Polluted domestic water in Costa Rica

-An analysis from a technical and an economic perspective

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Förorenat dricksvatten i Costa Rica
- En analys ur ett tekniskt och ett ekonomiskt perspektiv

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Abstract

The aim of this project was to investigate pollution of a water resource from fertilizer used in coffee plantations and to investigate the inhabitants' willingness to pay to maintain a good quality of the drinking water. Concentrations of nitrite and nitrate in water taken from a coffee plantation were compared with water from an area not as fertilizer intense. During seven weeks groundwater was taken weekly from the coffee farm La Pequeña, San Isidro. Surface water was taken weekly from the national park Los Chorros, Tacares de Grecia. Both areas are situated in the Central Valley, Costa Rica and they provide drinking water for the cities Atenas, Orotina and Alajuela. The water samples taken from La Pequeña had concentrations of about 14mg/l $NO_3^-$and the samples from Los Chorros had concentrations of about 3.5 mg/l NO_3^-. Concentrations of nitrate in water from the coffee plantations were therefore high just as suspected. Concentration of NO_2^- varied as NO_2^- is an unstable chemical form of nitrogen, N. The mean willingness to pay, WTP, for the people interviewed was ¢1,400 per month. The WTP was examined through interviews with people living in these areas. The mean WTP increased with a higher total household income and level of education. Many of the respondents were content with the water quality but were still willing to pay more for their drinking water. Even if the opinions of the current water cost differed the mean WTP were the same. The group with confidence for the distributor had a higher mean WTP. A continuation of the project could be to take water samples at least during a year to study the seasonal variations of concentrations of nitrate and nitrite. A cost benefit analysis could also be of interest to make.

Keywords: Costa Rica, drinking water, fertilizer, coffee, nitrate, nitrite, willingness to pay, environmental valuation, contingent valuation method

Sammanfattning

Syftet med detta projekt var att undersöka föroreningar i en vattenkälla från gödningsmedel som använts på en kaffeplantage, och undersöka vilken betalningsvilja som finns bland befolkningen för att behålla en god dricksvattenkvalitet alternativt förbättra vattenkvaliteten. Koncentrationer av nitrit och nitrat i vatten taget från kaffeplantagen jämfördes med vatten taget från ett område som inte är lika utsatt av gödningsmedlet. Under sju veckor togs prover av grundvattnet från kaffeplantagen La Pequeña, San Isidro. Ytvatten togs också veckovis från nationalparken Los Chorros, Tacares de Grecia. Båda områdena befinner sig i Central Valley, Costa Rica och de står för dricksvatten till städerna Atenas, Orotina and Alajuela. Vattenproverna tagna från La Pequeña hade koncentrationer av 14mg/l NO_3^- och proverna från Los Chorros hade koncentrationer av 3.5 mg/l NO_3^-. Koncentrationerna av nitrat I vattnet från kaffeplantaget var alltså högt som väntat. Koncentrationen av nitrit, NO_2^-, varierade eftersom NO_2^- är en labil kemisk form av kväve, N. Betalningsviljan bestämdes genom intervjuer med befolkningen i området som tog emot dricksvatten från källan. Medelbetalningsviljan för de intervjuade personerna är ¢1,400 per månad. Betalningsviljan ökade med högre total hushållsinkomst och utbildningsnivå. Många av dem som svarade på intervjun var nöjda med vattenkvaliteten men var ändå villiga att betala en summa för att höja kvaliteten av deras dricksvatten. Även om åsikterna om de nuvarande vattenkostnaderna skiljde sig var medelbetalningsviljan densamma. Gruppen som hade förtroende för vattendistributörerna hade högre medelbetalningsvilja. En uppföljning av projektet kan vara att ta vattenprov under minst ett år för att studera de variationerna i koncentrationerna av nitrit och nitrat under alla årstiderna. En cost-benefit analys skulle också vara en intressant fortsättning.

Nyckelord: Costa Rica, dricksvatten, gödningsmedel, kaffe, nitrat, nitrit, betalningsvilja, miljövärdering, contingent valuation method

Abbreviations

ARESEP	Autoridad Reguladora de los Servicios Públicos
	Legislative Autority for Public Services
AyA	El Instituto Costarricense de Acueductos y Alcantarillados
	The Costa Rican Institute of Aqueducts and Plumbings
CICA	Centro de Investigacion en Contaminacion Ambiental
	The Centre of Investigation in Environmental Contamination
ESPH	Empresa de Servicios Públicos de Heredia
	Office for Public Services for Heredia
INTA	Instituto Nacional de Innovación y Transferencia en Technología Agropecuaria
	The National Institute of Inovation and Transfer of Agriculture and Cattle Technique
MAG	Ministerio de Agricultura
	Ministery of Agriculture
MS	Ministerio de Salud
	Ministery of Health
MINAE	Ministerio del Ambiente y Energía
	Ministery of Environment and Energy
UNA	Universidad Nacional
	National University
UCR	Universidad de Costa Rica
	Universtity of Costa Rica

Contents

1 Introduction

1.1 Introduction

Costa Rica has an abundance of fresh water which can be used for irrigation, hydropower and as drinking water. This unfortunately does not mean that Costa Rica always has a drinking water of good quality. Costa Rica is a country with fast growing infrastructure and sometimes the environmental regulations are disregarded[1]. Concern regarding quality and quantity of drinking water is common in media as well as among the Costa Rican people. Almost everyday articles are published in local newspapers, such as la Nacion and al Día, concerning treatment, contamination or costs of the water. One of the most commonly discussed issues is contamination of waters with nitrates and nitrites from fertilizing of coffee plantations in the Central Valley, Costa Rica. As nitrates and nitrites cannot be detected by a change of flavour or colour of the water it can be a silent threat to human health. High concentrations can cause oxygen deficiency in the blood, metahemoglobinaemia, in infants and increase the risk for gastric cancer[2].

1.2 Purpose

The purpose of this project was to investigate how contamination from fertilizers for coffee plantations affects the uses of and the costs for domestic water in one part of Costa Rica. The investigation was made out of two perspectives. One of the perspectives was to analyse water samples to investigate if water from an area connected to a coffee plantation had higher concentrations of nitrate and nitrite compared with water taken from an area where fertilizer use is not as intense. The water quality in terms of other physical and chemical characters such as pH value, turbidity, conductivity and colour was also investigated to get a better understanding of the water quality in the areas in general.

The other perspective was to investigate the knowledge of the existing problem and the interest to make a change and improve the water quality among people in the nearby area. Through a survey of in-person interviews a willingness to pay, WTP, to get an improvement of their domestic water, was estimated. The willingness to pay estimation is in this case a measurement to see how much the population is willing, and is able, to sacrifice to get a better quality.

1.3 Method

Through contact with Bernardo Mora Brenes at The National Institute of Innovation and Transfer in Agriculture and Cattle Technique[3], INTA, San José, Costa Rica, a project about nitrates and nitrites in drinking water was discussed. Analyses of nitrates and nitrites are relatively easy to make and high concentrations can indicate that other substances, potentially more toxic, are present.

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[1] Yamileth Astorga, Crisis de Gobernalidad del Agua en Costa Rica, (Heredia:Ciencias Ambientales, 2003) p. 17-25.
[2] Ibid.
[3] For translation see Abbreviations.

The interviews are based on a method called the Contingent Valuation Method, CVM. A cost-benefit analysis of the current contamination problem is a method to understand if an improvement of the environment is motivated or not. Investigation of the willingness to pay may be useful in this decision making process. A notification is that this paper does not go any further into the information of cost-benefit analysis. The material from the interviews was also used to show whether there are any correlations between the WTP and other variables asked for, for example age, income or education of the respondents.

1.4 Disposition

The essay begins with a chapter presenting information of Costa Rica and current management and media cover of domestic water. Chapter three covers background of environmental valuation, willingness to pay and the contingent valuation method. Theory of coffee fertilization and effects of nitrate and nitrite, drinking water regulations as well as theory of the contingent valuation method is covered in chapter four. Chapter five includes methods for the water sampling, the interviews and the statistical analysis of the interviews. In chapter six results from the water analysis and the willingness to pay adhered from the interviews are gathered, followed by a discussion in chapter seven.

2 The current situation of domestic water in Costa Rica

2.1 Costa Rica

Figure 1. Map of Costa Rica[4]

Costa Rica has its borders to Nicaragua in the north, Panama in the south, the Caribbean Sea in the east and the Pacific Sea in the west. For a map of Costa Rica see Figure 1. The land territory is 51 100 km^2 which is divided in seven political zones. Costa Rica has about 4 000,000 inhabitants.[5] Costa Rica can also be divided in climate zones, see Figure 2. The country in general has three different climates, humid tropical areas at an altitude of 0-600 m, subtropical in the areas at an altitude of 600-1600 m and cold climate in the areas with a higher altitude than 1600 m.

The investigation was made in the Central Valley which is situated in the middle of the country and surrounded by volcanoes. This area has a climate with a mean temperature of 21.6 ºC and a rain period from May until November. Precipitation in the area is over 3,000 mm per year.[6]

[4] http://www.equus-ole.com, 01/03/2006
[5] *Geographica Atlas och uppslagsverk över världens folk och länder*, (Köln:Köneman, 2000) p.404-405.
[6] www.fao.org, 03/02/2005

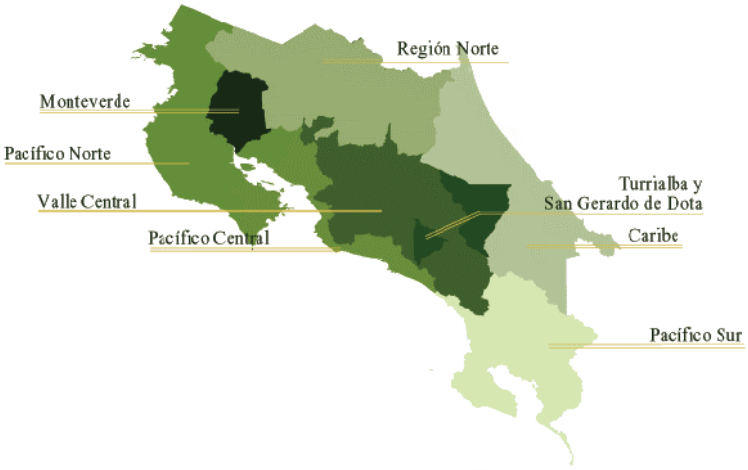

Figure 2. Map over climate zones in Costa Rica.[7]

The Central Valley only occupies about six percent of the land area but nonetheless about two thirds of the population inhabits the area. The capital San José and the major cities Alajuela, Heredia and Cartago are situated in the Central Valley. Major land use in the Central Valley is agriculture as the volcanic soils are suitable for cultivation.[8] Present cultivations are for example coffee, sugar canes and vegetables as chayote. The majority of the soils in the Central Valley are highly permeable and well structured Andisols. These soils usually have a high rate of annual run off, >1000mm.[9]

The water samples were taken in two areas situated north of Alajuela. The interviews were primarily made in Alajuela. Alajuela is Costa Rica's second biggest city and it is situated about 10 km north west from San José. Alajuela has about 35 000 inhabitants.[10] For location see Figure 1.

2.2 Coffee cultivation in Costa Rica

About 108,000 ha land are used for coffee cultivation in Costa Rica. Areas where coffee is grown are, Alajuela, Heredia, San José, Cartago, Turrialba and Perez Zeledon. After bananas, coffee is the most important export good and after tourism and bananas the most important foreign exchange in Costa Rica. There are about 65,000 coffee farms in Costa Rica and a major part of them are small farms. Many of them are situated in the Central Valley as fertile soils from the volcanoes are present in the area. The soil has enough organic matter and a good drainage.[11] Coffee can be cultivated in the sun or in the shade. In the Central Valley the shade grown coffee plantations are very rare. The rich soils and the altitude are understood as giving a coffee with a good quality without having trees included in the cultivation. Cultivation without shade trees usually has higher input of fertilizer. These monocultures usually have a high rate of erosion as heavy rains are common in these areas.[12]

[7] http://www.travelexcellence.com, 01/03/2006
[8] Jean McNeil, *The Rough Guide to Costa Rica*, (Rough Guides, 2001) p.117.
[9] Jenny Reynolds et. al., Environmental impacts of nitrtification and nitrate adsorption in fertilized Andisols in the Valle Central of Costa Rica, (Soil Science 157, 1994) p.289-299.
[10] McNeil, p. 22.
[11] Daniel H Janzen, Costa Rican Natural History, (Chicago: University of Chicago, 1983) p. 86-88.
[12] http://www.incae.ac.cr, 01/03/2006

The coffee bushes flower for a couple of days with white flowers. The fruit is green until maturity when it turns red. The fruit which is oval and about 10-20 mm contains the bean. The beans are separated from the pulp after harvest and are dried before roasting. A coffee bush can be productive for about six to ten years.[13]

2.3 Management of domestic water

The applicable law concerning conservation and management of water sources in Costa Rica is the General Water law No 276, which was introduced in 1942. Since then the country has evolved in terms of a rapid industrialisation, urbanisation and an increased population and a large tourist sector. The land use and the infrastructure have also changed. Sources of pollution have increased. These changes all affect the water resources and make the law out of date. The current law does not give a good legal ground for protection and conservation of the raw water used for drinking water production. A new water law is therefore under discussion.[14] Lack of good planning of areas that should be protected for giving water with a good quality is also apparent. Loss of areas covered with vegetation is a result of the lack of planning of urban areas.[15]

There is also a lack of coordinated institutional work and administration of the water management. At least fifteen institutions work with water regulations which have been proved to lead to decentralised and inefficient work.[16] Some areas are covered from regulations from more than one institution whereas others are not covered by regulation at all. Following are some of the institutions that work with water questions in Costa Rica.[17]

- MINAE – declare areas to be water protection areas
- Ministerio de Salud – controls contamination of water
- MAG – controls contamination of waters in zones with irrigation
- ARESEP – sets water tariffs
- Municipalities – control contamination of and use of public waters, can be owners of an area used as a water source
- AyA – sets norms for and plans use of public water[18]

Lack of technical knowledge, the monitoring of quality and quantity of the water and financial resources are also common within the institutions. There is a need to include in the new law how the institutions that regulate water use and protection of it are supposed to work.[19]

The providers of drinking water also work in different areas and at different levels which leads to a decentralised administration of drinking waters. Of the 97% of Costa Rica's inhabitants that have access to drinking water, 43% received their water by AyA[20], 24% from associations of users, 16% from the municipalities, 5% from ESPH[21] and 9% from private

[13] Janzen, 1983, p.86-88
[14] Astorga, 2002, p.17-25.
[15] Jiménez, Roberto, Agua, Legislación y Rectoría Estatal (Heredia:Ciencias Ambientales, 2003) p. 49-56
[16] www.incae.ac.cr, 01/03/2006
[17] For translations see Abbreviations.
[18] www.ifam.go.cr, collected 01/03/2006
[19] Jiménez, 2003, p.49-56.
[20] For translation see Abbreviations
[21] For translation see Abbreviations

wells or common sources. From these providers not all water followed the norms of quality for safe drinking water. For example only 10% of the water distributed by municipalities has a quality regarded as a safe drinking water. [22]

Regarding used household water only 2% of the water receives a sanitary treatment. 21% of the population is connected to a public plumbing system and 69% use septic tanks. A problem with the use of septic tanks is that they can leak untreated water. About 10% of the population has other systems of disposition.[23]

One of the most discussed problems with drinking water quality in Costa Rica is the leaching of nitrates and nitrites from fertilization of different cultivations or leakage from septic tanks. One area that is especially threatened by this is the Central Valley, which is surrounded by a large amount of coffee plantations along the sides of the volcanoes that surround the San José area.[24]

One problem with the protection of a watershed can be to keep human presence out from the area, especially if the area is privately owned. An area within 100 m radius from the watershed should be protected from all human presence and if the area needs a reforestation it shall be done. In a 200 m radius from the water source human presence can be allowed, but only in terms of for example an organic cultivation without fertilizer input. If the land is privately owned a permit to enter the grounds is required and actions can be taken if the land owner is not willing to agree to new conditions.[25]

The Municipality of Alajuela has begun a campaign to make inhabitants living in the area of a water source understand the need of keeping the source free from contamination. The Municipality is also working with enclosing some of the water sources as well as informing the inhabitants by adding information signs on the site.[26]

2.4 Media cover of water questions in Costa Rica

The media coverage concerning water quality and access to water has been abundant. Some examples of articles published during year 2005 in Costa Rica are *CNE is asking to declare an emergency of contaminated water*[27]and *214 families in Orotina receives water with clay* [28]. The articles describe situations more or less threatening of the quality of drinking water. The first article mentions that combustibles have been found in an aquifer supporting about 320,000 persons southeast of San José. The second article describes how people in Orotina, which is part of Alajuela, could not use or drink the water that they paid for as the water was brown of clay. An ongoing debate exists concerning the costs and prices of water in Costa Rica. For example an article in the TicoTimes mentions that a decree signed by the environment and energy minister will increase the costs for use of water up to 80 times. Through defining a value of water as a raw material the natural resource could be protected. This could be a way to pay for the environmental service and the increased income can be

[22] Astorga, 2003, p.17-25.
[23] Jiménez, 2002, p.49-56.
[24] Material from the seminar
[25] Interview with Felix Angulo from the Environemental Depertment at the Municipality of Alajuela
[26] Ibid
[27] Esteban Oviedo, CNE pide declarar emergencia por contaminación de agua, (San José:La Nacion, 2005).
[28] Jorge Umaña, 214 familias de Orotina reciben el agua con barro, (San José:La Nacion, 2005).

used to protect the water resources.[29] The decree has still not been signed by the president Abel Pacheco.

On September 22, 2005, the Tribunal Latinoamericano del Agua hosted a seminar in San José about the subject of contamination of nitrates in drinking water and the media response to this problem. The name of the seminar was: *Vulnerability and Risk Associated with Contamination of the Subterranean Waters of the Barba Aquifer.*[30] During the seminar different views of water contamination with nitrate and nitrite were presented by water distributors and scientists.[31]

3 Environmental valuation[32]

Environmental valuation is used to compare the value of an environmental change to the existing situation. The basic strategy for valuation is to treat the environmental services impacted as arguments in household utility functions, as commodities[33]. The information from a valuation of the environment is thus useful prior to making decisions regarding future changes. One example, as in this case, is to examine what benefit can be received by putting a price tag on a decreased nitrogen contamination. In some way the advantage of an improvement of the water quality has to be compared to the advantage of having the same level of contamination as before. This means keeping the same coffee production. An environmental valuation will not be the only information needed to make the final decision about the contamination issue but the valuation could give interesting material for an analysis of a project's advantages and disadvantages in a social welfare perspective.

The first step to analyse a project's social economic consequences is to estimate the effect in physical terms. The second step of the analysis is to set the effects of the project on a value scale, in purpose to show how different choices about the project will give different results. For example if the contamination is stopped the value is zero. On the other hand the level of contamination could be halved or allowed to remain as it is currently, where the latter choice would give a maximum value. It is preferable to choose the project that has the largest increase of welfare and it is here the willingness to pay is interesting because welfare changes and willingness to pay are closely linked. The third and last step is to choose between different projects. A common decision rule is to pick the project that gives the highest social economic gain when the sum of the willingness to pay is compared with the total costs for the project. It is not a flawless decision criterion, for several reasons; one is because it does not answer the question how the welfare should be shared.[34]

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[29] Rebecca Kimitch, Water Law Breaks New Ground, (San José:Tico Times, 2005)
[30] A translation of: Vulnerabilidad y Riesgo Asociados a la Contaminación de las Aguas Subterraneas del Aquífero Barba. Speakers in the seminar was Dr. Jenny Reynolds-Vargas from the Universidad Nacional Costa Rica, Dr. Darner Mora Alvarado director of AyA, Luis Ganes from ESPH and Isabela Román from Proyecto Estado de la Nacion.
[31] See Appendix 1 for further information about the seminar.
[32] Chapter 3 is based on Brännlund and Kriström, 1998, chapters 3 and 4.
[33] Perman et. al. 2003, p.402
[34] Brännlund and Kriström, p. 63-65.

3.1 Willingness to pay

The purpose of measuring willingness to pay is to measure a change in welfare. A change in welfare is not observable because it is built on the individual's subjectively experienced utility. The willingness to pay for a good is revealed in a perfect market economy by the market price, as it is possible to interpret the price as the marginal willingness to pay to get one more unit of the good. The price is a monetary measure of the welfare in the sense that it measures, is proportional to, the individual's marginal utility of buying one more unit.[35] The willingness to pay for non-market goods can be explained by monetary welfare measurements, which is described in the next section.

3.2 Monetary welfare measurements, Compensating Variation and Equivalent Variation

To understand the valuation methods to be used here, it is useful to introduce two concepts. Compensating Variation, CV, is a measurement of how much a person is at maximum willing to pay to get an improvement of the environment without lowering her well-being. Equivalent Variation, EV, is a measurement of how much a person is at minimum willing to accept to compensate that the environment is going to stay the same. To explain how Compensating Variation and Equivalent Variation are connected to willingness to pay it is easiest to look at a project example, where x is an environmental index and the environmental quality is going to change from x_0 to x_1. An individual's preferences can be represented by a utility function with two arguments: consumption (=income), q, and environmental quality, x. The utility function $U(q,x)$ describes how the individual apprehends different combinations of consumption and environmental quality, assuming that the individual gets a better economic standard if the consumption increases, at any given level of x.

Assume that the individual's income does not change because of the project, i.e. q will not be affected. This gives a change in utility equal to $U(q,x_1)-U(q,x_0)$, if the project is undertaken. As the utility can not be measured the question is how to measure the welfare change. If the individual increases her well-being, the utility changes positive, i.e. $U(q,x_1)-U(q,x_0)>0$. If an individual is prepared to decrease her income to get an environmental quality change, she pays A SEK and the project carries through, and q-A SEK is left for private consumption. The new environmental quality is x_1. The subjectively experienced utility is $U(q-A,x_1)$, and as long as $U(q-A,x_1)>U(q,x_0)$ she thinks that it is worth spending A SEK on the quality improvement. The willingness to pay for changing from x_0 to x_1 corresponds to the maximal amount of money she is willing to give up receiving the change. It is a sum, CV that corresponds to $U(q-CV,x_1)=U(q,x_0)$. CV specifies how much the individual maximum can pay without getting worse off.

If, on the other hand x_1 is chosen as starting-point then EV corresponds to the smallest compensation that has to be given to the individual that makes her accept giving up the environmental quality increases. The sum is defined by the equality $U(q,x_1)=U(q+EV,x_0)$. As mentioned before the initial income is assumed not to change because of the project and the starting points are therefore a horizontal line. See figure 6. The indifference curves

[35] Brännlund and Kriström, 1998, p. 66-67.

describe the combinations of consumption and environmental quality that the individual thinks are equivalent. If x increases from x_0 to x_1 the utility level equals U_2. The vertical distance between the indifference curves correspond to the utility change.

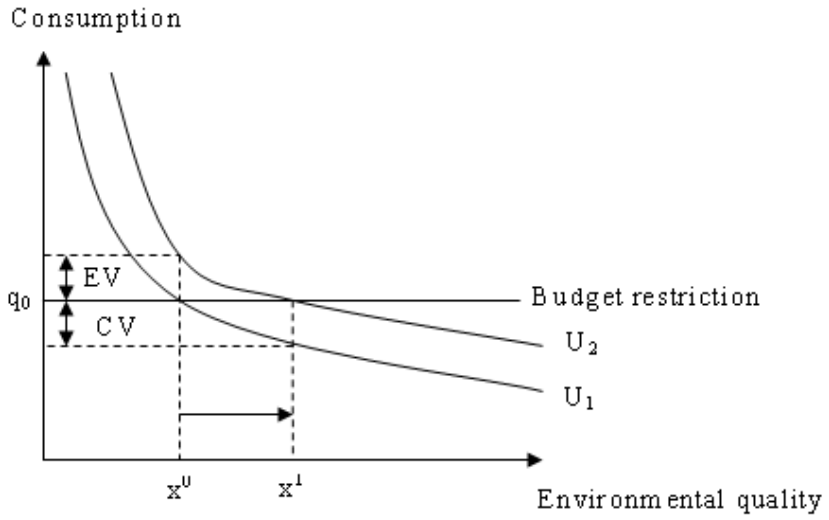

Figure 6. CV corresponds to the amount of money the individual is prepared to pay, given that she gets the environmental change x_1 without decreasing her utility U_0. EV implies the amount of money that has to be compensated to the individual if the environment is going to stay the same with a contamination or if it is going to decrease the quality and make the budget restriction increase so she has the same utility as in point x_0.

In the literature it is often written that the maximal willingness to pay and the smallest compensation demand should be equal. This makes it easier to decide which method is going to be chosen because it does not matter. But it has been observed that there are differences in practice. An explanation could be that it is more difficult to formulate a compensation question so that the individual reveals the smallest amount of compensation. It is therefore common that the environmental quality gets exaggerated.

The sum of the willingness to pay over all affected individuals is often compared to the costs to go through with a project. If the sum covers the costs the project is considered as social-economically profitable. A critique against this method is that the compensation is hypothetical; it is not going to be realized. The idea is to identify potential profitable projects and transfer the income distribution to the Government. The sum of the willingness to pay for a given project is depending on the income distribution in the society which makes it important to as far as possible analyse and explain how different groups in the society get affected by a project and not be satisfied by comparing the sum of the willingness to pay with the costs. The following sub-section is describing in general terms the method that has been chosen to estimate the WTP, the Contingent Valuation Method.

3.3 The Contingent Valuation Method

There are two types of methods to convey environmental valuations, the direct and the indirect method. The direct method is based on interviews, with direct questions about willingness to pay. The indirect method is using already existing connections between environmental quality and some market priced goods. Example: One advantage of the indirect method is that it is based on the people's actual behaviour. One disadvantage is that it is impossible to estimate existential values, although it can be important. The contingent valuation method is a direct method and is the method that is used in this project.

The contingent valuation method was developed in 1940 in USA but it took several years before it was internationally known. The first applications in Scandinavia are from the early 1980s in Norway. At the end of the 1980s the popularity of the method had grown drastically and was then the dominating method of environmental quality valuation. The method is often used for environmental issues but also in other applications, for example health economics.[36]

4 Theories

4.1 Nitrogen

4.1.1 Nitrogen in fertilizers

Nitrogen is crucial for the coffee plant as it contributes to the leaf growing, the chlorophyll molecules and enzymes. If nitrogen is deficient the plant will show chlorosis, yellow leaves, as it can not use the energy from the sun. The adding of nitrogen gives the best production response. Recommended for coffee production is about 300-350 kg/ha/year of nitrogen applied at two or three occasions per year. Normally a fertilizer that includes other substances that the coffee plant could require is applied twice a year with the first occasion at the beginning of the wet period. Other substances required in coffee fertilizer are potassium, magnesium, phosphorus, calcium, zinc and boron. An extra fertilization with only nitrogen is normally added at the end of the rains.[37] For a good response from the fertilizer it is supposed to be added when the climate is humid but without rain. The concentrations of added fertilizer can differ according to the age of the coffee bush.[38]

Nitrogen in fertilizer is normally added in form of ammonia, NH_4^+, and nitrate, NO_3^-, where ammonia is the first transformation from organic nitrogen. Nitrate is an inorganic form of nitrogen. The transformation from ammonia to nitrate goes through the formation of nitrite, NO_2^- which is an unstable form. This can be performed naturally by bacteria in the soil where the ammonia is first oxidised to nitrite and then to nitrate.

Ammonia is retained by the soil as soil particles have a negative charge. Nitrogen in form of nitrate on the other hand is negatively charged just as particles in the ground, which leads to the leaching of nitrate to surrounding water. Both forms are soluble in water. Nitrate is the chemical form of nitrogen that is easiest absorbed by the plant.[39]

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[36] Brännlund and Kriström, 1998, p. 101-102
[37] www.icafe.go.cr, 04/02/2005.
[38] Interview with Oscar Gonzales Rodrigues, 06/10/2005.
[39] http://www.mirat.net, 01/03/2006.

Investigations have shown that concentrations of nitrate in soil can vary seasonally. Soil NO_3^- accumulated in the soil during the dry season and was reduced during the wet season. Soil NO_3^- is believed to be reduced because of a higher rate of root uptake, leaching and possible denitrification during the wet season. Allophanous Andisols that are frequent in the Central Valley are believed to be able to absorb relatively high contents of NO_3^-, especially at a low pH, but high input of fertilizer and liming of coffee soils reduce these effects. Leaching of NO_3^- is also affected by organic matter, cation exchange and competing anions in the soil. Soil moisture can also control mineralization and nitrification, but the process in the Central Valley has not been studied properly.[40]

One of the existing problems with a successful fertilization of coffee is that usually only about 30% of the nitrogen applied is absorbed by the plants.[41] The rest of the nitrogen in form of ammonia accumulates in the soil and gradually turns to nitrate and leaks to surrounding waters or goes to the atmosphere in form of N_2. The formation of N_2 gives an acidification of the soil. The nitrate that leaks out to surrounding water can have several negative consequences. As nitrate is a nutrient that plants use for growth this is also the case for plants that grow in the water. This leads to eutrofication and oxygen deficient waters[42]. Nitrate in water used for drinking water can also have health effects for humans. It can take time for nitrogen to move from soil to groundwater and for increased concentrations of nitrates to appear in aquifers.[43]

In order to avoid leaching of nitrogen to surrounding water several measurements can be done. By soil and plant analysis levels of fertilizer used can be better regulated. Realistic goals for the yield can also keep levels of fertilizer used down.[44] Application of fertilizer should also be varied within the field after varying topography, soil type and age of the coffee plant. Fertilization covers about 10% of the production cost, another reason to adjust the amount used.[45] A way to stop nitrates from reaching surrounding waters could be to have ditches around the plantation with nutrient absorbing plants. Instead it is usually recommended that weed should be controlled before fertilization is added to avoid that nitrogen added goes to these plants instead which makes land owners “clean” areas as ditches from grass as they see it as weed. This makes the run off water going straight to surrounding waters.[46]

4.1.2 Nitrate and nitrite and the effect on human health

Absorbed nitrite can be oxidised to nitrate in the blood during the transformation of Fe^{2+} in the blood to Fe^{3+}. Fe^{3+} is a chemical form of iron that cannot transport oxygen. The condition metahaemoglobinaemia can appear which can lead to cyanosis. Most affected are infants and pregnant women.[47]

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[40] Reynolds, p. 289-299.
[41] Renderos Durán, Harmand, Jiménez, Kass, Contaminación del agua con nitratos en microcuencas con sistemas agroforestales de *Coffea Arabica* con *Eucalyptus deglupta* en la Zona Sur de Costa Rica, (San José:Agroforestales en las Americas, 2002) Vol 9 p.81-85.
[42] Renderos Durán, Harmand, Jiménez, Kass: p.81-85.
[43] www.who.int, 12/02/2006
[44] www.aces.edu, 02/02/2005
[45] www.aces.edu, 02/02/2005
[46] Personal contact with Carlos Hidalgo at INTA
[47] www.who.int, 12/02/2006

Nitrite can also react with compounds in the human stomach and form N-nitroso compounds that can be carcinogenic. The correlation of high concentrations of nitrate in drinking water and gastric cancer can not be excluded. Another health implication due to high concentrations of nitrate in drinking water can be the swelling of the thyroid gland in the front of the neck.[48] The thyroid gland is included in the metabolism process in the human body.[49]

Formation of nitrite can appear when a drinking water is chloraminated as small amounts of ammonia are present which can be oxidised to nitrite. This decreases levels of disinfectants and increases the amount of ammonia oxidation bacteria.[50]

4.2 Drinking water regulations

Recommendations for the quality of drinking water in Costa Rica follow *Decrete 32327-S MINAE Regulations for Drinking Water Quality*[51]. See table 1 for recommended and maximal values of substances and physiological characteristics analysed in this project.

Table 1. Recommended and maximal values for analysed substances and physiological characteristics.

	Recommended value	Maximal value
Nitrate [mg/l]	0	50
Nitrite [µg/l]	0	100
pH	6.5	8.5
Turbidity [UNT]	1	5
Conductivity [µS/cm]	400	-
Colour [mg/l]	5	15

The pH value is measured to examine the acidity of the water. At low pH values corrosion of pipes and tubes can occur which can release metals in the water. pH values over 10.5 cannot be used as drinking water as it can affect mucous membranes and eyes. Turbidity is a measurement of particles in the water and high levels show that particles can be present in the water. Conductivity is a measurement of salt in the water. High levels can indicate that chloride can reach the water from drains or wastes. It can also affect corrosion of tubing. Coloured water can appear if iron or organic material is present in the water. Abnormal changes of colour can indicate abnormal levels of these or other substances.[52] For effects of nitrate and nitrite in drinking water see section 4.1.

The following section is about the theory of the Contingent Valuation Method and how to perform a CVM survey.

[48] www.who.int, 12/02/2006
[49] www.patient.co.uk, 01/03/2006
[50] http://www.h2o4u.org, 01/03/2006.
[51] A translation of: Decreto 32327-S MINAE Reglamento para la Calidad del Agua Potable.
[52] www.sos.se, 01/03/2006.

4.3 Theory of the Contingent Valuation Method

The contingent valuation method is used to estimate economic values for all kinds of ecosystems and environmental services. It can be used to estimate both *use* and *non- use values* and it is the most widely used method for estimating non use values. Use value is the benefit accruing from use of the resource and non-use value is the value a consumer attaches to a resource independent of her use of it[53]. The method involves directly asking people, in a survey, how much they would be willing to pay, WTP, for specific environmental services. The contingent valuation method is a "stated preference" method which means that it asks people to directly state their values in contrast to the "revealed preference" method which is letting the people revealed the value by actual choices.[54]

4.3.1 Application of the Contingent Valuation Method

The CVM is based on an accurately structured interview where the respondent is introduced to a specific change. A strategy of how to make the interview is presented in different phases below.

- Define the valuation problem, including what services are being valued and which the relevant population is. It is important to define the change that is going to be valued as exact as possible. It will then be easier for the respondent to understand and value. To make the survey as useful as possible it is important that these criteria are fulfilled:
    - ✓ Theoretical consistency
    - ✓ Relevant for the policy
    - ✓ Credibility
    - ✓ Easy to understand

  It can also be important to examine which means of payment that is going to be used in the process to make it possible to change the environment. Examples of this could be raising the tax or paying a fee as a lump sum. It is of importance to notice that the different mean of payment can give different answers.[55]

  When a project generates indirect effects on for example health it is almost impossible to know how and whom it will affect. Most of the times it is enough to estimate probability distributions that describe how health risks get affected of the changes of contamination.[56] In order for the questions to be effective, the respondent must believe that if the money were paid, whoever was collecting it could effect the specified environmental change[57].

  As written earlier it is possible to use both CV and EV to measure a change in welfare in monetary terms, but the theory does not say anything about whether to use willingness to pay or willingness to accept, a minimum compensation that you are willing to accept to let an environmental pollution keep on polluting.

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[53] Bengt Kriström, *Valuing environmental benefits using the contingent valuation method,* (Umeå: Solfjädern Offset AB, 1990), p. 9.
[54] www.ecosystemvaluation.org, 17/02/2006.
[55] Brännlund and Kriström, 1998, p. 102.
[56] Ibid, p. 102.
[57] www.ecosystemvaluation.org/contingent_valuation.htm, 17/02/2006.

Questions can be asked in a variety of ways, using both open-ended and close-ended formats. In the open-ended format, respondents are asked to state their maximum willingness to pay for the environmental improvement. With the close-ended format, also referred to as discrete choice, respondents are asked whether or not they would be willing to pay a particular amount for the environmental improvement, or whether they would vote yes or no for a specific policy at a given cost.

- Make decisions about the survey itself, whether it will be conducted by mail, phone or in person, how many interviews that will be conveyed, who will be interviewed and other related questions. These questions are depending on things like the importance of the valuation issue, the complexity of the question being asked, and the budget constraint. In-person interviews are to prefer and are most effective when you are dealing with complex questions, because of the ability to explain about the issue is higher. On the other hand it happens easier that the respondents' answers get affected in an unwanted direction. Although in-person interviews are considered to be the most expensive type of survey they are more useful because it has been shown that the respondents are more likely to complete a long survey when they are interviewed in person, than by mail or phone. The amount of background information the method requires can also affect which type of interview that is to prefer. The CV method requires relatively much background information and therefore it is more difficult to use phone surveys even though it may be less expensive.[58]

- Design the survey. This is the most difficult and time-consuming step but also very important. It is common to start with initial interviews and/or focus groups with questions about peoples´ understanding of the issue related to the situation, whether they are familiar with it, whether and how they value this problem and the habitat services it provides. This will help to develop and clarify specific questions for the survey, as well as decide what kind of background information is needed and how to present it. To use photos, drawings or even videos in the background information is preferable if it makes it easier to understand the issue of the survey. When it comes to questions about willingness to pay for an environmental change it is important to remind the respondents to consider their budget constraints, so they do not exaggerate the amount of money or the other way around[59].

  After the focus groups and when the background information is collected a pre-testing survey is a good thing before the real survey that is going to be used statistically. The purpose is to see if the respondents understand the survey and let them ask questions if anything is confusing.

- The survey implementation. In-person surveys may be conducted with random samples of respondents, or "convenience" samples may be used– asking people in public places to fill out the survey.

- Compile, analyze and report the results. The data must be entered and analyzed using statistical techniques appropriate for the type of question.[60]

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[58] Brännlund and Kriström, 1998, p. 112.
[59] www.ecosystemvaluation.org, 02/02/2006.
[60] www.ecosystemvaluation.org, 02/02/2006.

4.3.2 Advantages and limitations of the Contingent Valuation Method

The aim with this subsection is to give information about some of the advantages and problems that can come up while working with environmental valuation and the contingent valuation method.

Environmental valuation is relatively often criticized on the grounds that the environment has an infinite, immeasurable value, which can not be measured in money. But money is only used because of the comparison convenience, using the wide understanding of it. As long as the same unit is kept it is possible to use any measure that is preferable for the project.[61]

The advantage of a CVM is that it is a flexible method that can measure almost anything. Even if the research about the project has to be precise and is rather difficult, the analyses of the results are not that complicated. It is often enough to use the mean or the median value per capita, per household or an aggregated value for the affected population.[62]

The disadvantages with the CVM are that most people are unfamiliar with placing monetary values on environmental goods or services. Therefore, they may not have an adequate basis for stating their true value. Experiences show that the respondents sometimes answer the wrong question. They may express a positive willingness to pay because they feel good about the act of giving for a social good, also called the "warm glow" effect, although they believe that the good itself is not that important. The respondents may also state a too high WTP to emphasise that they are positive to improvement of the environmental quality in general. Sometimes it happens that the respondent adds another perspective to the WTP that the researcher had not intended. For example, if asked about their WTP for improved visibility, through reduced pollution, the respondents may include the health risk in the valuation. Different means of payment could give different WTP. The respondents may state a lower WTP if a tax is going to be used just to protest about the increased tax.[63]

Although it might seem like it is too difficult to make a valuation of the environment with a good precision, it is necessary to compare the advantages with the disadvantages of not going through with it. It is a bigger risk to overexploit a natural resource if no valuation has been done. The value of the good can also be considered as zero if it has not been valued, which could be misinterpreted.

5 Material and methods

5.1 Material and method

The two areas where samples of water were taken from, La Fuente and Los Chorros, are both situated in the Central Valley. La Fuente provides drinking water for Alajuela, distributed by the Municipality of Alajuela. Los Chorros provides drinking water for Atenas and Orotina, situated southwest of Alajuela, distributed by AyA. For location of the cities see Figure 4. These were spots chosen after discussion with Bernardo Mora Brenes at INTA. He has a good

[61] Brännlund and Kriström, 1998, p. 66.
[62] www.ecosystemvaluation.org, 02/02/2006.
[63] www.ecosystemvaluation.org, 02/02/2006.

knowledge of water distribution and land use in the area and identified these sources as important drinking water sources for the people in the province as well as areas with different land use. For more information of precipitation and temperature in the areas see section 2.1.

Figure 4. Map over the Central Valley with two arrows indicating the approximate situation of the areas where the water samples were taken.[64]

5.1.1 La Fuente

The coffee plantation La Pequeña[65], San Isidro, Alajuela, is situated in a valley. For a map over the area see Appendix 6. La Fuente[66] is a groundwater source for drinking water situated in the middle of the coffee plantation.

It is the Municipality of Alajuela that is responsible for the water quality, as well as the protection, of this watershed. The only treatment that the water receives before use is chlorination. Some of their work in the area at the moment is to work with the cleaning of the tank where chlorination is made and to see to that people or animals cannot get access to the surface water.[67]

History of the area was received from an interview with Oscar Rodriguez Gonzales who has been managing the coffee plantation for twelve years. La Pequeña has been managed as a coffee plantation since 1983 and the farm is about 11 manzanas, mz[68]. As one manzana is

[64] www.guiascostarica.com, 01/03/2006

[65] For photos of the coffee plantation see Appendix 2.
[66] Altitude at this spot is approximately 1270 m above the sea and N 10º 0.4 min 34.3 sec and WO 34º 11 min 17.7 sec. Error 12m.
[67] Interview with Felix Angulo, 21/10/2005.
[68] One manzana give about 60 fanagas, fa of coffee which is approximately 400 l of coffee beans

approximated as 0.7 ha the farm is approximately of the size 7.7 ha. The coffee type used in the area is called *Arabica Caturra*, which is a high quality coffee that might have a lower production than other types of coffee cultivated in the country.

Fertilizer is applied three times a year in May, August and November. About 60 g of fertilizer is applied per adult bush and there are about 5,850 bushes per ha in this area. This gives that the applied fertilizer added per occasion measures about 350 kg/ha and about 1050 kg/ha/year. The fertilizer used in La Pequeña contained 18% nitrogen, 5% of phosphor added as P_2O_5, 15% of potassium added as K_2O, 6% magnesium added as MgO and 2% of boron added as B_2O_3. This gives an amount of about 63 kg N/ha added per fertilization occasion which gives about 189 kg N/ha/year.

5.1.2 Los Chorros

The second area from where water samples were taken is situated in the national park, Los Chorros. The park is situated in an area called Tacares de Grecia north of the town Grecia. For location see Figure 4. The park is used as a recreation area. The area is surrounded by cultivations of different vegetables and sugar canes. The spot was chosen to compare the concentrations of nitrates and nitrites in water with the concentrations from La Fuente as cultivation of vegetables is not as fertilizer intense as coffee plantations. The spot was also chosen since water is taken for use as drinking water distribution for Orotina and Atenas.

Water from the area is managed by AyA who collects surface water flowing down a mountain. Their tank is situated in a confined area and the water for the samples was taken from the excessive surface water flowing outside the tank.[69] The excessive water runs down to a river that runs through the park which is connected with water from two waterfalls in the area.

5.2 Procedure for the water sampling

Once a week during seven weeks water samples were collected in the two areas chosen for analysis of nitrate and nitrite concentrations in water. At two occasions pH, temperature, conductivity, turbidity and colour were also analysed. The water for analysis of physical and chemical characters was collected in an empty and cleaned 1.5 l pet bottle. The water for analysis of concentrations of nitrate and nitrite was collected in brown bottles as light affects the chemical transformation of nitrogen. The nitrate sample was collected in a 500 ml bottle and the nitrite sample was collected in a 125 ml bottle. Before any water was taken the bottles were cleaned three times in the water examined. To the water sample for nitrite analysis eight drops of chloroform were added. A blank sample with distilled water was also brought from The Centre for Investigation of Environmental Contamination, CICA.[70] The bottles with the blank samples were opened for about a minute in the area to see if the air affected levels of nitrate or nitrite. After collection the bottles were marked and guarded in an icebox and brought to a refrigerator kept at 4ºC at the laboratory at CICA, at the University of Costa Rica. The nitrates are analysed with ionic chromatography and the nitrites with UV-visible

[69] For photos see Appendix 2.
[70] For translation see Abbreviations.

spectophotometry. The methods used by CICA follow Standard Methods for the Examination of Water and Wastewater.[71]

5.3 Method of the interviewing

The contingent valuation method was chosen because it is a relatively easy method to accomplish as the aim was to find a method that can measure the use value of domestic water. The reason to choose in-person surveys was that the other survey techniques would have brought too many difficulties. The city of Alajuela is a suburb to the capital San José and has a relatively small geographical area. In-person interviews were chosen instead of phone or mail interviews because it is interesting to have an open discussion about the subject while interviewing and to see their reaction to the questions and also for the possibility to easily reply to the respondents' questions about the interview. Another reason is that it was possible to get a large diversity of people. The ability to select respondents with different sex and age is easier with in-person interviews.

5.3.1 The interview

To design the interview, regular contact with the tutors was kept. Both Luis Alpizar and Bernardo Mora Brenes live in the area and have knowledge of the land and water use in the area. They became the focus group that helped us with development of the interviews. Even though they are not economists they knew how to express the situation and compile the questions so that it would be easy to understand for the respondents.

The background information explained the current situation of problems with contaminated water that can cause problems regarding the human health. Continuously the information described how the increased amount of money that the people are willing to pay for the water is going to be used to develop better sanitation and for recreation and rehabilitation.

The questions in the interview were separated into three parts. The first part contained background questions, for example if the respondent receives water in the household and who the distributor is, if they have had any problems with the water etc. The second part included more direct questions about how much they pay at the moment for the water, how much water they consume and if they were willing to pay more for receiving water with higher quality and, if so, how much they are willing to pay. The third part was strictly socio-demographical questions about the respondent and his/her household.[72]

The first day about 60 pre-starting interviews were made. Certain absences of information and incomprehensible questions were easy to discover. A few different methods of interviewing were tried out to see which fitted best, to get the best results and get as many completed interviews as possible. The most important but also most difficult question to answer was the question of willingness to pay. The first attempt was that the respondent should answer yes or no if they are willing to pay more for a better water quality. If they answered yes they should also indicate the amount of money they are willing to pay per month. The problem became that most of the respondents answered yes or no but did not bother to estimate an amount of

[71] American Public Health Association, American Water Works Association, Water Environmental Federation, Standard Methods for the Examination of Water and Wastewater, 20 va. Ed 1998
[72] See the entire interview in Appendix 3.

money that they were willing to pay. In a second attempt to really show which questions that are most important the questions were underlined. The attempt with underlined questions did not succeed satisfyingly. Even though the actual interviews were begun it was necessary to add five alternatives of willingness to pay amounts[73]. When the respondents got the alternatives to choose from it went much easier, more respondents thought about an alternative and picked one.

To have a large diversity of respondents the interviews were performed in different places and during the whole day when the sun was up. The interviewing started in a residential district, the idea was to make random samples of respondents from a number of places in the area, but because it was during the day just a few people were at home and they were only from one social-demographic group, housewives. Instead convenience samples were used, at the central bus stop in Alajuela and in a park in the centre of the city. This method had an advantage because it was done a lot faster and with a larger diversity of people referring to socio-demographical differentiations like sex, age, income, education etc.

5.3.2 Economical statistics

The total sum of the interviews is 213. 72 of them are from the interviews where the respondents had to indicate an amount of money while the rest, 141 are from the interviews with alternative amounts of willingness to pay. The 72 interviews are also used, although they are not complete, because they give a larger test and a more representative sample of the affected population, concerning the question that is willing to pay more or not for an improvement of the water quality.

6 Results

6.1 Analysis results from the water samples

The analysis of the seven water samples taken from La Fuente demonstrated concentrations of nitrate of about 14 mg/l NO_3^-. One exception was concentrations from water taken October 20 that showed concentrations of nitrate of about 3.6 mg/l NO_3^-. Concentrations of nitrite in water taken from La Fuente varied, from less than 1.6 µg/l NO_2^- to around 16µg/l NO_2^-. See Table 2 for analysis results.

Table 2. La Fuente

Dates 2005	Sep. 23	Sep. 30	Oct. 6	Oct. 13	Oct. 20	Oct. 27	Nov. 2
Nitrate mg/l NO_3^-	13.09±0.30	14.43±0.31	14.71±0.41	12.45±0.31	3.57±0.19	15.55±0.20	13.36±0.31
Nitrite µg/l NO_2^-	<1.6	9.6±1.1	2.98±0.67	11.5±3.0	<1.6	16.10±0.58	9.4±2.1

The analysis of the seven water samples taken from Los Chorros had concentrations of nitrate of about 3.5 mg/l NO_3^-, except water samples from October 20 which had concentrations of 14 mg/l NO_3^- and water samples from October 27 that had a nitrate concentration of less that

[73] See the different amounts in Chapter 6.2 Results of the economic survey.

0.8 mg/l NO_3^-. Concentrations of nitrite in water samples from Los Chorros varied between less than 1.6 µg/l NO_2^- and 40 µg/l NO_2^-. See Table 3 for the analysis results.

Table 3. Los Chorros

Dates 2005	Sep. 23	Sep. 30	Oct. 6	Oct. 13	Oct. 20	Oct. 27	Nov. 2
Nitrate mg/l NO_3^-	3.23±0.29	4.73±0.28	3.70±0.40	3.34±0.31	14.03±0.20	<0.80	3.53±0.31
Nitrite µg/l NO_2^-	39.85±0.42	3.8±1.2	2.52±0.67	13.0±2.9	<1.6	18.81±0.58	7.7±2.1

Levels of nitrate can be expressed in two ways and it is important that the difference between them is noted. It can either be expressed as N-NO_3^- mg/l or as NO_3^- mg/l. Concentrations of 50 mg/l NO_3^- is equivalent to 11.3 mg/l N-NO_3^-.[74]

The water sample taken September 23 from La Fuente had a pH value of 6.4 which is just around the recommended pH value of 6.5. Colour had a concentration of 5 mg/l (U-Pt-Co) which is lower than the maximal level of 15 mg/l (U-Pt-Co) and equals the recommended concentration of 5 mg/l (U-Pt-Co). Conductivity was about 129µS/cm which is under the recommended value of 400 µS/cm. Turbidity had a value of 5.8 UNT. This value can be disregarded as water for the first sample from La Fuente was taken from water flowing on the ground whereas the rest were taken from the tube that transfer the groundwater to the tank where it is chlorinated. Therefore this value had a higher level of dissolved particles than could be expected from water in the tube in La Fuente. The temperature of the water was 20 ºC. See Table 4.

Water sample from Los Chorros from September 23 had a pH value of 7.6 which is under the maximal pH value 8.5. Colour had a concentration of 5 mg/l (U-Pt-Co) which is lower than the maximal level of 15 mg/l (U-Pt-Co) and equals the recommended concentration of 5 mg/l (U-Pt-Co). Conductivity was about 160 µS/cm which is under the recommended value of 400 µS/cm. Turbidity had a value of less than 0.4 UNT which is lower than the recommended level of 1. The temperature of the water was 20 ºC. See Table 4.

Table 4. Physical and chemical characteristics of the samples from sampling made September 23.

Sites	La Fuente	Los Chorros
pH at 20ºC	6.35±0.02	7.56±0.02
Colour mg/l (U-Pt-Co)	5	5
Conductivity µS/cm	129.0±0.9	159.4±1.1
Turbidity UNT	5.81±0.13	<0.40
Temperature	20ºC	20ºC

The water sample taken October 20 from La Fuente had a pH value of 7.4 which is over the recommended pH value of 6.5 but under the maximal value of 8.5. No colour could be detected from the water. Conductivity was about 157µS/cm which is under the recommended

[74] www.who.int, 01/03/2006

value of 400 µS/cm. Turbidity where less than 0.4 UNT. The temperature of the water was 20 ºC. See Table 5.

Water sample from Los Chorros from October 20 had a pH value of 7.4 which is over the recommended pH value of 6.5 but under the maximal pH value 8.5. No colour could be detected from the water. Conductivity was about 127 µS/cm which is under the recommended value of 400 µS/cm. Turbidity had a value of less than 0.4 UNT which is lower than the recommended level of 1. The temperature of the water was 20 ºC. See Table 5.

Table 5. Physical and chemical characteristics of the samples from sampling made October 20.

Sites	La Fuente	Los Chorros
pH at 20ºC	7.36±0.02	7.36±0.02
Colour mg/l (U-Pt-Co)	0	0
Conductivity µS/cm	157.0±1.1	126.6±0.9
Turbidity UNT	<0.40	<0.40
Temperature	20ºC	20ºC

The maximum concentration of nitrates before it is considered as a health hazard in Costa Rica is 50 mg/l NO_3^-. Water samples from La Fuente had concentrations of nitrates substantially lower than 50 mg/l NO_3^-. Concentrations of nitrates are except from water samples from October 20 higher in water from La Fuente than in water from Los Chorros. Water taken from La Fuente and Los Chorros had concentrations of nitrites under 100µg/l which is the maximum concentration of nitrite considered a health hazard in Costa Rica.

6.2 Results from the economic survey

Of the 213 respondents 141 got the opportunity to choose among different WTP alternatives. These 141 are used in the statistical estimation. 120 of them (86%) were willing to pay more for an improvement of the water quality and 21 (14%) were respondents who were not willing to pay more for an environmental change.

The result of the economic survey for the people of Alajuela that participated gave a mean WTP of 2.4, of a 5 scale interval, which corresponds to a value up to ¢1,400[75], per month. The calculation can be seen below. The mean level of income, of the entire household per month, is 3.4, of a 6 scale interval, which corresponds to a value up to ¢ 70,000[76].

[75] ¢1,400 is approximately 22 SEK.
[76] ¢ 70,000 is approximately 1120 SEK

Calculation:

The sum of the 141 respondents WTP: 338

Mean WTP: 338/141 = 2.40

Mean WTP in monetary terms: 1,000 + ((2,000-1,001)*0.4) = 1,400

As the maximum WTP for level 2 equals ¢1,000 this amount is added with 0.4 times the difference between the maximum and the minimum amount of level 3.

Table 6. The values of WTP used in the interview and in the graphs below.

Levels of WTP	**Colones, ¢**	**Kronor, SEK***
0	Respondent is not willing to pay	Respondent is not willing to pay
1	0-500	0-8
2	501-1,000	8-16
3	1,001-2,000	16-32
4	2,001-5,000	32-40
5	5,001-	40-

*Currency counted from ¢500 ≈ $1 ≈ 8SEK. An approximated amount is used as the currency changed from day to day.

Following subsections contain presentations of the correlation between WTP and different variables.

6.2.1 Willingness to pay among men and women

Of the 141 respondents 73 were men and 68 were women. The mean WTP for men and for women are equal at 2.4. Figure 8 illustrates the allocation of how much women and men are willing to pay for a better water quality. The major part of the women, 31%, chose a WTP amount of ¢1,001-¢2,000. Among the men there were two groups of about the same size: 29% chose a WTP amount of ¢2,001-¢5,000 and 26% chose a WTP amount of ¢501-¢1,000.

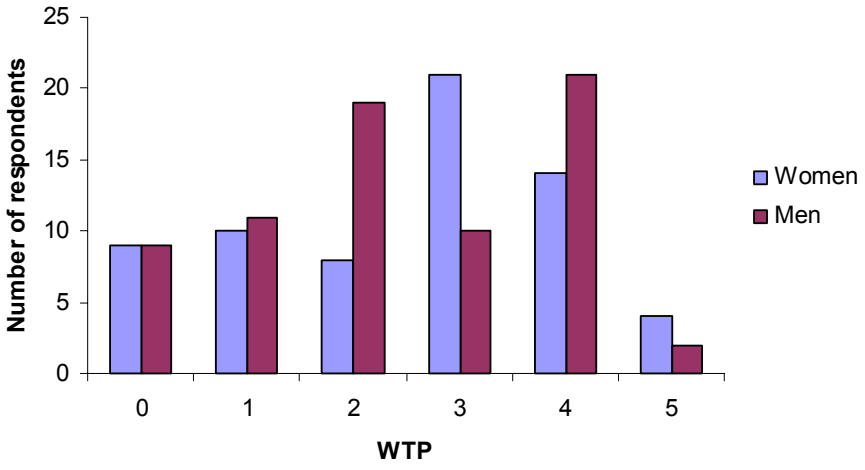

Figure 8. Number of men and women interviewed and their WTP.

6.2.2 Willingness to pay and different levels of education

3 of the 141 respondents did not reply the question about education. Figure 9 illustrates how the mean WTP changes with different levels of education. The pattern is that the mean WTP increases slightly with higher level of education. The largest group, 43%, of the interviewed people, responded that they had completed their second grade, i.e. level 3.

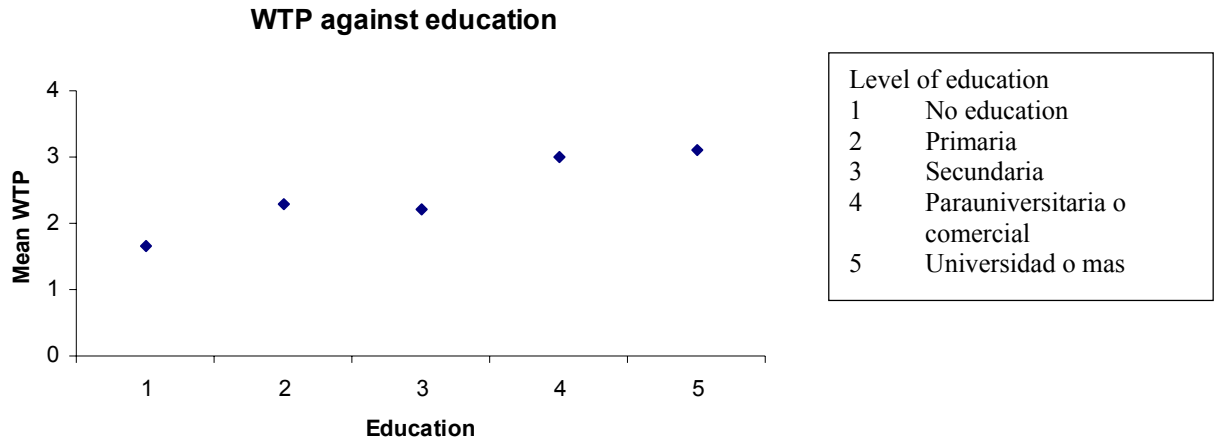

Figure 9. Mean WTP for different levels of education.

6.2.3 Willingness to pay with different levels of income

134 persons replied to the question about the total income in the household. Figure 10 illustrates how the mean WTP changes with different levels of total income. The pattern is that the mean WTP increase somewhat with higher income. The largest group, 33%, of the respondents had a total income in the household of ¢100,000-¢250,000.

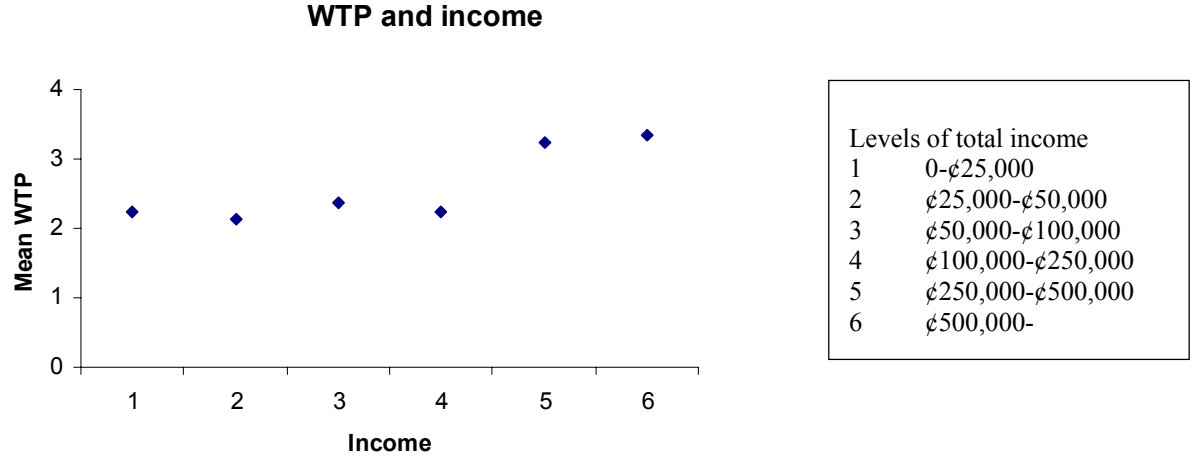

Figure 10. Mean WTP for different levels of income.

6.2.4 Willingness to pay and different opinions about water quality

Of the 141 respondents 138 answered the question about their opinion of the current water quality. 114 were satisfied with the water quality and 24 were not. Of the satisfied respondents 96 were willing to pay more for an improvement of the water quality. Of the 24 not satisfied respondents 21 were willing to pay more for their water. Figure 11 illustrates the allocation for WTP according to different opinions of the current water quality. It can seem a bit strange that the persons that are satisfied with the water quality are willing to pay more than the respondents that are not satisfied. The explanation can be that the respondents are satisfied with the water quality but if it is a problem with the quality they are willing to do something about it.

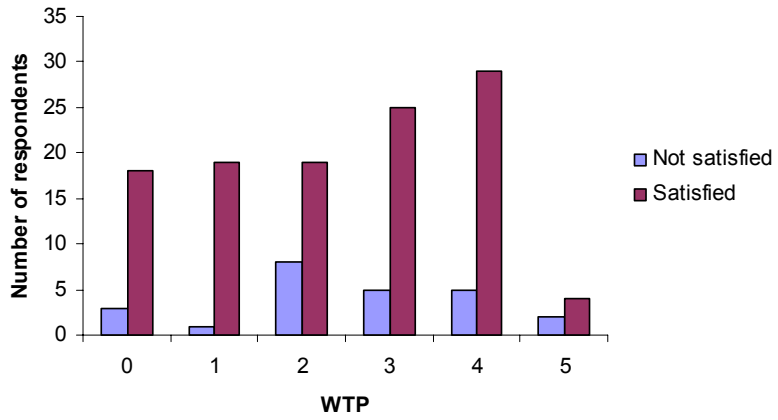

Figure 11. Allocation of WTP for different opinions of current water quality

6.2.5 Willingness to pay and opinion of water cost

Of the 141 respondents 125 have replied the question about their opinion of their current water cost. 30 respondents stated that they are paying a low fee for the water and the largest part of them responded that they were willing to pay ¢1,001-¢2,000 more for the water. 66 stated that they pay a moderate fee and there is not a specific amount of WTP in between them as there were three large groups among their replies. 29 stated that they pay a high fee, the largest group among them stated that they were willing to pay ¢2,001-¢5,000. Figure 12 illustrates how WTP is stated according to the respondents' opinion about their water costs.

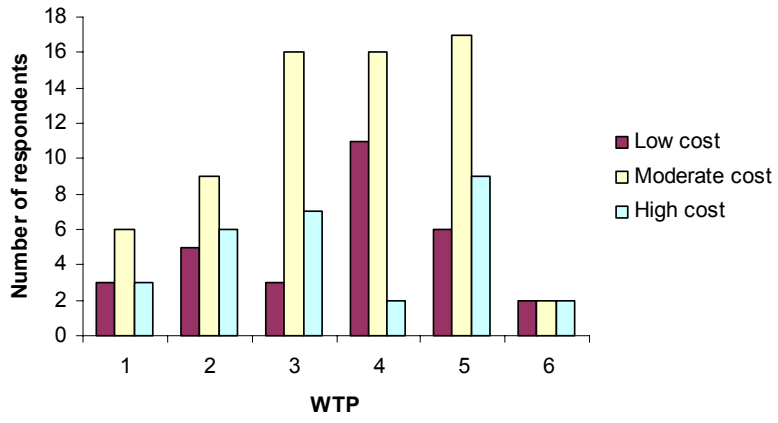

Figure 12. Respondents' choice of WTP according to the opinion of their current cost for water use.

6.2.6 Willingness to pay and confidence of the distributors

Of the 141 respondents 140 replied the question about if they have confidence in the distributors, the municipalities or AyA, if the respondents believed that the distributors would make the environmental change, and if the water tariff was increased for that purpose or not. 65%, i.e. 91 respondents, revealed that they had confidence for the distributors and 49 revealed that they had a lack of confidence. Figure 13 illustrates how the respondents with and without confidence for the distributors are willing to pay more for an improvement of the water quality. The largest part of the respondents with confidence are willing to pay ¢1,000-¢2,000 but almost every respondent is allocated between ¢500 and ¢5,000. Among the respondents without confidence for the distributors the largest parts are those who are not willing to pay anything (27%) and those who want to pay ¢2,000-¢5,000 (27%).

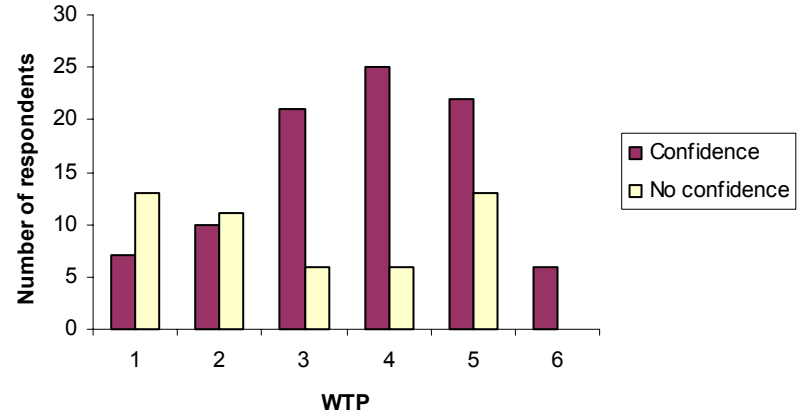

Figure 13. Respondents choice of WTP according to if they have confidence in the distributors or not.

7 Discussion

7.1 Water analysis and fertilizer use

The water samples taken from La Fuente had concentrations of about 14 mg/l NO_3^-. Concentrations of nitrate from water samples taken in Los Chorros were around 3.5 mg/l NO_3^-. As the results of the analysis demonstrated higher concentrations of nitrate from the coffee plantation at all dates for sampling except for October 20 this can indicate a leaching of nitrate from the coffee plantation. The only explanation found for the difference in concentrations of nitrate is that differences in levels of precipitation affected nitrate leaching.

Concentrations of nitrite varied from less than 1.6µg/l NO_2^- up to 16.1µg/l NO_2^- in La Fuente and from less than 1.6µg/l NO_2^-up to 39.9µg/l NO_2^- in Los Chorros. As nitrite is an unstable chemical form of nitrogen, easily oxidised to nitrate, shifting concentrations were not unexpected analysis results.

Concentrations of nitrate in water taken from the coffee plantation were lower than the limit of 50 mg/l NO_3^- set as a guideline for concentration of nitrate that can have an impact on the human health. Concentrations of nitrite in water from the coffee plantation were also lower than the limit of 100 µg/l NO_2^- sets as a guideline for concentration of nitrite that can have an impact on the human health. These were positive results as the inhabitants in the areas drink the water from the tap.

Even if concentrations of nitrates seem to be quite stable around 14 mg/l NO_3^-, in water samples from La Pequeña, this might not be the case for water samples taken at different times of the year. Concentrations of nitrates and nitrites leaving the coffee plantation depend on precipitation, temperature and the time when fertilizer is added. Water samples taken during seven weeks are not enough to draw a conclusion regarding nitrogen leaching to the surrounding water. To get a good understanding about nitrate leaching in the area water sampling would be needed to be done at least once a month during one year. The highest concentrations of nitrates are suspected to appear at the beginning of the wet season as the soils might accumulate levels of ammonia during the dry period that can be transformed to nitrate and leave the soil when the heavy rains start. The first fertilization is normally also added in the beginning of the wet season. To see impacts of nitrogen containing fertilizer soil samples could also be investigated.

Recommended levels of nitrogen containing fertilizer are about 300-350 kg/N/year for a coffee plantation. The amount of fertilizer used in La Pequeña was about 189 kg N/ha/year which is a relatively low amount of used nitrogen. If amounts of fertilizer would be increased this could have immediate impact on the concentration of nitrate in the water taken from La Fuente. It is important that the levels of fertiliser used are well regulated in terms of when and where it is applied.

Values of pH were about neutral at both La Fuente and Los Chorros at the two chosen occasions. Colour had a concentration of 5 mg/l (U-Pt-C) at the first occasion measured at both at La Fuente and Los Chorros, but were zero at the second occasion measured which means that a higher level iron or organic particles could be entering the water at the first occasion. Conductivity were between 126 µS/cm and 159 µS/cm at both spots and occasions which are lower than recommended and shows that salts where not entering the water in a

large extent. Turbidity was less than 0.4 UNT from both spots at the second occasion and at the first occasion at Los Chorros. The turbidity measured from the first occasion at the coffee plantation can be disregarded as the water was taken from surface water.

The spots for the water sampling in this investigation were chosen where drinking water is taken that supports people in the Alajuela province. For a thorough investigation of fertilization impact on the water quality a better understanding of the water movements in the areas is crucial. To be able to convey a study limited in time and monetary terms the amount of water samples taken needed to be narrowed from the primary plan and the spots were chosen according to this.

For a further study of the drinking water in the area it could also be of interest to investigate occurrence of toxic substances in the area. For example at the first water sampling, at La Fuente, endosulphur pesticides were being added to the coffee plantation which could affect the drinking water quality. Unfortunately toxicological water analyses are expensive and for this reason it could not be included in the project.

Another problem observed from the coffee plantation is that the land owner at La Pequeña does not follow the recommendations from the Municipality regarding water protection areas. As the land is privately owned the Municipality requires a permit to enter the grounds. The water is taken in an area in the middle of the coffee plantation and the water source does not have the 200 m area of radius surrounding the water where only ecologically grown coffee can be allowed if any at all. The water source is also open to access of human movements as the water source is situated in the coffee plantation. The tubes in the area are also old and in need of repair.

Both areas for water sampling are situated in desolated areas which makes the chances that septic tanks affect the water lower. This is not the case for several areas in the Central Valley where smaller coffee plantations are situated closer to an inhabited area. In these areas surrounding waters might have higher levels of nitrates and nitrites as the septic tanks could leak and add to the levels of nitrates and nitrites.

In Costa Rica a former strategy of how to use a fertilizer in coffee production seems to have been the more the better. Hopefully a better use of fertilizer and a safer drinking water in general can be achieved with a better law for water protection together with a better institutional control of the work with water use and protection. For a further control of levels of nitrate and nitrite in drinking water a continuous control of the drinking water quality needs to be done for all of the distributors. Better plans for infrastructure are also crucial to keep areas for water protection free from human presence. An improvement of the sanitary water treatment is also needed and a higher percentage of the Costa Rican people need to be connected to public treatment of the waste waters. Fortunately an existing debate of how to work against deterioration of the water resources in Costa Rica is present which can lead to better protection of the water and the human health. One problem is how to finance the work that is needed to be done to change the current distribution of drinking water and treatment of waste waters. In an existing debate on the prices for the use of the water it is argued that the prices are too low according to the service that is provided. This is something easily said but maybe not the case for the respondents to the interview that had a total income to the household of up to ¢ 25,000 which is about 400 SEK a month.

7.2 Discussion about the economic survey

The problem that emerged during the interview part of the project was that the respondents did not seem to pay much or enough attention to the background information. This is according to us the problem that makes the largest error in the statistical estimation because then there is a chance that the respondents did not understand and did not take the problem seriously enough to answer correctly.

Water is difficult to evaluate because of the fact that everybody needs water. No one could manage to live without water and everyone would buy it, maybe not the same amount of it but still, even if the price would rise to the same price level as the water that you can buy in bottles at the market. Therefore, we think that even if the price of water would rise to a higher level than the respondents have answered, he or she would pay for consuming the water that they receive to their house. Because of the lack of knowledge about the health risks that nitrate and nitrite could cause and the great importance of having access to water, it is more difficult to get a real value. On the other hand there is a big knowledge about water, more than anyone can expect of any other natural resource, of course for the reason that everyone uses water every day. It is easier to state a value of a good that is so common than a good that is not used this much.

The fact that a lot of the respondents are poor and never have seen any problems that the drinking water has caused and are unaware about the consequences that the contamination might cause makes it even more difficult. This problem is rather obvious and not very special for the people in Costa Rica. We think without a doubt that not until a catastrophe is happening in Sweden everyone is going to consume the water without worrying about the consequences.

An interesting discussion we had with the respondents was that they were afraid that the decision-makers in the municipalities and AyA were going to use this article to decide about the future price of water. They did have a confidence that it was possible to make a difference but not sure that the municipality would do anything about the water situation even if the tariff of the water increased. Therefore they were suspicious about giving us the information about their WTP. Especially they did not want to state a WTP that was unnecessarily high because of the fear that the municipalities or AyA would use their power and increase the tariff of the water higher than necessary and take the rest of the money as a profit.

One weakness of the interview is that it does not fully explain the effects that would avise if more of the respondents and the people in the area would pay more for the drinking water. To have the exact change of quality and restoration are preferred. Also the means of payment would be good to include. But we encountered a lot of difficulties in finding out how much money is needed to make a change, which new system that would clean the water and by which amount of nitrate and nitrite will decrease because of the technique. We were in contact with a lot of people at the municipality, the University of Costa Rica and INTA but a lot of them were fieldworkers and did not know much about costs of the changes. It had been good to come in touch with more people from institutions like healthcare centres, to find out the costs of the health problems, and with economists, to see how much it would cost to make the change in the water quality, but because of the time limit it was not possible to do. To make this study even better an environmental impact analysis is needed for estimating the costs in physical terms.

An interesting continuation of this project would be to do a cost-benefit analysis and to pay more attention to the costs of making a change and to have more contact and an open discussion with the decision-makers.

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Oscar Rodriguez Gonzales, Manager of La Pequeña, September 30 2005.

Appendix 1: Abstract of the seminar

The seminar was introduced with a presentation from Dr. Jenny Reynolds-Vargas about an investigation that UNA made from the Barba Aquifer. More than half a million persons live by water from the Barba Aquifer. In the area land use is dominated by coffee plantations. For twelve years water sampling was made at twenty points for analysis of primarily nitrate and nitrite. The investigation demonstrated that coffee plantations together with urbanisation, with non functioning septic tanks probably gave most of the nitrates to the waters. Concentrations of nitrates were not over the recommended level for drinking water but increasing concentrations were noticed. The recommendation is to get a better regulation for the use of soils and water in the area and to find the sources of contamination.

The seminar was continued with a presentation by Darner Mora Alvarado from AyA who claimed that results from the investigation made by UNA were incorrect. He also presented examples from newspaper articles that he claimed showed upon incorrect results. One thing that he doesn't seem to have understood though was the difference between levels of $N\text{-}NO_3^-$ or NO_3^- and that they have different values for recommended levels because ha kept arguing that the levels of $N\text{-}NO_3^-$ could be as high as 50mg/l which is not the case decided by Ministerio del Ambiente y Energía, MINAE. He also kept pledging that nitrates do not give an increased risk for gastric cancer. But neither is proved today.

Luis Ganes from ESPH talked about the cost for drinking water. He claimed that receiving drinking waters at the low prices that Costa Rican citizens does today is practically to do people a favour. He meant that the price for drinking water should include preservation of the areas surrounding the water to prevent contamination instead of spending money on healthcare for treating waterborne diseases. He claims that not doing this would be to choose the more expensive choice. He also stressed the importance of a permanent disinfection of drinking water, which is not the case today, as well as understanding that use of septic tanks are not enough for taking care of waste waters from the households. He claimed that to solve the water question for the San José area could cost about $300 million. He also added that the legislation for protection of drinking water is not enough and that the municipalities are not doing their job by permitting constructions in areas that should be used exclusively as water protection areas.

Isabela Román who have been working with evaluations of environmental questions in Costa Rica claimed that the situation have not changed markedly in several years.

Appendix 2: Photos from the water sampling and the interviewing

Doing the interviews in Alajuela centrum

Therese at the water sample site in Los Chorros

Melvin Allpizar from CICA at the water sample sight in La Pequeña and the entrance to La Pequeña.

Appendix 3: The interview

Cuestionario

Somos dos estudiantes de Suecia que hacemos un estudio en cooperación con Instituto Nacional de Innovación y Transferencia en Tecnología Agropecuaria, INTA, y Universidad de Uppsala, Suecia. El asunto de este estudio es de medir niveles de nitratos y nitritos en agua sacado en un naciente situado en San Isidro, Alajuela, y al mismo tiempo conocer si hay un interès entre los habitantes de este area de ver un cambio en la calidad y el manejo del mismo agua.

La conversación con Usted es para conocer la voluntad de pago por el agua, tratando calidad y protección de resursos hidricos. Hemos eligido de entrevistar 100 personas que utilizan agua desde nacientes en Alajuela del manejo del Municipalidad de Alajuela. Esperamos de su colaboración respondiendo a las siguientes preguntas. Toda la información en este cuestionario será manejada de manera de confidencial.

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1. ¿Recibe el servicio de agua en su casa?
( ) Sí
( ) No

2. ¿En que region de Alajuela vive Usted?
( ) Sabanilla
( ) San Isidro
( ) Itiquis
( ) Otro. Dónde:……..

3. ¿Le provee la Municipalidad el servicio de agua?
( ) Sí
( ) No

4. ¿Está satisfecho(-a) con el calidad de agua que Usted recibe? En este caso con mala calidad estamos referiendo a agua con olor, color o si ha notado problemas con su salud
( ) Sí
( ) No. Si la respuesta con Usted eligió es no, por favour describe por

que:…….

5. ¿La calidad de agua, le da a Usted confianza de consumirla sin tratarla?
( ) Sí
( ) No

6. ¿ Tratando salud humano, conoce Usted cuales problemas nitratos y nitritos en agua pueden causar?

( ) Sí. Cuales:……
( ) No

Deforestación y sobre utilización de tierras han deteriorado la calidad de agua en diferentes partes de Costa Rica. Fertilización de cafetales y otros cultivos puede adicionar nitratos y nitritos al agua que puede ser un riesgo para la salud humano. Por esto un problema actual es de como resolver esta situación de la mala calidad de agua en los nacientes.

Lo que estamos investigando es en que medido los Alajuelenses podrían pagar para mejorar la calidad de agua que consumen. Un aumento de las tarifas de agua significa un ingreso a la Municipalidad que puede utilizar para proteger los recursos hídricos y dar un mejoramiento a la calidad de agua.

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7. ¿Quién cree Usted que tiene la responsabilidad de proteger las nacientes de agua?

( ) Del Gobierno
( ) De la Municipalidad, AyA o otro proveedor
( ) De todos, incluyendo los habitants en el área

8. ¿Cuanto paga Usted por el agua que recibe por mes y cuanto consume (m^3)?

( ) ¢…… …….. m^3
( ) No sé.

9. ¿Usted piensa que la tarifa que paga por el agua está:

( ) Barata
( ) Cara
( ) Adecuada

10. ¿Tiene Usted confianza en que la Municipalidad de Alajuela, o otro proveedor, podría mejorar la calidad de la misma, aumentaría la tarifa?

( ) Sí
( ) No

11. a) ¿Estaría Usted disponible de pagar una tarifa más alta para recibir una agua de buena calidad y para proteger dicha calidad en el futuro?

( ) Sí.
( ) No

b) ¿En caso afirmativo, cuanto puede Usted pagar más para recibir una agua de buena calidad?

( ) De cero a menos que ¢500
( ) De ¢500 a menos de ¢1000
( ) De ¢1000 a menos de ¢2000
( ) De ¢2000 a menos de ¢5000
( ) De ¢5000 y más

12. ¿Piensa Usted que el problema de calidad o contaminación de agua es un problema actual?

( ) Sí
( ) No

13. ¿Conoce Usted de información en periódicos, por television o radio refiriéndose a la calidad o contaminación de agua?

( ) Sí
( ) No

Preguntas socio-demográficas. Estas preguntas están incluidas para tener un conocimiento de la persona entrevistado.

---

14. ¿Sexo del entrevistado?

( ) Hombre
( ) Mujer

15. ¿Su edad se encuentra entre?

( ) 18 a 25 años
( ) 26 a 35 años
( ) 36 a 45 años
( ) 46 a 55 años
( ) 56 a 65 años
( ) 66 a 100 años

16. ¿Cuántas personas viven en su hogar? ……..

17. ¿Cuántos adultos viven en el hogar incluyéndose usted?.....

18. ¿Cuál es su último nivel de estudios aprobado?

( ) Ninguna
( ) Primaria
( ) Secundaria
( ) Parauniversitaria o comercial
( ) Universidad o más
( ) Otros

19. ¿Podría indicarnos el ingreso mensual total aproximado de su núcleo familiar?

( ) De cero a menos de ¢ 25.000
( ) De ¢ 25.000 a menos de ¢ 50.000
( ) De ¢ 50.000 a menos de ¢ 100.000
( ) De ¢ 100.000 a menos de ¢ 250.000
( ) De ¢ 250.000 a menos de ¢ 500.000
( ) De ¢ 500.000 y más

¡MUCHAS GRACIAS POR SU COLABORACION!

Appendix 4: Article from local and national newspapers about the water problem

Deben pagar por agua embotellada

214 familias de Orotina reciben el agua con barr

- Administradores del acueducto local denunciaron que río está contaminado
- Usuarios pagan ¢1.800 cada mes por el servicio y compran agua embotellada

Jorge Umaña
Corresponsal

OROTINA, ALAJUELA. – Para lavar la ropa de su familia, María Eugenia Robles debe recoger agua de lluvia. Más aún, para bañarse debe primero limpiar el líquido de las basuras que acumula en el recipiente donde lo recoge.

Esta situación es la misma que viven 213 familias más en Guayabal, Mastate y La Cañera, en Orotina de Alajuela, donde los usuarios reciben el agua sucia.

"Para el consumo nuestro y de los niños tenemos que comprar agua embotellada a pesar de que pagamos ¢1.800 por mes", aseguró María Eugenia Robles.

El 23 de abril, los dirigentes de la Asociación de Acueducto Rural Pital-Centeno, administradora del acueducto, solicitó la intervención del Ministerio del Ambiente y Energía (Minae).

María Eugenia Robles mostró la suciedad del agua. JORGE UMAÑA PARA LN

Según denunciaron, en la finca Rancho Ecológico El Bosque, en Ramadas de Higuito de San Mateo, un tractor realizó trabajos y tiró la tierra en el cauce de la Quebrada Centeno, lo que originó el problema de contaminación.

"La tierra removida fue depositada en una ladera. Al llegar a la quebrada encontramos que cala al cauce", señaló el técnico forestal del Minae, Stanley Estrada, en una inspección que realizó.

Otras anomalías son la construcción de un sendero en el área de bosque, dentro de la zona de protección de la quebrada.

"El principal problema es la caída de tierra en donde está la toma de agua del acueducto, y son los abonados los que están sufriendo las consecuencias", agrega.

Niega responsabilidad. Edgar Gutiérrez Fernández, propietario de la finca Rancho Ecológico El Bosque dijo, vía telefónica desde su oficina en San José, que no son los responsables de lo que sucedió.

"Recuerdo que hubo una queja hace varios meses. Poco después se comprobó que los caminos y trabajos eran en una finca que no es la nuestra", señaló.

Por el contrario, declaró su interés en colaborar por el sano suministro de agua para los vecinos de esta localidad alajuelense.

Indicó que ellos se encargaban de dar mantenimiento y limpieza gratuita al tanque que abastece a Coyolar, el cual está en su terreno.

"Nuestra finca es de 1.000 hectáreas y de ellas 700 son de bosque primario. Estamos reforestando algunas partes", agregó.

Román Campos Castellón, secretario de la asociación que administra el acueducto, explicó que la suciedad dañó 50 hidrómetros.

"Se colocó una llave en el tanque de almacenamiento y se contrató a un trabajador para que cierre el paso del agua, principalmente cuando llueve", describió.

Especificó que en un caso como el actual, la cloración no sirve con el agua llena de lodo y que con toda razón, algunos usuarios se niegan a pagar el servicio, justificando su negativa en que no es de calidad.

El alcalde de San Mateo, Erwen Masís, dijo: "Hace unos 4 meses recibimos una denuncia y la pusimos en manos del Minae en Esparza". ■

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