was used to analyze factors related to income per capita. For each farm and off-farm activities of the household, net revenues were computed from a detailed account of gross revenues and costs. The household consumption of its own yield was carefully assigned for agricultural and non-agricultural activities, and it was added as the household opportunity cost. The other explanatory variables for estimation were carefully addressed in the survey. In Table 4.9 the means and standard deviations of these explanatory variables were presented. Coefficients, standard errors and t-statistics are summarized in Table 5.6. The results performed as expected with the main variables.

Dependent Variable:
Income per capita
Method: Ordinary Least Squares
Included observations: 78

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	388.0754	109.5207	3.543397	0.0007
WEALTH	0.537994	0.160719	3.347415	0.0013
DIST	-2.980699	1.387526	-2.148212	0.0351
FAMILY	-23.70548	10.54953	-2.247065	0.0277
EDUIND	383.4886	174.6881	2.195276	0.0314
PARTIND	-33.63799	156.2893	-0.215229	0.8302
R-squared	0.307529	Mean dependent var		242.9099
Adjusted R-squared	0.259440	S.D. dependent var		248.0652
Log likelihood	-525.9099	F-statistic		6.395087
Durbin-Watson stat	2.334300	Prob(F-statistic)		0.000057

Table 5.6 Estimation of Income equation

As expected, a household's wealth (*WEALTH*) coefficient has a positive sign and is statistically significant. Accordingly, farmers who own more land have higher incomes. However, two of the farmers with the highest income of the sample are dropped because they are outliers (exceptional individual economic achievements) and may affect the analysis and interpretation of the results. The presence exceptional economical achievements made by two individuals bias the analysis of the sample and affect the overall interpretation. Distance (*DIST*), which is the measure in minutes of the time that a household member takes to the nearest paved road and a proxy that measures the accessibility of the household to urban markets and jobs, has the expected negative sign and is statistically significant. Farmers living closer to the urban market have more opportunities to sell their products and find a job. Furthermore, the coefficient of household family size (*FAMILY*) has the expected negative sign and is statistically significant. Large families had lower per capita incomes, which is not a surprise because the earnings of the economically active members of the household are shared with non-working members. Education (*EDUIND*) also has the expected positive sign in the coefficient and is statistically significant in this study, as it has done with other similar studies. It is expected that individuals with more human capital are better able to compete for jobs with higher wages.

Although it was expected to have an effect on income, individual participation on community's activities (*PARTIND*) was not statistically significant. One supposes that individuals get involved in activities that provide them benefits in order to increase their expected utility. The results of this study may be due to the possibility that individuals could not see the potential benefits they can obtain from the participation, or that these benefits are so far in the future that they do not have any effect on their current expected utility. The latter might explain the negative sign of the coefficient, meaning that more participation in a community's activities might not have a significant positive effect on an individual's existing income.

Income estimation from the equation 4.17 was undertaken mainly to obtain the predicted (fitted) value of per capita income (*INC**), which is used as an explanatory variable in the regression equation in which the dependent variable is the maximum willingness to pay (*MAX*) for improvements of the spring water systems. A censored TOBIT model was used to estimate *MAX*. A censored TOBIT model is used when some information (called censored) is missing in the dependent variable, in this case the *MAX*. This missing information has to do with those members of the community who were not part of the survey. The sample of this study was small, and as a result could not record all community members' preferences. Running an ordinary least squared (OLS) of this censored regression model could generate biased and inconsistent parameters. Thus, a censored TOBIT model is used instead.

The maximum likelihood TOBIT model performed as expected with respect of the signs of the main variables. The *MAX* equation revealed that most of the households are willing to pay 50 percent more than what they are currently paying to improve the quality and reliability of drinking water. Respondents' maximum willingness to pay was related positively to income, which indicates that clean drinking water is a normal (not inferior) good. All coefficients, standard errors and t-statistics are summarized in Table 5.7.

The size of the family statistically significant and the coefficient is positive, as expected. Households with more members are willing to pay more for improving the quality and availability of drinking water systems. This was also expected because the demand for water is higher in households; as a result they would request increasing quality and reliability of the system and would be willing to pay to assure it. This result also confirms how important water is for the members of Cotacachi communities and also how important family relationships are.

A variable that combines the effects of fertile soils and irrigation (*FERTI*×*IRRI*) is added to see if it has any effect on the household willingness to pay. Both variables estimated separately do not present significant levels, but as a product have a significant value and a negative coefficient. It seems that households with

Dependent Variable:
Maximum Willingness to Pay
Method: ML - Censored Normal (TOBIT)
Convergence achieved after 11 iterations
Covariance matrix computed using second derivatives

	Coefficient	Std. Error	z-Statistic	Prob.
C	-0.670643	1.721370	-0.389598	0.6968
INCF^2	2.05E-05	1.05E-05	1.947655	0.0515
WEALTH	-0.007866	0.004501	-1.747581	0.0805
DIST	0.004118	0.019222	0.214210	0.8304
FAMILY	0.304212	0.149188	2.039116	0.0414
EDUIND	-3.558061	3.030550	-1.174064	0.2404
PARTIND	2.089149	1.426531	1.464496	0.1431
FERTI*IRRI	-0.336067	0.153692	-2.186634	0.0288
		Error Distribution		
SCALE:C(9)	1.715276	0.157091	10.91902	0.0000
R-squared	0.136349	Mean dependent var		1.845000
Adjusted R-squared	0.039036	S.D. dependent var		1.569237
Log likelihood	-142.1771	Hannan-Quinn criter.		3.886868
Avg. log likelihood	-1.777214			
Left censored obs	15	Right censored obs		0
Uncensored obs	65	Total obs		80

Table 5.7 Estimation of maximum willingness to pay (MAX) equation

unfertile farms and no irrigation are willing to pay more for improving the spring water systems. Farmers with no irrigation may weigh their decision to have better quality and reliable amounts of drinking water more heavily and are willing to pay more for improvements in the system.

The other variables of the maximum willingness to pay equation did not have statistically significant coefficients. However, the coefficients had the expected signs, except in the case of *WEALTH*, which had a negative sign. It was expected that wealthy individuals would be willing to pay more for improvements in the water system.

As in the OLS, participation (*PARTIND*) has not statistically significant coefficient. Education (*EDUIND*), on the other hand, has statistically significant coefficient in the OLS, but not in this model. It had been expected that families with more education are more aware of the potential health problems that a spring water system can carry, and thus may be willing to par more for improving this problem.

Additionally, this study did not find any significant difference between non-irrigated land and irrigated land. Most of the households were willing to pay between 1.00 to 3.00 dollars. The maximum willingness to pay for both non-irrigated land and irrigated land are summarized in Figures 5.1 and 5.2.

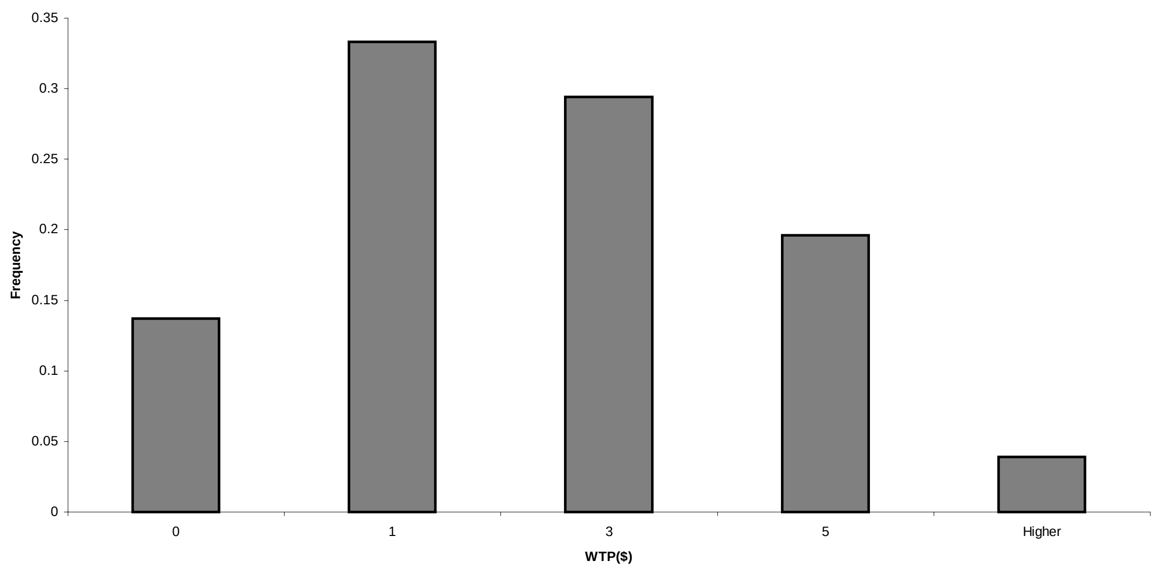

Figure 5.1 Frequency of WTP bids in non-irrigated land communities

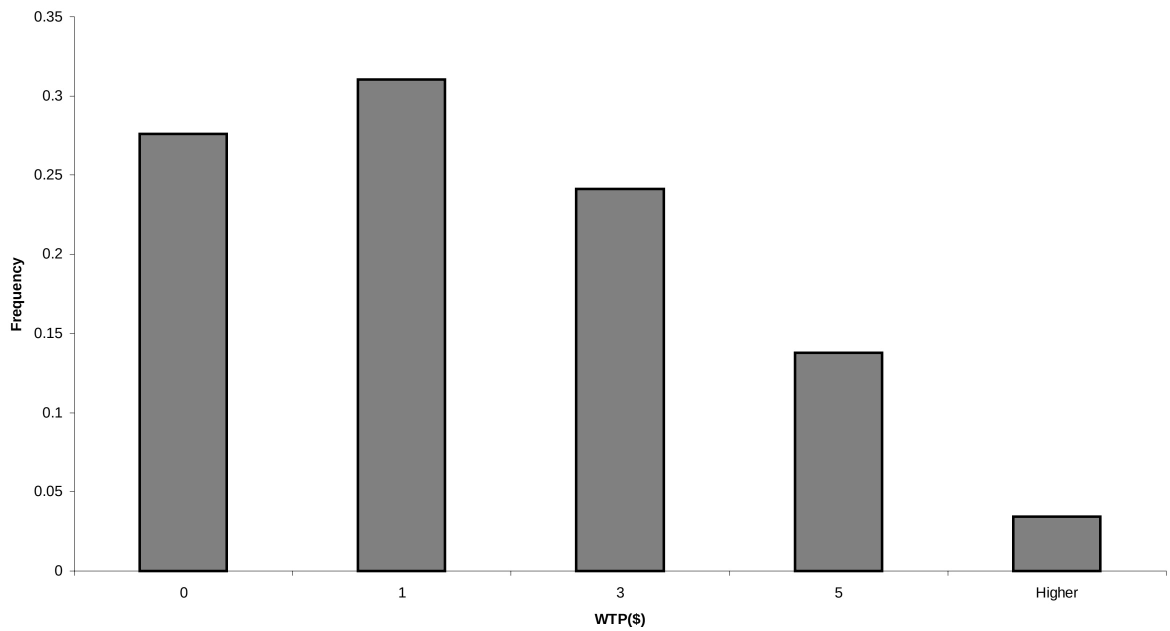

Figure 5.2 Frequency of WTP bids on irrigated land communities

The NO responses in the dichotomous choice may be due to, as the PROBIT model revealed, the income of the household. Families with lower income were more likely to say no to the initial bid. As discussed earlier in the model design, the dichotomous attribute of 1 or 0 value for the responses required an additional analysis – that is, to know if there is a relationship between the maximum WTP and the initial random bid selected for each household. A maximum likelihood PROBIT model was used to estimate the relationship between the randomly selected initial bid and the maximum willingness to pay. As expected, the maximum willingness to pay for improving spring water systems is the result of the randomly selected initial bid (Table 5.8)

Dependent Variable:
Initial dichotomous response (NO = 0, and YES =1)
Method: ML - Binary Probit
Convergence achieved after 12 iterations
Covariance matrix computed using second derivatives

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	-1.408094	1.192122	-1.181166	0.2375
INCF	1.49E-06	7.82E-06	0.190461	0.8489
BID	0.028865	0.096229	0.299964	0.7642
WEALTH	-0.000112	0.003311	-0.033966	0.9729
DIST	0.011940	0.013069	0.913621	0.3609
FAMILY	0.079684	0.109169	0.729917	0.4654
EDUIND	-0.066220	2.234188	-0.029640	0.9764
PARTIND	-0.072276	1.094205	-0.066053	0.9473
Mean dependent var	0.375000	S.D. dependent var		0.487177
S.E. of regression	0.501823	Akaike info criterion		1.489029
Sum squared resid	18.13151	Schwarz criterion		1.727232
Log likelihood	-51.56118	Hannan-Quinn criter.		1.584532
Restr. log likelihood	-52.92506	Avg. log likelihood		-0.644515
LR statistic (7 df)	2.727759	McFadden R-squared		0.025770
Probability(LR stat)	0.908994			
Obs with Dep=0	50	Total obs		80
Obs with Dep=1	30			

Table 5.8 Responses to a randomly selected initial bid

None of the explanatory variables presents are statistically significant. However, most of the coefficients present the expected signs. The expected per capita income has the expected positive sign. Farmers with higher incomes are willing to say YES to participate and willing to pay more for improvements in their drinking water systems. Additionally, it seems that farmers are willing to pay a higher initial bid. The positive sign of the coefficient for the initial bid (*BID*) indicates it.

The number of members of the household also presents a positive sign in its coefficient, although it is not significant. It seems that large families are willing to say YES to participate and to the initial bid. This result is very similar to the maximum willingness to pay, where larger families are willing to pay higher bids. It seems that larger families have a higher demand for water; thus they are interested in improving the quality and reliability of the system and would willing to pay to assure it.

Surprisingly, the explanatory variables, *WEALTH*, *EDUIND*, and *PARTIND* show coefficients with a negative sign, even though is expected that people with more assets and better education would be willing to respond YES and willing to pay more for the initial bid. Similarly, participation is expected to have a positive coefficient. It is interesting that farmers that helped to construct the water systems are not willing to say YES and pay more for the initial bid.

In a separate test, participation (*PARTIND*) is described by explanatory variables including the expected per capita squared income, education, and proxy of wealth. These explanatory variables are statistically significant and present the expected coefficient sign. The exception is the expected per capita squared income. It is expected that members with higher incomes participate more in community activities. Education has a positive coefficient sign as expected and is statistically significant. The results show that farmers with more education participate more in community activities. Wealth is also statistically significant and has the expected positive sign. The results of the sample show that farmers with more assets participate more in community activities.

The size of the household also is statistically significant, and has the expected negative sign in the coefficient. Small families have more time to participate in community activities than larger families (Table 5.9).

Dependent Variable:
Participation in Community activities
Method: Least Squares

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.405428	0.056660	7.155406	0.0000
INCF^2	-1.73E-06	5.34E-07	-3.235953	0.0018
WEALTH	0.000984	0.000234	4.209731	0.0001
FAMILY	-0.019071	0.009443	-2.019544	0.0470
EDUIND	0.670588	0.188798	3.551887	0.0007
R-squared	0.229237	Mean dependent var		0.391291
Adjusted R-squared	0.188130	S.D. dependent var		0.165511
Log likelihood	41.30048	F-statistic		5.576556
Durbin-Watson stat	2.012088	Prob(F-statistic)		0.000552

Table 5.9 Estimation of Community Participation Index (*PARTIND*) equation

The findings of this study are similar to others that evaluated individual participation on communal activities. Similar to other studies, higher income is strongly associated with participation, as well as education, family size and wealth.

CHAPTER 6

DISCUSSION

The main objective of this study was to estimate the value of water in the region of Cotacachi, Ecuador, a region where watershed management is a major concern. LP analysis yielded information about the shadow price irrigation water (Table 5.5) and CV analysis was undertaken to estimate what households are willing to pay for drinking water (Table 5.7). These values are important indicators for the guidance of policies for using water efficiently and for the conservation of this valuable resource. Shadow prices, for example, can be an exceptional tool for donor organizations to allocate their financial funding efficiently for each community. These values can allow the donors to determine where, in terms of location and activity, the water should be allocated to maximize economic returns. This benefit is also valid for individual householders who can better plan their production activities.

Policy-makers, with the assistance of donor organizations and the participation of local communities, could establish tradable property rights for water. Establishment of tradable property rights could play an important role in improving the efficiency, equity, and sustainability of water use. These types of policies will, among others things, empower water users by requiring their consent to any reallocation of water and compensation for any water transferred.

However, this type of market solution would be difficult to establish in the region because current legislation does not establish the legal prerequisites for water markets in Ecuador, as pointed out by Southgate *et al*. (1999). Moreover, specifying clear and enforceable water property rights in the Cotacachi region may be even more difficult because there is distrust between indigenous groups and wealthier farmers.

The results obtained from LP modeling are particularly important in regions such as Cotacachi, where irrigation is heavily subsidized. The low price that farmers paid for water leads to the waste of resources and unprofitable agricultural activities. Many researchers as well as international organizations such as the World Bank advocate price rises so that the cost of operating and maintaining irrigation systems are fully covered. Adopting this sort of reform would encourage resource conservation. Price rises would not affect production as long as the new price are below of shadow value of water. LP analysis indicates that shadow prices are will above existing water tariffs in Cotacachi, which implies that there is considerable scope for pricing reform.

A farmer, for example, pays an annual fee of $1.20 per year to the provincial water agency for irrigation rights. In particular, farmers are allowed to irrigate their land every three weeks (approximately 10 times during the growing season). Farmers in Cotacachi generally irrigate their land by inundation, which is considered the least efficient type of irrigation.

From the LP model, the shadow price of water is $0.27 per cubic meter per hectare per growing season. Additionally, during the dry season, a minimum of 169.1

cubic meters of water per hectare is needed. Thus a farmer should pay $47.35 per cubic meter for the minimum water requirements during the dry season, which is an enormous difference from what he actually pays. Under these circumstances, the provincial agency is not recovering the opportunity cost of water, thereby discouraging users to adapt technologies that help to conserve the resource.

Information yielded by the LP model also provides important information for the farmer. In addition to crop prices, a farmer can use this information to decide what crop he should produce. Farmers in Cotacachi generally plant traditional crops: corn-beans rotation, potatoes, and peas. Each crop has different water requirements per hectare. Of these crops, potatoes have the highest water requirement per hectare. Using the shadow price of water, a farmer could decide in favor of the most lucrative crop and the least costly. Accordingly, it is possible to evaluate whether it is worthwhile to introduce new crops in the region. This judgment should be based upon crops' water consumption per unit area, the estimated unit benefits, and the marginal value of water.

Furthermore, shadow prices provide strong incentives to distribute water where would yield the highest net return. If the marginal price of water is sufficiently high in agricultural activities compared to the marginal value of water in other activities, then it makes sense to dedicate more of the resource to agriculture. On the other hand, if the shadow price of water is low, it will be worthwhile to allocate the resource to other activities.

Recently the communities of Cotacachi have been putting into operation and expanding their irrigation systems with support from international donors such as SWISAID (Switzerland). The project is designed to rehabilitate old irrigation channels, line new channels with concrete (to reduce seepage), and replace those that were not made with concrete. The members of communities commit to the construction of the water channels, providing labor, meals and beverages to workers when they work in their community, or providing outside labor and its cost, covering the wages and other forms of compensation to these workers. If a household of any community participating in this project does not provide any form of labor described, it is not allowed access to the irrigation water system. This is a very similar participation and construction practice that was described in chapter 3 for the drinking water system.

In order to succeed, this improved irrigation system must be capable of obtaining adequate rate revenues, including buffer cash, and raising fees when needed to pay for maintenance and operators. The information provided by the LP model of this study can be useful in terms of distribution and allocation of water among users as well as deciding a new irrigation fee. Furthermore, this LP information provides the value of water per hectare that should be paid by the users. The LP information of this study suggests that an increase of the yearly irrigation fee would not have a significant impact on farm revenues.

Additionally, this dissertation addressed fundamental issues of subsistence agriculture, which relate to the returns to agriculture under deprived social conditions. The size of the farms in the study is relatively small (Table 4.2), yet having small farms does not necessarily mean low yields. Production per hectare in Cotacachi is very low (Table 4.4) for various reasons. Improved seeds are virtually unknown; instead, farmers hold back part of their crop production as seeds for the next cropping season. Likewise, there is very little use of chemical fertilizers and pesticides (Table 4.7). Most of the farmers use natural fertilizers and do not use any pesticide at all. In some cases, this means that a season' entire crop is lost.

Education attainment is very low in Cotacachi (Table 4.3). With few adults having more than an elementary education, human capital in this region is limited. The participation index, which measures with measures the participation of individuals in communities' activities, is also low (Table 4.8). Finally, survey results and LP models analysis suggest that farmers are shifting to off-farm jobs (Tables 4.1 and 4.5). IT seems that off=farm work is more profitable for farmers; the majority of the heads of households are working as labor on other farms or in construction workers in urban areas such as Quito or Otavalo. This shift in employment can be seen in many rural areas in the Third World, where subsistence farmers generally are looking for a way to work outside their own holdings.

To increase agricultural productivity, farmers will need to change current patterns of agricultural development. They should seek crops that are more profitable per area unit. Since they own small farms, agricultural intensification should be the approach for profitability. Agricultural intensification should be accomplished with the use of new technologies such as mechanization, the use of new and more efficient bioengineeried seeds that would yield more per hectare of land, and increased use of fertilizers and pesticides. This pattern should improve the social-economic conditions of rural areas and lead to the economic development. As farmers earn profits, they could improve their living standards, invest more in their farms to yield even more, which could also lead to the improvement of human capital of the regions through education.

However, in the majority of the communities of Cotacachi, incomes gained from off-farm work, which compromise the major source of financing for agriculture and other activities, are very low. Under these limited conditions, the LP model suggested that farmers should only produce to satisfy their basic consumption needs, and shift to the economic activities (off-farm work and dairying) that produce higher net returns.

The relationship between income and the explanatory variables, revealed by the regression analysis (Chapter five), yields insights into current economic conditions of households in the area of study. Table 5.6 showed that all of the explanatory variables, but community participation were statistically significant; which household size perhaps being the most important. The negative sign of this variable's coefficient was as expected. As the number of members of a household increases, the income of the household decreases. A farmer working off-farm and having a big family would not have enough resources to cover all the needs of the family and, at the same time, invest time and capital in farm activities. Thus, members of the household are economically active. The other statistically significant explanatory variable is wealth. This is not surprising because it measures wealth as possession of real estate. The farmers with the biggest farms were also those with the largest incomes.

The other two explanatory variables are statistically significant and with the expected signs of coefficients. Of these variables, the education level may be more important. As it is established earlier, the education level in the area of study is very low; the majority of individuals have only elementary education. The positive sign of the coefficient for education in Table 5.6 indicates that individuals with more education will have higher incomes. Finally, the distance to urban markets and access to labor had the expected coefficient sign. The close to the market an individual lives, the better off he is in terms of income.

Individual participation in community activities has a negative coefficient sign, implying that individuals that participate more in these activities may not receive benefits from these meetings that would not have an effect in their current incomes. This study shows that participation does not explain income, but income explains participation. Table 5.9 shows that participation in community activities does depend on income.

An important objective of this study, as stated in the research hypotheses, was to know if community members would be willing to pay for improving the quality and reliability of their spring drinking water systems, through watershed management for example. Communities of Cotacachi have been seeking and receiving outside assistance to build their own drinking water systems. Modest financial support from Switzerland has been used to build the Cambugan system, which provides spring drinking water to 18 communities. Similar projects have been implemented during last couple of years to reach more communities and there are plans to add even more. The goal of UNORCAC was and still is to provide water to all communities belonging to the association. Because of limited funding, systems have had limitations regarding quality of water; as a result, quality standards of the drinking water system did not attain those that can be found in urban areas. A study of the University of Auburn, supported by the SANREM-CRSP Andes project, has found that all supply sources of drinking water are contaminated with E. coli and other bacteria. Because of the major concern about contamination, this study sought to determine if households would be willing to pay more for a better quality system. The results showed that respondents of the ten communities participants of this study were willing to pay an average of US$ 1.84 per month (std. dev. 1.569, S.E. Mean 0.188) to improve the quality and reliability of their system, approximately 50% more than what they are currently paying.

This study reveals the problems related to drinking water that most of indigenous communities from the Andes of Ecuador have to face. Most communities have enough water, but mismanagement routinely leads to shortages and quality problems. The drinking water systems in the communities of the area of study were small and were facing financial problems. No system was able to raise enough funds to cover the maintenance and operating cost. There were problems collecting the water fees because of consumers who were not paying the prearranged fee. In addition, corruption appeared to be present in at least one of these community systems. Specifically, the collector who was hired to collect fees and fix any pipe problem by this community kept these funds for himself. Fortunately, the problem was discovered soon, and the collector was fired and replaced. However, these problems added to financial difficulties. Regarding the supply, there were constant complaints about breaks in the pipe system, which management tried to solve as soon as they had notice of problems. During the dry season, households complained about the quantity or lack of water. Furthermore, a potable system that could provide high water quality would require heavy investment, including the construction of water treatment plants and spending on equipment and monitoring of the system.

Most of these problems are related to economies of scale. Communities could organize and create a unified management system that could deal better with operating, maintenance, and construction costs. A unified system of this sort would be in a better position to access credit; the financial cost per dollar of borrowing is more expensive in small systems. A unified approach would allow water management to be more cost-effective. Moreover, it would have better access to national and international assistance and could take better advantage of credit markets.

This study has a small sample and, because of that, the findings may not be consistent with other studies. However, it shows that farmers in the area of Cotacachi are willing to pay more to improve the quality and reliability of their drinking water systems. Additional studies are needed, maybe with a larger sample that might yield more consistent results. Furthermore, it would be interesting to carry out research using CVM to estimate how much farmers are willing to pay for improvements in the irrigation system. As already indicated, LP analysis that water is extremely under-priced.

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APPENDIX

SOCIO-ECONOMIC QUESTIONNAIRE USED WITH COTACAHI COMMUNITIES, ECUADOR

NOMBRE:_____________________
Dirección:_____________________

Cuestionario para manejo sustentable de recursos en Cotacachi

Cuestionario familiar

 Promotores: Se administrará el cuestionario solo a personas adultas, cabeza de la familia, esposa, hijos o hijas adultos. Especifique quien es el entrevistado (cabeza de la familia, esposa, hijo o hija).

Primera sección

1. Fecha (DDMMAA):__________________

2. Resultado de la entrevista:

Completo	Incompleto	No adulto	No participo	No se hizo
01	02	03	04	05

Identificación:

3. Numero de indentificación de la familia**:**

4. Nombre de la Comunidad**:**

Chilcapamba	Iltaqui	Morochos	Topo Grande	Ugshapungo
01	02	03	04	05

5. ¿Cuántos años ha vivido en el cantón Cotacachi?

_______ **número de años**

6. ¿Dónde generalmente suele ir a comprar los insumos agrículas, vender productos agrícolas u otros fines comeciales?, ¿Cuál es la forma de transporte para llegar a ese lugar?, ¿Cuánto tarda en llegar a ese lugar? Aproximadamente, ¿qué porcentaje de la venta de productos o compra de insumos hace en ese lugar?

Mercado	Transporte (cód).	Tiempo (min.)	% compra insum.	% venta prod.
Cotacachi				
Otavalo				
Ibarra				
Otro				

Código de transporte

Autobus	auto propio	Bicicleta	A pie	otros (detallar)
01	**02**	**03**	**04**	**05**

6a. ¿Cuántos minutos le toma llegar a carretera pavimentada?

________ *auto* ________ *bus* _______ *a pie* ________ *otro (detallar)*

7. Preguntar el nombre, la edad, el sexo y educación de los miembros de la familia que viven en la casa *(llenar la tabla)*

		Nombre	**Edad**	**Sexo**	**Estado civil**[1]	**Tipo de educación**[1]
1	**Esposo**					
2	**Esposa**					
3	**Hijo/a**					
4	**Hijo/a**					
5	**Hijo/a**					
6	**Hijo/a**					
7	**Hijo/a**					
8	**Hijo/a**					
9	**Hijo/a**					
10	**Hijo/a**					

[1]Código del nivel de educación, sexo y estado civil.

Hombre	**Mujer**					
01	02					
Casado/a	**Soltero/a**	**Vuido/a**	**Divorciado/a**	**Separado/a**	**Acompañado/a**	**No corresponde**
01	02	03	04	05	06	07
Primaria	**ciclo básico**	**colegio**	**Universidad**	**Maestria o doctorado**	**Curso técnico o profesional**	**Otros (detallar)**
01	02	03	04	05	06	07

8**.** **¿**Cuáles son las fuentes de su ingreso anual o mensual? (cada miembro adulto de la familia)

Miembro	**01**	**02**	**03**	**04**	**05**	**06**	**07**	**08**	**09**	**10**
Codigo										

Código de las distintas actividades:

Trabajo agrícola	Peon agrícola	Cuidado animales	Venta productos	Tiendita
01	**02**	**03**	**04**	**05**
Producción artesanias	Venta artesanías	Recolección de agua	Labores domésticas	Recolección de leña
06	**07**	**08**	**09**	**10**

8a. ¿Qué tiempo ha trabajado en las labores de campo?, ¿Y su esposa?

______ años esposo   _______ años esposa

Segunda sección

Actividad Agricola
Terreno 1.

9. ¿Qué tamaño tiene su terreno(s)?, ¿Cuántas hectáreas tiene su propiedad?, Por favor, haga un mapa con las dimensiones de cada lado de la terreno(s) Propocionar una hoja para el dibujo del croquis

(ir al croquis) __________ hectáreas

9a. ¿Podría estimar la pendiente de su terreno? ______________

Alta	**Media**	**Baja**
01	02	03

9b. En su opinión, ¿Qué tan fertil es su suelo? ______________

Alto	**Medio**	**Bajo**
01	02	03

10. ¿En que año adquirió esta terreno? 19 _______

11. ¿Cómo obtuvo su terreno? __________

Heredó	**Compró**	**Asentó**	**Otros**
01	02	03	04

12 Usted es el propietario del terreno? (Promotores: aclarar a las familias que este es solo para una investigación que no tiene ninun tipo de relación con el gobierno o con otra agencia del gobierno. Es solo para la investigación, lo que permitiría observar si existen diferencias entre los encuestados)

SI NO

(Si la respuesta es SI) ir a pregunta 13.

(Si la respuesta es No) ir a pregunta 14.

13 ¿Qué tipo de derecho de propiedad tiene? (Codigo de propiedad) ____________

Escrituras	Permiso INDAG	Derechos comunitario	Tramitando escrituras	Huashipunguero	Otros (detallar)
01	02	03	04	05	06

14. ¿Arrienda Usted la propiedad?(Haga un círculo en la respuesta correcta)

SI NO

Si la respuesta es SI, ir a la pregunta 14a.

Si la respuesta es NO, ir a la pregunta 16.

14a. ¿Cuanto paga por el arriendo del terreno?

_____________ dólares/mes

14b. ¿Qué tanto de la producción le dedica a pagar el arriendo del terreno?

___________ por ciento

SOBRE EL RIEGO

15. De dónde obtiene el agua para el riego? _______________

01 de la lluvia (ir a pregunta 20)
02 el canal de riego (ir a la pregunta 16)
03 Desviación del rio (ir a la pregunta 20)
04 Otras formas de irrigación (ir a la pregunta 20)

16. Si terreno es regado con el agua del canal de riego, ¿Cuantas veces al año riega su terreno?, ¿Cuantas días al mes puede regar su terreno? Y ¿Cuantas horas por día se le permite regar el terreno?

_______ veces por año. _______ días por mes. _______ horas por día.

17. ¿Cuanto paga por año para coger el agua de riego? ______ dólares
Tiene problemas por el uso del agua de riego?

SI NO

(Si la respuesta es NO) ir a la pregunta 19.

(Si la respuesta es SI) ¿Qué tipos de problemas? __________

01 Cantidad disponible al año.
02 Cantidad disponible cada mes.
03 Filtración agua en los canales.
04 Disputas con los vecinos durante la irrigación de su terreno.
05 Participación en la construcción de los canales.
06 Otros (detallar) _____________

Si la respuesta es 04., ir a la pregunta 18a.

18a. ¿ha participado en las mingas construcción de los canales de riego?

SI NO

18b. ¿Cuántos días/semanas participó en la construcción del canal?

________ días/semanas.

18c. ¿ha participado en las mingas para la limpia de los canales de riego?

_______ días/semanas.

18d. ¿Cuántas veces al año se limpia los canales? ____________

una vez	dos veces	tres veces	más de tres	Nunca
01	02	03	04	05

SOBRE EL ARADO

19. ¿Qué tipo de arado utiliza en su propiedad? Y ¿Cuantas veces al año prepara su terreno?

Tipo de arado ____________ Uso del arado ______________

Código	Yunta 01	Tractor 02	Usted solo 03
01	1 vez	1 vez	1 vez
02	2 veces	2 veces	2 veces

03	3 veces	3 veces	3 veces
04	Más de 3 veces	Más de 3 veces	Mas de 3 veces

20. Las siguientes preguntas nos va a ayudar a conocer los tipos de cultivos que tiene en su propiedad, además el tipo de rotación de sus cultivos. Como también el area de su terreno dedicada a cada rotación y cultivo. Finalmente, si vendió sus productos, el precio que le pagaron por sus productos, y la cantidad del total de la producción que fue vendida

Survey Cotacachi	**Porción de**	**Producción**	**Producción**	**Cantidad**	**Precio**
	Terreno(%)	**en qq./año**	**en lbs/año**	**Vendida (qq/lbs)**	**$/qq. o lb.**
Maíz-frejol					
Maíz-arberja					
Maíz-quinua					
Papas-habas					
Arberja-cebada					
Arberja-frejol					
Tomate riñon					
Pimiento					
Chochos					
Avena					
Zanahoria blanca					
Tomate de arbol					

Terreno 2.

21 ¿Qué tamaño tiene su terreno(s)?, ¿Cuántas hectáreas tiene su propiedad? Por favor, haga un mapa con las dimensiones de cada lado de la terreno(s) Propocionar una hoja para el dibujo del croquis

(ir al croquis) ___________ hectáreas

21a. ¿Podría estimar la pendiente de su terreno? ______________

Alta	**Media**	**Baja**
01	02	03

21b. En su opinión, ¿Qué tan fertil es su suelo? ______________

Alto	**Medio**	**Bajo**
01	02	03

22. ¿En que año adquirió esta terreno? 19 _______

23. ¿Cómo obtuvo su terreno? _________

Heredó	**compró**	**Asentó**	**otros**
01	02	03	04

24. ¿Usted es le propietario del terreno? (Promotores: aclarar a las familias que este es solo para una investigación que no tiene ninun tipo de relación con el gobierno o con otra agencia del gobierno. Es solo para la investigación, lo que permitiría observar si existen diferencias entre los encuestados)

SI NO

(Si la respuesta es SI) ir a pregunta 25.

(Si la respuesta es No) ir a pregunta 26.

25. ¿Qué tipo de derecho de propiedad tiene? ___________

Escrituras	**Permiso INDAG**	**Derechos comunitario**	**Tramitando escrituras**	**Huashipunguero**	**Otros (detallar)**
01	02	03	04	05	06

26. ¿Arrienda Usted la propiedad?

SI NO (ir a la pregunta 28)

27a. ¿Cuanto paga por el arriendo del terreno?

____________ dólares/mes

27b. ¿Qué tanto de la producción le dedica a pagar el arriendo del terreno?

___________ por ciento

SOBRE EL RIEGO

28. ¿De dónde obtiene el agua para el riego? __________

01. De la lluvia (ir a pregunta 31)
02. Del canal de riego (ir a la pregunta 29)
03. Desviación del rio (ir a la pregunta 31)
04. Otras formas de irrigación (ir a la pregunta 31)

29. Si terreno es regado con el agua del canal de riego, ¿Cuantas veces al año riega su terreno?, ¿Cuantas días al mes puede regar su terreno? Y ¿Cuantas horas por día se le permite regar el terreno?

_______ veces por año. _______ días por mes. _______ horas por día.

30. ¿Cuanto paga por año para coger el agua de riego? ______ dólares

31. Tiene problemas por el uso del agua?

SI NO

(Si la respuesta es SI) ¿Qué tipo de problemas?.
(Si la respuesta es NO) ir a la pregunta 32. __________

01. Cantidad disponible al año.
02. Cantidad disponible cada mes.
03. Filtración agua en los canales.
04. Disputas con los vecinos durante la irrigación de su terreno.
05. Participación en la construcción de los canales.
06. Otros (detallar) _____________

Si la respuesta es 04., ir a la pregunta 31a.

31a. ¿Ha participado en las mingas construcción de los canales de riego?

SI NO

Si la respuesta es SI, ir a la pregunta 31b.
Si la respuesta es NO, ir a la pregunta 32.

31b. ¿Cuántos días/semanas participó en la construcción del canal?

________ días/semanas.

31c.¿ha participado en las mingas para la limpia de los canales de riego?

_______ días/semanas.

31d. ¿Cuántas veces al año se limpia los canales?
(haga un círculo en la respuesta correcta)

Una vez	Dos veces	Tres veces	más de tres	Nunca
01	02	03	04	05

SOBRE EL ARADO

32. ¿Qué tipo de arado utiliza en su propiedad? Y ¿Cuantas veces al año prepara su terreno? (Haga un circulo en la respuesta y anote cuantas veces al año).

Codigo	Yunta 01	Tractor 02	Usted solo 03
01	1 vez	1 vez	1 vez
02	2 veces	2 veces	2 veces
03	3 veces	3 veces	3 veces
04	Más de 3 veces	más de 3 veces	más de 3 veces

33. Las siguientes preguntas nos va a ayudar a conocer los tipos de cultivos que tiene en su propiedad, además el tipo de rotación de sus cultivos. Como también el area de su terreno dedicada a cada rotación y cultivo. Finalmente, si vendió sus productos, el precio que le pagaron por sus productos, y la cantidad del total de la producción que fue vendida

Survey Cotacachi	**Porción de Terreno(%)**	**Producción en qq./año**	**Producción en lbs/año**	**Cantidad Vendida (qq/lbs)**	**Precio $/qq. o lb.**
Maíz-frejol					
Maíz-arberja					
Maíz-quinua					
Papas-habas					
Arberja-cebada					
Arberja-frejol					
Tomate riñon					
Pimiento					
Chochos					
Avena					
Zanahoria blanca					
Tomate de arbol					

Tercera sección

SOBRE LOS GASTOS ANUALES EN INSUMOS CONSUMIDOS.

34. ¿Qué tipo de abonos y químicos para el control de plagas artificiales o naturales utiliza en sus cultivos? ¿Cuánta cantidad de insumos usa por año en su(s) terreno(s)?¿Cuánto gastó en los insumos el ultimo año?

Tipos de insumo		Total	precio por unidad	Terreno 1	Terreno 2
		sacos/año	$/saco o galón	cantidad	Cantidad
Fetilizantes	Químico				
	Natural				
Semillas	Propias				
	comerciales				
Insecticides	Químico				
	Natural				
Herbicidas	Químico				
	Natural				
Total					

35. ¿Qué otros productos agrícolas produce, además de las rotaciones ya anotadas?

Anuales				Perennes			
Producto	Prod./año	% vendido	Precio	Producto	Prod. Año	% vendido	Precio
Cebada				Avena			
Trigo				Capuli			
Camote				Mora			
Melloco				Aguacate			
Oca				Granadilla			
Frejol				Taxo			
Lenteja				Uvillas			
Arberja				Naranjas			
Habas				Limones			
Chochos				Otros (detallar)			

36. ¿Qué tipo de animales cría?, ¿Qué productos obtiene de cada tipo de animal?, ¿Cuántos animales o los productos de los animales ha vendido?, ¿Cuál fue el precio por animal o producto? (Llenar la tabla)

36a. ¿Qué animales tiene?

01. Toros	05. Novillos	09. Gallinas	12. Pavos	16. Ovejas
02. Ganado de carne	06. Bueyes	10. Pollos	13. Caballos y yeguas	17. Conejos
03. Vacas lecheras	07. Cerdos	11. Patos	14. Burros mulas	18. Llamas
04. terneros	08. cuyes	12. Gansos	15. Cabras chivos	20. abejas

36b. ¿Cuántos animales ______ (llene el nombre de cada animal en el espacio y repita para cada animal) tenía al principio del año?

36c. ¿Cuántos animales ______ (llene el nombre de cada animal en el espacio y repita para cada animal) nacieron en el último año?

36d. ¿Cuántos animales ______ (llene el nombre de cada animal en el espacio y repita para cada animal) compraron el último año?

36e. ¿Cuántos animales ______ (llene el nombre de cada animal en el espacio y repita para cada animal) vendieron el último año?

36f. ¿Cuántos animales ______ (llene el nombre de cada animal en el espacio y repita para cada animal) consumió la familia?

36g. ¿Cuántos animales ______ (llene el nombre de cada animal en el espacio y repita para cada animal) murieron en el último año?

36h. ¿Cuántos animales ______ (llene el nombre de cada animal en el espacio y repita para cada animal) se perdieron o murieron el último año?

36i. Cuantos animales ______ (llene el nombre de cada animal en el espacio y repita para cada animal) tiene ahora?

36j. ¿A qué precio vendió cada animal ______ (llene el nombre de cada animal en el espacio) o cuanto estima que vale cada animal ______ (llene el nombre de cada animal en el espacio)?

36k. Si vendió los animales ______ (llene el nombre de cada animal en el espacio), ¿los vendió en pie?

01 SI 02 NO

Pregunta	Codigo animal	Código animal	Código animal	Código animal	Código animal	Código animal
36b						
36c						
36d						
36e						
36f						
36g						
36h						
36i						
36j						
36k						

37. ¿Cuánto gasto en veterinario para sus animales incluyendo vacunas y medicamentos?

___________ dólares.

38. ¿Cuánto gasto en comida para animales ya preparada?

___________ dólares.

39. ¿Cuánto gastó en alimento preparado por usted mismo para sus animales?

___________ dólares.

40. ¿Cuánto más gasto en sus animales?

___________ dólares.

41. ¿Qué productos de los animales de crianza produjo en el año pasado?

01. Ninguno
02. Miel
03. Leche
04. Quesos
05. Crema de leche.
06. Huevos
07. Carne
08. Cuero/piel
09. otros (especifique) _________

41a. ¿Qué cantidad de productos _______ (llene el nombre de cada animal en el espacio y repita para producto) produjo en último año?

Cantidad	Producto código	Producto código	Producto código	Producto código
01. litros				
02. galones				
03. libras				
04. kilos				
05. toneladas				
06. cientos				
07. decenas				
08. unidades				
/01. por día				
/02. por mes				
/03. por año				

41b. ¿Qué cantidad de __________ (llene el nombre de cada animal en el espacio y repita para producto) vendió el último año?

Cantidad	Producto código	Producto código	Producto código	Producto código
01. litros				
02. galones				
03. libras				
04. kilos				
05. toneladas				
06. cientos				
07. decenas				
08. unidades				
/01. por día				
/02. por mes				
/03. por año				

41c. ¿A qué precio vendió?

Cantidad	Producto código	Producto código	Producto código	Producto código
01. litros				
02. galones				
03. libras				
04. kilos				
05. toneladas				
06. cientos				
07. decenas				
08. unidades				

Cuarta sección

SOBRE LA MANO DE OBRA

42. ¿Emplea otras personas o compañeros fuera de su familia para trabajar en su propiedad?

SI NO

(Si la respuesta es SI, ir a la pregunta 43)

(Si la respuesta es NO, ir a la pregunta 45)

43. ¿Cuántos personas emplea? ¿Cuándo los emplea? (en que meses)¿Cuántos días trabajan?

	Rotación 1			Rotación 2		
Actividad	**Limpia**	**siembra**	**cosecha**	**limpia**	**Siembra**	**cosecha**
Numero de semanas						
Horas por semana						
Número de peones						

44. **¿**Cuánto paga por día? ____________ dólares/día

44a. Además del salario, ¿el contrato incluía otra forma de pago?

01. comida
02. alojamiento
03. Otro (especificar)
04. Nada más

44b. ¿Cuánto estima que cuesta en dólares?

01. comida ________
02. alojamiento ________
03. Otro ________

45. Si renta una yunta o un tractor, ¿Cuantas horas trabaja por año el asalariado con la yunta o tractor en cada terreno?

01. _______ horas yunta terreno 1 02. ______ horas tractor terreno 1

03. _______ horas yunta terreno 2 04. ______ horas tractor terreno 2

46. ¿Cuánto paga por el diario/horas por el uso del la yunta o tractor?

_________dólares por día

47. ¿En que meses del año hace la limpia, la siembra y la cosecha? (marque los meses correspondientes para cada actividad)

Codigo	Meses	Ene.	Feb.	Mar.	Abr.	May.	Jun.	Jul.	Ago.	Sep.	Oct.	Nov.	Dic.
01	Siembra												
02	Limpia												
03	Cosecha												

Quinta sección

SOBRE LOS INGRESOS ANUALES

48. ¿Obtiene usted su dinero mensual de su propiedad?

SI NO

49. ¿Cuál es aproximadamente sus ganancias por mes promedio? _______________ dólares

	Dolares/mes		dolares/mes		dolares/mes
01	0.00-10.00	**05**	101.00-200.00	**09**	751.00-1,000.00
02	11.00-20.00	**06**	201.00-300.00	**10**	1,001.00-1,500.00
03	20.00-50.00	**07**	301.00-500.00	**11**	1,501.00-2,000.00
04	51.00-100.00	**08**	501.00-750.00	**12**	mas de 2,000.00

49a. ¿En qué mes fue su ganancia mínima mensual en el último año?

_______________ mes

49b. ¿Cuál fue su ganancia mínima mensual en el último año? ____________ dólares.

49c. ¿En qué mes fue su ganancia máxima mensual en el último año? _______________ mes

49d. ¿Cuál fue su ganancia máxima mensual en el último año? ___________ dólares.

50. Ha comprado recientemente alguna otro terreno, equipo agricola, o animales para el arado?

SI NO

(Si la respuesta es SI ir a pregunta 51)
(Si la respuesta es NO, ir a la siguiente sección)

51. ¿Que tipo de compra?

	Tipo	Precio		Tipo	Precio		Tipo	Precio
a.	Tractor		f.	cultivadora		k.	sembradora	
b.	Arado		g.	empacadora		l.	rastra	
c.	Rociadora		h.	Molino		m.	carro	
d.	bomba de agua		i.	Carreta		n.	moto	
e.	desgranadora		j.	Yunta		o.	ninguna	

52. ¿Ha recibido algún préstamo o crédito para su producción agrícola?

SI NO

Si la respuesta es SI, ir a la pregunta 52a.
Si la respuesta es NO, ir a la pregunta 53.

52a. ¿Qué tipo de institución el otorgó el prestamo? _________

01. Banco Comercial
02. Banco de Fomento
03.Cooperativa de ahorro y crédito
04. Otro tipo de cooperativa
05. Mutualista
06. UNORCAC (proyectos de organizaciones internacionales)
07. Familia
08. Otros (detallar)

52b. ¿Cuánto fue el monto del préstamo?

__________ dólares

52c. ¿Cuál fue la tasa de interés al préstamo?

__________ por ciento

52d. ¿Cuándo le otorgaron el préstamo?

_________ mes __________ año

52e. ¿Cuándo es/fue la fecha de vencimiento del préstamo?

_________ mes __________ año

52f. ¿Cuál fue el destino del préstamo?

01. Consumo familiar
02. Adquisición de bienes para la casa
03. Construcción de la vivienda
04. Reparar o ampliar la vivienda
05. Comprar insumos para la producción
06. Comprar maquinaria u otros equipos para la producción
07. Comprar animales
08. Para atender una emergencia
09. Otros (especificar) __________

52g. ¿Qué garantía ofreció para el préstamo?

01. Ninguna, solo reputación
02. La tierra
03. Animales
04. Otra propiedad
05. La cosecha
06. Letras de cambio
07. Casa
08. Otro (especificar) ________

53. ¿Sí utiliza solo parte del tiempo para la limpia, preparación, siembra, y cosecha de sus productos, en que emplea el resto del tiempo?

Actividad	**Dias por semana**	**horas por dia**	**meses al año**	**salario/dia**
Trabajo peón agrícola				
Tienda				
Producción de artesanías				
Venta de artesanías				
Producción de textiles				
Venta de textiles				
Industria flores				
Fabricación productos de cuero				
Venta de productos de cuero				
Comercio al por mayor				
Transporte, almacenamiento				
Construccion				
Oficina o Banco				
Ninguno				
Otros (detallar)				

Sexta sección

SOBRE PARTICIPACIÓN DE LA COMUNIDAD

54. ¿Cuántos años ha venido participando en las reuniones de la comunidad?

_______________ años

55. ¿Ha sido miembro de la directiva de la comunidad?

SI NO

Si la respuesta es SI, ir a la pregunta 56.

Si la respuesta es NO, ir a la pregunta 61.

56. ¿Cuál fue la posición directiva que ocupó en la comunidad? (Haga un círculo en cada respuesta relevante)

01. Presidente de la comunidad.	02. Presidente de la junta de agua.
03. Representante en UNORCAC	04. Secretario de la comunidad.
05. Tesorero de la comunidad	06. Vicepresidente
07. Otros (detallar) ______________	

57. ¿Cómo se elijen los miembros del directorio de la comunidad? (Haga un círculo en la respuesta correcta).

01. Elegidos por los miembros de la comunidad en elecciones regulares internas
02. Elegidos por los miembros de la comunidad en elecciones irregulares.
03. Heredados.
04. Seleccionados por la dirección del UNORCAC.
05. Seleccionados por el gobierno cantonal.
06. Seleccionados por el gobierno nacional.

58. ¿Por cuánto tiempo se elije un miembro del directorio de la comunidad?

______________ años

59. ¿Cada cuánto tiempo se reune la comunidad? (Haga un círculo en la respuesta correcta)

01. Una vez a la semana.
02. Una vez cada 15 días.
03. Una vez al mes.
04. Una vez cada tres meses.
05. Una vez cada seis meses.
06. Una vez cada año.
07. De forma irregular
08. De vez en cuando
09. No es aplicable.

60. ¿Cuántas veces ha asistido a las reuniones de la comunidad? ____________

01. Todas las reuniones.	02. 90 por ciento.
03. 80 por ciento.	04. 70 por ciento.
05. 60 por ciento.	06. 50 por ciento.
07. 40 por ciento.	08. 30 por ciento.
09. 20 por ciento.	10. 10 por ciento.

10. No ha asistido a ninguna reunion.

61. ¿Los compañeros de la comunidad participan en le reuniones? ____________

01. todos
02. la mayoría
03. más o menos la mitad
04. menos de la mitad
05. muy pocos.

Séptima Sección

VALORACIÓN CONTINGENTE DE AGUA ENTUBADA Y RIEGO

Promotor: Declaración inicial en la cual se explica la naturaleza de esta sección del cuestionario:

"Le voy a preguntar algunas preguntas para conocer si Usted o alguien de su casa apoyarían a la construcción de un proyecto de construcción y mejoramiento del sistema de agua potable y los canales de riego para la comunidad. Su nombre e información no será compartida con nadie, sus respuestas serán totalmente confidenciales y no serán directamente asociadas con su nombre.

Esta parte del cuestionario busca conocer la importancia que ustedes le dan al agua, y ayudaría a una organización donante a conocer el nivel de participación que el proyecto tendría y si las personas de la comunidad estarían dispuestas a cubrir parte del costo de construcción, operación y mantenimiento a través de un cobro mensual por el agua. El proyecto de construcción y mejora del agua potable buscaría mejorar la calidad del agua y garantizar su surtido a lo largo del año. El sistema de canales de riego buscaría eliminar el desperdicio y filtración de agua que actualmente ocurre, para lo cual sería necesario ampliar los actuales canales y hacerlos de cemento y concreto.

El manejo del sistema tanto de agua potable como de agua para irrigación sería hecho por un comité de la propia comunidad. La gente de la comunidad podrá elegir a los miembros encargados de administrar el sistema de agua potable, para lo cual la organización donante requiere conocer cuanto estarían dispuestos a pagar para asegurar el éxito del proyecto de irrigación.

Sin embargo es muy importante para la organización donante que Usted conteste con la verdad para que tomen la decisión o no de implementar el proyecto."

62. ¿Cuál es el uso principal que Usted le da al agua? __________

01. Cocinar
02. Bañarse
03. Lavar
04. Irrigación
05. Otros (detallar)

63. ¿El agua que utiliza para cocinar, lavar o para bañarse proviene del agua potable? (Haga un círculo en la respuesta correcta)

SI NO

Si la respuesta es SI, vaya a la pregunta 64.
Si la respuesta es no vaya a la pregunta 67

SOBRE EL AGUA POTABLE

64. ¿Cuánto paga por el consumo del agua potable por mes?

    a. _____________ dólares

65. Aproximadamente, ¿que porcentaje del agua potable utiliza para cocinar, lavar, o bañarse? ________

    01. Cocinar(%)   02. Lavar(%)   03. Bañarse(%)

Codigo	0-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	91-100
	01	02	03	04	05	06	07	08	09	10

66. ¿Tiene algún problema con la cantidad de agua potable que recibe cada mes?

    SI   NO

Si la respuesta es SI, vaya a la pregunta 67,
Si la respuesta es NO, vaya a la pregunta 70.

67. ¿Qué meses del año la reducción de la cantidad de agua que recibe cada mes se hace mas notoria? ________

ene	feb	mar	Abr	may	jun	jul	ago	sept	oct	nov	Dic
01	02	03	04	05	06	07	08	09	10	11	12

Usted o alguien de su casa apoyarían a la construcción de un proyecto de construcción y mejoramiento del sistema de agua potable. Estaría dispuesto a cubrir parte del costo de construcción, operación y mantenimiento a través de un cobro mensual por el agua. El proyecto de construcción y mejora del agua potable buscaría mejorar la calidad del agua y garantizar su surtido a lo largo del año.

68. ¿Estaría dispuesto a pagar una cantidad mensual para mejorar la calidad de agua y mantener la cantidad de agua a lo largo del año?

    SI   NO

Si la respuesta es SI, ir a la pregunta 69.
Si la respuesta es NO, ir a la pregunta 70.

69. ¿Pagaría mensualmente 3.00[1] dólares para garantizar el surtido de agua mensual y mejorar la calidad del agua? ([1] valor asignado al azar a cada entrevistado. Los valores asignados al azar son: 1.00, 3.00, 5.00)

SI NO

Si la respuesta es SI, ir a la pregunta 69a.
Si la respuesta es NO, ir a la pregunta 69c.

69a. (Aumentar el valor asignado al azar en 1.00 dólar, valores asigandos al azar 2.00, 4.00, 6.00) ¿Estaría dispuesto a pagar mensualmente 4.00 dólares?

SI NO

Si la respuesta es SI, ir al pregunta 64b.
Si la respuesta es NO, determinar el rango más exacto del valor final del entrevistado. (Aumentar el valor en 0.50 ctvs, y repetir el procedimiento)

69b. ¿Cuánto dólares maximo estaría dispuesto a pagar mensualmente?

__________ dólares.

69c. (Reducir el valor asignado al azar en 1.00 dólar, valores, asignados al azar 0.50. 2.00, 4.00) ¿Estaría dispuesto a pagar mensualmente 2.00 dólares?

SI NO

Si la respuesta es NO, ir al pregunta 64d.
Si la respuesta es SI, determinar el rango más exacto del valor final del entrevistado. (Disminuir el valor en 0.50 ctvs, y repetir el procedimiento)

69d.¿Cuál sería lo mínimo en dólares que estaría dispuesto a pagar?

________ dólares.

SOBRE EL AGUA DE RIEGO

Usted o alguien de su casa apoyarían a la construcción de un proyecto de construcción y mejoramiento de los canales de riego para la comunidad. Estaría dispuesto a cubrir parte del costo de construcción, operación y mantenimiento a través de un cobro mensual por el agua para el riego del campo. El sistema de canales de riego buscaría eliminar el desperdicio y filtración de agua que actualmente ocurre, para lo cual sería necesario ampliar los actuales canales y hacerlos de cemento y concreto

70. ¿De dónde lo obtiene el agua para regar sus cultivos? ___________

01. De la lluvia
02. Del canal de riego
03. Desviación del río
04. Otro (detallar)

Si la respuesta es 01. termine con la entrevista. Si la respuesta es 02. siga con la pregunta 71. Si la respuesta es 03. especifique de donde obtiene el agua.

71. En su opinión, el invertir en un proyecto de construcción y mejoramiento de los canales de riego para la comunidad debería ser una prioridad importante _________

No Se	**Un poco importante**	**Importante**	**Algo importante**	**Muy importante**
01	02	03	04	05

Si considera que la prioridad de construir y reparar los canales de riego de la comunidad es "importante", vaya a la pregunta 72.
Si considera que la prioridad de construir y reparar los canales de riego de la comunidad es "poco importante" o "no sabe," termine la entrevista.

72. Si considera que invertir en un proyecto para construir y mejorara los canales de riego de la comunidad, ¿estaría Usted dispuesto a ayudar en la construcción y mantenimiento de los canales?

SI NO

Si la respuesta es SI, vaya a la pregunta 73.
Si la respuesta es NO, termine con la entrevista.

73. Si la respuesta es SI, la organización donante le gustaría saber como estaría dispuesto a ayudar en la construcción y mantenimiento de los canales. _________

01. Ayudaría en las mingas de construcción
02. Ayudaría en el mantenimiento
03. Estaría dispuesto a dar una ayuda económica
04. No estaría dispuesto a dar una ayuda económica o ayudar en las mingas o mantenimiento.
05. Otro (detallar) ________________________

Si la respuesta es 01, vaya a la pregunta 74.
Si la respuesta es 02, vaya a la pregunta 75.
Si la respuesta es 03, vaya a la pregunta 76.
Si la respuesta es 04, termine con la entrevista.

74. Si esta dispuesto a ayudar en las mingas para la construcción de los canales de riego para la comunidad, ¿como le gustaría que se le reconozca su trabajo? ___________

01. Con comida y bebida en las mingas
02. Con un sueldo, pero sin las comida y bebida
03. Con un sueldo, pero con la comida y bebida
04. Otros (detallar) __________________________

75. Si esta dispuesto a ayudar en el mantenimiento de los canales de riego para la comunidad, ¿como le gustaría que se le reconozca su trabajo? ________

01. Con un sueldo más la comida y bebida
02. Con un sueldo pero sin la comida
03. Otros (detallar) _____________________

76. Si estaría dispuesto a pagar para la construcción de los canales de riego, ¿Cómo estaría dispuesto a dar esa ayuda económica?

SI NO

77. Si la respuesta es SI, ¿estaría dispuesto a pagar mensualmente o anualmente? ________

01. Mensualmente 02. Anualmente

Si la respuesta es 02, vaya a la pregunta 78.
Si la respuesta es 01, vaya a la pregunta 79.

78. Si estaría dispuesto a dar una ayuda económica con un solo pago anual para la construcción de los canales de riego ¿Estaría dispuesto a pagar 10.00[1] dólares? ([1] valor asignado al azar a cada entrevistado. Los valores asignados al azar son: 5.00, 10.00, 20.00, 40.00)

SI NO

Si la respuesta es SI, ir a la pregunta 78a.
Si la respuesta es NO, ir a la pregunta 78c.

78a. (Aumentar el valor asignado al azar en 5.00 dólares) ¿Estaría dispuesto a pagar mensualmente más o menos de 15.00 dólares?

SI NO

Si la respuesta es SI, ir a la pregunta 72b.
Si la respuesta es NO, determinar el rango más exacto del valor final del entrevistado. (reducir el valor a la mitad, y repetir el procedimiento)

78b. (¿Cuál sería el valor máximo en dólares que estaría dispuesto a pagar anualmente?

__________ dólares.

78c. (Reducir el valor asignado al azar en 5.00 dólares, valores asignados al azar 2.50, 5.00, 10.00, 20.00) ¿Estaría dispuesto a pagar anualmente 5.00 dólares?

SI NO

Si la respuesta es NO, ir al pregunta 78d.
Si la respuesta es SI, determinar el rango más exacto del valor final del entrevistado. (Disminuir el valor a la mitad, y repetir el procedimiento)

78d.¿Cuál sería el valor mínimo en dólares que estaría dispuesto a pagar anualmente?

__________ dólares.

79. Si estaría dispuesto a dar una ayuda económica con pago mensual para la construcción de los canales de riego ¿Estaría dispuesto a pagar mensualmente 3.00 dólares? ([1] valor asignado al azar a cada entrevistado. Los valores asignados al azar son: 1.00, 3.00, 5.00)

SI NO

Si la respuesta es SI, ir a la pregunta 79a.
Si la respuesta es NO, ir a la pregunta 79c.

79a. (Aumentar el valor asignado al azar en 1.00 dólar, valores asignados al azar 2.00, 4.00, 6.00) ¿Estaría dispuesto a pagar mensualmente 4.00 dólares?

SI NO

Si la respuesta es SI, ir al pregunta 73b.
Si la respuesta es NO, determinar el rango más exacto del valor final del entrevistado. (Aumentar el valor en 0.50 ctvs, y repetir el procedimiento)

79b.¿Cuál sería el valor máximo en dólares que estaría dispuesto a pagar mensualmente?

_________ dólares.

79c. (Reducir el valor asignado al azar en 1.00 dólar, valores asignados al azar 0.50, 2.00, 4.00) ¿Estaría dispuesto a pagar mensualmente 2.00 dólares?

NO SI

Si la respuesta es NO, ir al pregunta 79d.
Si la respuesta es SI, determinar el rango más exacto del valor final del entrevistado. (Disminuir el valor en 0.50 ctvs, y repetir el procedimiento)

79d. ¿Cuál sería el valor mínimo en dólares que estaría dispuesto a pagar mensualmente?

_________ dólares.

Los científicos, promotores y todos los compañeros que trabajan en el proyecto SANREM, están muy agradecidos por su tiempo y participación en este estudio.