Exploring the Interrelationships Between Farmers and their Watershed: A Case Study in Human Ecology from Río La Paz, Costa Rica

by

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Abstract

Residents of the Río La Paz micro-watershed make day-to-day land-use decisions that affect the quality and quantity of their freshwater resources. Powerful external forces—mainly climate change and a potential governmental plan to divert Río La Paz water to downstream cities—will significantly diminish the quantity of water flowing in the river and streams within the next decade. Therefore, local land-use decisions are crucial in protecting the remaining supply of water and ensuring its integrity. While many farmers make decisions that conserve water and reduce contamination of the river and streams—such as using drip irrigation and non-chemical fertilizers—other farmers make decisions that diminish water quantity and quality—such as using water-wasting sprinklers and chemical pesticides. Determining why farmers and other residents are making different decisions is of immediate importance for the protection of the watershed and the continuation of a sufficient supply of clean fresh water for agricultural, domestic, and industrial uses.

The existing watershed management literature highlights the importance of ecological and socio-economic factors in planning and implementation. However, the literature largely ignores cultural variables that may affect the decision-making behavior of individuals. In this study, I follow Davis et. al. and Toupal to narrow culture to shared traditions, values, and beliefs or assumptions that affect people's relationship to the natural environment.[1] Using interview data from over fifty farmers and watershed residents, I find that these three aspects of culture likely influence land-use decisions made by individuals that alter the water quality and quantity of the watershed. I conclude by arguing that certain aspects of culture need to be considered by watershed planners in striving towards sustainable and resilient freshwater plans.

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[1]Davis, S. A., Lawrence R. Shaffer, and Julie H. Edmister (2003). Sustainability of aquatic systems and the role of culture and values. Achieving sustainable freshwater systems. M. M. Holland, Elizabeth R. Blood, and Lawrence R. Shaffer.; Toupal, R. S. (2003). "Cultural landscapes as a methodology for understanding natural resource
management impacts in the western United States." Conservation Ecology **7**(1): 12.

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Introduction

Part 1. Water and the World

"Si me diera la oportunidad de hacer un regalo a la siguiente generación, sería el amor por el agua."

("If I were given the opportunity to give a gift to the next generation, it would be the love of water.")

–Sign at a trout farm, Bajo La Paz, Costa Rica.

"Agua es vida," the farmer stated simply. For a moment I just stood there, stunned that I had failed to realize the greater importance of the research I was doing. Despite all my attempts to analyze the economic, social, political, and environmental facets of water, the clear fact remains: both humans and the earth's surface are about 70% water.[2] Water literally connects us to our planet. As humans we need no greater reason to cherish this precious life-giving substance and do everything in our power to conserve and protect it.

In many regions of the world, freshwater has become a scarce resource. Although the earth's surface is about 70% water, freshwater only comprises 3%. While ice locks up 2% a precious 1% is left to be split among terrestrial and freshwater ecosystems and diverse sectors of human society—domestics, industry, and agriculture. Currently, 54% of the world's accessible freshwater in rivers, lakes, and aquifers is allocated to human

[2] Emoto, M., and David A. Thayne (2005). The Hidden Messages in Water, Simon and Schuster.

uses.[3] Learning how to manage and partition freshwater will be one of the greatest and most crucial challenges faced by humanity, as forces such as overpopulation, climate change, and environmental degradation threaten our freshwater supplies.

Distribution problems: Water quantity

Although approximately the same number of water molecules have been present in the earth's atmosphere since its formation,[4] the distribution of freshwater has changed dramatically. The distribution of freshwater is impacted by climate change, management practices including diversion and damming, and use by multiple sectors of society. In the future, climate change will continue to make the distribution of freshwater resources more unpredictable and variable, with a greater frequency of extreme weather events such as flooding and drought, and more variable rainfall. Governments and water managers must cooperate across regional and national boundaries as water resources become more unequally distributed between and within nations. Far from obeying political lines, many of the world's most extensive freshwater systems—including the Amazon, the Nile, the Paraná—are international. The river Jordan, for example, borders Israel, the Palestinian areas, Jordan, Lebanon, and Syria.

Contamination problems: Water quality

Contamination of freshwater is caused by point-source and non-point-source pollution. Among point-source pollution are chemicals emitted by industry, businesses, and households, trash thrown into water sources, and livestock excreting into water sources. Non-point-source pollution is more difficult to regulate and includes agricultural run-off from fertilizers and pesticides, sediment from erosion, road salt, grease, and oil from parking lots, roads, and impermeable surfaces, and human wastes from leaky sewage systems. In addition, in many coastal areas saltwater is permeating aquifers due to lowering levels of fresh groundwater, rendering the aquifers unusable. Many factors influence the prevalence of point-source and non-point-source pollution, including governmental regulations, local management practices, and decisions made by individuals, as well as larger forces such as suburban sprawl and agricultural policy.

As the quality of freshwater continues to be degraded, basic sanitation and water-borne illnesses have arisen as critical issues facing the world today. Diarrhea causes 2.2 million deaths annually, mostly small children; intestinal worms infect about one-tenth of all people in developing countries and cause malnutrition, anemia, or retarded growth; trachoma, an eye infection, has caused 6 million people to become blind.[5] Improved access to safe drinking and domestic water and a greater supply of water to allow for better sanitation practices could reduce the incidence of these diseases.[6]

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[3] UNESCO. "Facts and Figures." World Water Assessment Programme, from http://www.unesco.org/water/wwap/facts_figures/index.shtml.

[4] T, W. "Water Abundance and History." Ask A Scientist: General Science Archive, from http://www.newton.dep.anl.gov/askasci/gen99/gen99891.htm.

[5] UNICEF. "Statistics by Area: Water and Sanitation." Childinfo, from http://www.childinfo.org/water.html.

[6] Ibid.

The road ahead

Experts expect that in the coming decades, water will become the "new oil," as large-scale conflicts will emerge over the control of limited freshwater resources.[7] We are already beginning to witness the escalation of deadly water-related conflicts. Water continues to play a central role in the Darfur crisis that has cost hundreds of thousands of lives to date. In Darfur, rainfall has decreased by 40% over the past 50 years, dropping the water tables and shrinking the water supplies used for irrigation, livestock, and human consumption. Many agree that climate change was an instigating factor in the genocide, since it exacerbated the age-old conflict between nomadic herdsmen and sedentary farmers over land and water.[8]

We should avoid viewing Darfur as an isolated event; rather, we should expect further conflicts to arise over competition for limited freshwater resources as world populations grow (populations are climbing the fastest in Africa, the Middle East, and Southeast Asia)[9], as the distribution of freshwater becomes more variable, and as the quality of freshwater diminishes. According to data from the United Nations, today 1/6 of the world's population, more than a billion people, lack adequate access to safe freshwater. [10] By 2025, 1.8 billion people will be living in countries or regions with absolute water scarcity and two-thirds of all humans could be under water stress.[11] Water scarcity is defined as not having a great enough quantity or quality of freshwater available and accessible to provide for the needs of humans and the ecosystem.[12]

Through these emerging conflicts, water will become subject to increasing politicization. Water resource systems such as dams and canals may be transformed into instruments of war or become military targets; control of water resources may become crucial political and military goals. Privatization of water supplies is increasing as the forces of globalization implement ideologies of free trade. As a result, procurement and export of water resources by transnational companies may make some nations more powerful at the environmental, economic, and/or social expense of others.[13]

Despite the vast extent of these problems, there is still hope. As we move towards a more globalized world, water can act as a unifying force, flowing across boundaries to connect nations and heal disease. If we continue to foster a willingness to reach across borders to learn from and work with people from other nations, ethnicities, and races, and if we then unite our awareness of global problems with our knowledge of contexts and

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[7] Gleick, P. H. (1993). "Water and Conflict: Fresh Water Resources and International Security." International Security **18**(1): 79-112.

[8] Baldauf, S. (2007). "Climate Change Escalates Darfur Crisis." Christian Science Monitor **July 27**.

[9] Gapminder Foundation. "Population Growth (%) for 2006." Gapminder World Retrieved 1/25/09, from http://graphs.gapminder.org/world/.

[10] Rogers, P. (2008). "Facing the Freshwater Crisis." Scientific American **July 22**.

[11] FAO (2007). coping with water scarcity: challenge of the twenty-first century. world water day 2007, UN Water.

[12] UN Water (2006). Coping with water scarcity. U.-W. T. Initiatives.

UN Water's exact definition of water scarcity: "the point at which the aggregate impact of all users impinges on the supply or quality of water under prevailing institutional arrangements to the extent that the demand by all sectors, including the environment, cannot be satisfied fully."

[13] Gleick, P. H. (1993). "Water and Conflict: Fresh Water Resources and International Security." International Security **18**(1): 79-112.

connection to place locally, we may be able to work together to solve the problems we have created separately and build a more sustainable future.

Part 2. Water in Costa Rica

Costa Rica has a high potential to sustainably manage its freshwater resources. Costa Rica harbors largely untapped freshwater resources in aquifers, springs, streams, and rivers—only 2.4% of freshwater is withdrawn annually.[14] The country ranks highly on the Water Poverty Index (WPI)—20th out of 147 countries—which uses multiple indicators to assess the availability of and access to safe freshwater. The indicators include internal and external water resources, the percentage of population with access to safe water and sanitation, water available for irrigation, the capacity of the population to access water, domestic water use, industrial water efficiency, and agricultural water efficiency, and aspects of overall environmental health.[15] Costa Rica also ranks highly on both the ESI (Environmental Sustainability Index) and the EPI (Environmental Performance Index). The ESI combines indicators for air quality, water quality, water quantity, biodiversity protection, ecosystem stresses, waste and consumption patterns, population growth, and human environment-dependent health problems.[16] The EPI's indicators include air quality, water quality, sanitation, biodiversity protection, productive natural resource sustainability, and greenhouse gas emissions. Costa Rica ranks 9th out of 142 countries in the ESI, and 5th out of 149 countries in the EPI.[17]

The country also has the institutional and legal framework necessary for effective management of water resources by the government and the populace, as it possesses an extensive system of laws and organizations geared towards allowing individuals and communities to protect their natural resources. As a second-world country, Costa Rica also faces less problems of extreme poverty than other countries that require short-term, mostly social solutions rather than sustainable, long-term management perspectives that integrate social and ecological systems. Citizens are highly educated compared to the rest of Latin America and the developing world—the youth literacy rate is 97% for males and 98% for females, primary school attendance is 87% for males and 89% for females, and secondary school attendance is 77% for males and 82% for females.[18]

Nonetheless, Costa Rica faces significant freshwater problems: Frequent water shortages plague arid regions like Guanacaste as droughts dry up water supplies; Maintenance or provisioning problems with the aqueduct system strike highly populated areas such as the capital city of San José, forcing water supplies to be rationed; Citizens violently protested the construction of water pipelines in Guanacaste that will supply

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[14] Gapminder Foundation. "Annual freshwater withdrawals, total (% of internal resources), 2002." Gapminder World Retrieved 1/25/09, from http://graphs.gapminder.org/world/.
[15] World Resources Institute. (2002). "Freshwater Indices: Water Poverty Index (2002)." Earthtrends Retrieved 1/26/09, from http://earthtrends.wri.org/searchable_db/index.php?theme=2&variable_ID=1299&action=select_countries.
[16] Global Leaders of Tomorrow Environment Task Force (2002). 2002 Environmental Sustainability Index. World Economic Forum, Yale Center for Environmental Law and Policy.
[17] Yale and Columbia Universities. (2008). "Environmental Performance Index." Retrieved 1/20/09, from http://epi.yale.edu/Home.
[18] UNICEF. "Costa Rica: Statistics." At A Glance Retrieved 1/26/09, from http://www.unicef.org/infobycountry/costarica_statistics.html.

hotels and golf courses with water at the expense of local towns;[19] According to the IPCC, in Latin America "highly unusual extreme weather events" due to climate change continue to make the availability of freshwater supplies more variable and unpredictable.[20] Nationally, the production capacity of the aqueduct system is very close to the country's demand for water.[21] To better understand these problems, we will examine key aspects of national water provision and watershed management.

Organizational Framework

Even though 97% of the population has access to improved water sources,[22] only 70% receive potable water.[23] Most of the people without potable water are located in rural areas where infrastructure is more difficult to set up and maintain. Water is controlled and managed by a complex web of government and semi-private organizations. Formed in 1961, the governmental organization AyA, Instituto Costarricense de Acueductos y Alcantarillados (National Institute of Aqueducts and Sewerage), is in charge of providing portable water and sewerage to urban and semi-urban populations.[24] The function of AyA is to manage all aspects of potable water provision, recollection and disposal of black water, and liquid industrial waste, including the establishment and enforcement of policies and the planning, financing, and development of projects and infrastructure. AyA is also charged with preventing the contamination of water resources.[25]

A separate organization, ASADAS, Asociaciones Administradoras de Acueductos Rurales (Administrative Associations of Rural Aqueducts) provides water to rural populations. ASADAS are legally-constituted water organizations that have raised funds to pay for and manage their aqueducts and distribution of potable water. AyA regulates the ASADAS and has recently tried to take more control over them: according to the

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19 Cantero, M. (2008, May 20). "Turba vapuleó a policías en protesta por acueducto." La Nación, from http://www.nacion.com/ln_ee/2008/mayo/21/pais1544922.html.

20 United Nations Environment Programme (2007, April 10.). "IPCC Report: Climate Change Hits Hard On Latin America And The Caribbean." Science Daily.

21 Sanchez, A., Max Campos and Daly Espinoza Conference of Party Perspectives - Adaptation of Costa Rica's and Panama's Hydropower Generation to Climate Change. Complex Systems Research Center University of New Hampshire.

22 Gapminder Foundation. "Improved Water Source (2002)." Gapminder World Retrieved 1/25/09, from http://graphs.gapminder.org/world/.
Definition of improved water source: "The percentage of the population with reasonable access to an adequate amount of water from an improved source, such as a household connection, public standpipe, borehole, protected well or spring, and rainwater collection. Unimproved sources include vendors, tanker trucks, and unprotected wells and springs. Reasonable access is defined as the availability of at least 20 liters a person a day from a source within one kilometer of the dwelling."

23 AyA's National Water Laboratory, as cited in: Agua Solutions. (2007). "Fundamentals of rainwater harvesting." Retrieved 5/9/09, from http://74.125.95.132/search?q=cache:KKveegZAHegJ:www.aguasolutions.com/fundamentals-en.html+70%25+of+population+potable+water+costa+rica&cd=4&hl=en&ct=clnk&gl=us.

24 AyA. (2007). "Instituto Costarricense de Acueductos y Alcantarillados." Retrieved 1/10/09, from http://www.aya.go.cr/.

25 CONSULTORES CENTROAMERICANOS EN INGENIERÍA S. A. (31 Enero de 2005). Estudio de la Situación y Propuestas de Mejoras para el Abastecimiento de Agua Potable en las Zonas de San Ramón y Palmares: Informe Principal. INSTITUTO COSTARRICENSE DE ACUEDUCTOS Y ALCANTARILLADOS. República de Costa Rica.; MINAET. (2007). "Subsector Recursos Hidricos." Retrieved 1/12/09, from http://www.minae.go.cr/ejes_estrategicos/aguas/.

"convenio de delegación," all rural water organizations must turn over control of water-related assets to AyA. However, this caused an outcry from rural communities, and most have yet to sign the agreement. There are 2000 water associations in Costa Rica in charge of managing freshwater. Only some of these are legal ASADAS, while others are unofficial associations operating independently, such as sub-committees of otherwise legal Community Development (*Desarrollo Comunal)* organizations.[26]

To make the institutional framework more confusing, private organizations, municipalities, and ESPH (*Empresa de Servicios Publicos de Heredia,* Heredia Public Service Enterprise) are also involved in managing potable water provisioning (**Figure 1**). At the national level, according to the General Law of Health, the Ministerio de Salud (Ministry of Health) is in charge of preventing the contamination of water for the protection of human health, including monitoring potable water provision and gray and black water disposal. In this way, the Ministerio de Salud must work with and supervise the actions of AyA, ASADAS, ESPH, and municipalities to assure they comply with health standards.[27]

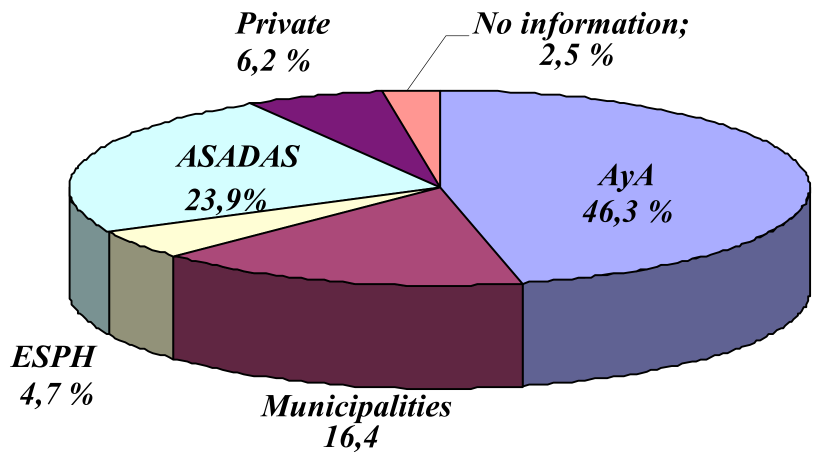

Figure 1. Percent of Costa Rican population provisioned with potable water from various entities.[28]

Other organizations are involved in the management and protection of streams, rivers, aquifers, and general environment. AyA exists within MINAET, the national Ministry of Environment, Energy, and Telecommunications. MINAET also has an Environmental Sector that among many tasks, manages the national park system, aims to implement a strategy of sustainable development throughout the country, and invests in environmental conservation efforts.[29] FONAFIFO, the National Fund of Forestry

[26] Villa, L. (4-24-2008). Personal comm. Discussion of water provisioning with Nectandra Institute. A. Gulley. San Ramón, Costa Rica.
[27] See note 25 above (Consultores 2005).
[28] Nectandra, I. (2008). Entidades prestatarias del servicio de agua para consumo humano en Costa Rica. El Recurso Hidrico: Capacitacion a ASADAS. San Ramon, Costa Rica.
[29] MINAET. (2007). "Sector Ambiente." Retrieved 1/12/09, from http://www.minae.go.cr/ejes_estrategicos/ambiente/.

Financing, runs the Environmental Services Payment Program (ESPP), discussed further below.[30]

Water Concessions

In Costa Rica, a concession is required to use water from a well, stream, or river. A concession is a legal document that entails its owner to use a specified amount of water for a specified purpose. The vast majority of the farmers in the RLP watershed do not have concessions for the water they withdraw in pipes out of the river, and therefore are using the water illegally. The process of obtaining a concession is lengthy and bureaucratic, taking between one and two years to complete. In addition to filling out a four-page form, the applicant must submit documents including a Preliminary Environmental Evaluation Form, certification concerning the ownership of the land involving the water use, drawings of the location of water withdrawal, statements of approval from downstream landowners, and a survey of water source volumes. Finally, a site visit by a government worker must be completed.[31] Although it may not be realistic to assume that each individual farmer will obtain a concession on his/her own, the option to apply as a group also exists. Each community or multiple communities could organize under their Community Development organizations and apply together to increase their chances of successfully obtaining concessions. There are three ways to apply for a group concession in accordance with two different laws:

1) The Society of Users: Created under Law No. 5516 (the water law) in 1974.
2) The District of Irrigation: Created under Law No. 6877 by the National Service of Irrigation and Drainage (SENARA).
3) Rural Aqueducts: Created under Law No. 5516 under AyA.

The District of Irrigation was created to support agricultural development, including irrigation water, so this law may be the best route for the RLP communities.[32]

Challenges of Water Resource Management

The legal and institutional framework for potable water provision and management is extensive and promising. However, the large number of organizations in charge of water provision and freshwater protection poses significant managerial and bureaucratic challenges to ensuring a constant supply of clean water to the population. Furthermore, a divide exists between urban and rural areas—the government is more likely to give financial and servicing priority to the urban populations that are served by AyA over the rural areas served by ASADAS. In fact, Álvaro Ugalde, one of the founders of the national park system in Costa Rica, stated that an "underground war between AyA and ASADAS" is raging as the two organizations vie for political power.[33]

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[30] FONAFIFO (Fondo Nacional de Financiamiento Forestal). (2007). "Environmental Services." Retrieved 1/26/09, from http://www.fonafifo.com/paginas_english/environmental_services/servicios_ambientales.htm.
[31] MEIC (Ministerio de economia, i., y comercio). (2005). "6.2 Procedure involving concessions for water use." Retrieved 1/19/09, from http://www.tramites.go.cr/manual/english/6/6-2.htm.
[32] Kravet, E. (2008). "The Diversion Conflict of the Rio la Paz Watershed: Recommendations for Legal Action and Sustainable Watershed Management." School for Field Studies Directed Research paper.
[33] Ugalde, A. (4-19-2008). Personal comm. Water management in Costa Rica. A. Gulley. Angeles Norte, Costa Rica.

The current legal and organizational framework has also failed to manage sewage effectively. Ninety-six percent of the country's sewage does not pass through sewage treatment plants and is dumped directly into the many rivers in Costa Rica that flow to the Pacific or Atlantic oceans.[34] This statistic is surprising since Costa Rica possesses extensive infrastructure to handle sewage–89% of the urban population has at least adequate access to sanitation facilities, and much of the rural population uses septic tanks.[35] Nonetheless, the solid wastes that must be collected from the septic tanks usually get dumped directly into rivers, and AyA has not made it a priority to construct sewage treatment facilities.

Another difficulty in the effective management of water resources is the under-valuation of water, leading to the under-funding of management organizations. AyA charges 155 colones, or $0.27 US dollars, per cubic meter of water, a price that is nationally set by ARESEP. This is compared to about $1.22 per cubic meter of water in the US, a meager price.[36] The income from this price does not even cover the governmental expenses for the maintenance and operation of the national aqueducts, much less upgrades or expansions. For example, water in one aquifer near San José gets piped halfway across the country to the coast in 70-year-old pipes.[37] In order to raise the price of water, AyA would have to undertake an extensive study and submit their findings to ARESEP, so bureaucracy has so far stood in the way.[38] Although the national demand for water is extremely close to the production capacity of the aqueduct system, the government cannot afford to expand the aqueducts. Furthermore, inadequate funding leads to high water losses from leaks and other maintenance problems. Under-valuation of water is also dangerous because it does not encourage water-saving behavior in consumers or the development of graywater recycling centers or reclamation facilities.[39]

<u>CAFTA and privatization of water</u>

As challenges in managing their freshwater, Costa Rica not only faces climate change and threats to water quality and quantity, but also a new free trade agreement. The forces of globalization have propelled free trade agreements to the forefront of economic and political forums. CAFTA, the Central American Free Trade Agreement, was signed in 2004 between the governments of the United States, Nicaragua, El Salvador, Honduras, Guatemala, the Dominican Republic, and Costa Rica. However, Costa Rica strongly opposed ratifying the agreement, at least until certain debilitating stipulations

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[34] US Dept of State. (2009). "Background Note: Costa Rica." Retrieved 5/10/09, from http://www.state.gov/r/pa/ei/bgn/2019.htm.

[35] Gapminder Foundation. "Improved Sanitation Facilities." <u>Gapminder World</u> Retrieved 1/25/09, from http://graphs.gapminder.org/world/.

Definition of improved sanitation facilities: "The percentage of the population with at least adequate access to excreta disposal facilities, such as a connection to a sewer or septic tank system, a pour-flush latrine, a simple or improved ventilated improved pit latrine, that can effectively prevent human, animal, and insect contact with excreta."

[36] Pennsylvania State University. (2008). "Household Water Conservation." 4/11/09, from http://pubs.cas.psu.edu/FreePubs/pdfs/uh164.pdf.

[37] Zayda Mora of AyA, personal comm. 5/14/08 (office in San Ramón). Mora, S. (5-18-2008). Personal comm. AyA and water management. A. Gulley. AyA office, San Ramon, Costa Rica.

[38] Ibid.

[39] Rogers, P. (2008). "Facing the Freshwater Crisis." <u>Scientific American</u> **July 22**.

were removed. After four years of debating and waiting, Costa Rica finally ratified the agreement that took effect on January 1, 2009.[40]

Opposition to the free trade agreement (known in Costa Rica as the Tratado Libre Comercial, or TLC) remains strong among Costa Rican citizens. Many fear that duty-free rice imports from the highly-subsidized farmers in the United States would run rice farmers in Costa Rica out of business, and force the country to depend more heavily on the US for their food security.[41] Other small and medium-scale farmers could be forced out of business throughout Central America and the US as large-scale agribusiness flood the market with cheap produce, lowering the market costs below smaller farmers' costs of production.[42] Other concerns abound: Multinational corporations, in their constant search for lowered production costs, will commit environmental infractions and violate the human rights of their labor forces;[43] the privatization of telecommunications companies will drastically increase prices for Costa Rican citizens;[44] generic medicines with lowered costs for HIV/AIDS, malaria, and other diseases would be illegal to manufacture due to the violation of intellectual property rights.[45]

In addition, CAFTA will most likely lead to the privatization of freshwater resources. Multinational companies such as Coca-Cola will be able to bottle the water from a spring or river and export it duty-free to the United States and throughout Central America. In addition, the agreement disallows the Costa Rican government to favor their own communities in giving them increased access to water—for example, a farmer needing a water concession to irrigate his crops would not receive priority over Coca-Cola wishing to bottle the water and export it. Clearly, this poses significant food security and environmental problems, among others. Another issue that has already arisen throughout Costa Rica but will continue to increase with CAFTA is that large hotel chains, seeking to make a profit from the country's huge tourism industry, use large percentages of the limited freshwater currently available, threatening the potable water supply in nearby towns.[46] Violent protests in the dry region of Guanacaste occurred in May of 2008 over the construction of water lines that would give hotels and golf courses access to precious freshwater, threatening the water security of local residents.[47]

Promising Environmental Programs

Fortunately, the government has set up promising environmental programs that encourage good stewardship of the land and water. AyA's program Bosque, Agua, y Cultura (Forest, Water, and Culture) aims to plant 1,500,000 native trees in coastal zones

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[40] Murillo, A. (1-2-2009). Azucar y textiles reciben primeros beneficios de TLC. La Nacion. Costa Rica.
[41] Oxfam America. (11-26-2004). "A Raw Deal for Rice." Retrieved 1/29/09, from http://www.oxfamamerica.org/newsandpublications/press_releases/archive2004/press_release.2004-11-16.1308905260.
[42] Citizens Trade Campaign. "CAFTA, Family Farmers and Food Security." Retrieved 1/2/09, from http://citizenstrade.org/caftaagri.php.
[43] Ibid.
[44] Llana, S. M. (10-5-2007). Will Costa Rica join Latin America's leftward tide? Christian Science Monitor.
[45] Citizens Trade Campaign. "Key reasons to oppose CAFTA." Retrieved 1/2/09, from http://citizenstrade.org/caftaagri.php.
[46] Florez-Estrada, M. (4-11-2007). "Costa Rica: CAFTA threatens to turn water into merchandise." Latinamerica Press Retrieved 1/27/09, from http://www.bilaterals.org/article.php3?id_article=10204.
[47] See note 19 above (Cantero 2008).

and "green zones" of educational centers and public institutions from 2006-2010.[48] MINAET and sponsoring organizations have set up the campaign "A que sembrás un árbol," establishing tree nurseries all over the country. Individuals, school groups, and organizations can look up a nearby nursery in the online database and pick up the trees to plant.[49] In 2008, the campaign resulted in the planting of 7,007,323 trees, almost half of which were native species![50]

Costa Rica's Payment for Environmental Services (PES) programs have earned the country worldwide recognition. Since 1997, FONAFIFO, the National Fund of Forestry Financing, has been paying small and medium forest and plantation owners for the ecosystem services provided by their land. The program, called Environmental Services Payment Program (ESPP), recognizes these environmental services: "Mitigation of gases produced by the greenhouse effect; protection of water for urban, rural or hydroelectric purposes; protection of biodiversity for conservation, sustainable, scientific and pharmaceutical uses; research and genetic improvement; protection of ecosystems and life forms, including natural scenic beauty for tourism and scientific purposes." The program aims to conserve and restore forests throughout Costa Rica, vast tracts of which have been cleared for agricultural purposes, and to encourage environmental stewardship by placing an economic value on ecosystem services. The program gives Environmental Service Certificates to foreign companies who invest in the program to help protect watersheds, conserve biodiversity, and mitigate their greenhouse gas emissions.[51]

Literature abounds on the strengths and weaknesses of the program. One of its weaknesses is that the program has not yet reached the large majority of the population—as of 2004, only 4400 landowners had received payments from the program. One study found that larger farm and forest owners are more likely to register for the program and therefore be compensated.[52] Another study used GIS and remote sensing to determine that deforestation rates had not significantly decreased in areas receiving payments compared to those not receiving payments, from 1997-2000.[53] Nonetheless, the program holds promise as an innovative, economically-minded mechanism to promote environmental consciousness and concern.

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[48] AyA. (2007). "Instituto Costarricense de Acueductos y Alcantarillados." Retrieved 1/10/09, from http://www.aya.go.cr/.
[49] Aguacate. "A Que Sembras Un Arbol." Retrieved 1/29/09, from http://www.aquesembrasunarbol.com/.
[50] Fonseca, P. (1-27-2009). "País sembró más de 7 millones de árboles en el 2008." La Nacion Retrieved 1/27/09, from http://www.nacion.com/ln_ee/2009/enero/27/aldea1855171.html.
[51] FONAFIFO (Fondo Nacional de Financiamiento Forestal). (2007). "Environmental Services." Retrieved 1/26/09, from http://www.fonafifo.com/paginas_english/environmental_services/servicios_ambientales.htm.
[52] Zbinden, S., and David R. Lee (2005). "Paying for Environmental Services: an analysis of participation in Costa Rica's PSA program." World Development **33**(2): 255-272.
[53] Sanchez-Azofeifa, A., ALEXANDER PFAFF, JUAN ANDRES ROBALINO, and A. J. P. BOOMHOWER (2007). "Costa Rica's Payment for Environmental Services Program: Intention, Implementation, and Impact." Conservation Biology **21**(5): 1165 - 1173.

Part 3. The Río La Paz Micro-watershed

Study Site

The Río La Paz micro-watershed is located in District 4 of Piedades Norte of County 2 of San Ramón in the province of Alajuela, Costa Rica.[54] The watershed (also known as a drainage basin or catchment) is defined by the area where rainwater drains into Río La Paz or one of its many affluent streams.[55] Río La Paz is an affluent of Río Barranca, which flows to the Pacific Ocean past the city of San Ramón (**Figure 2B**). The watershed is about 14 kilometers (9 miles) in length, comprising an area of about 34 square kilometers, with elevations spanning 960-1580 meters above sea level (**Figure 2**).[56] The region is mountainous and gains in elevation proceeding upstream along Río La Paz, until arriving at the springs that feed the river located in the cloud forest of the Tilarán mountains. There are five main communities in the Río La Paz (The Peace River) watershed, although spatial boundaries separating communities are hard to distinguish (**Figures 2, 2A, and 3)**. Bajo La Paz, La Paz, Piedades Norte, Bajo Zúñiga, and La Esperanza are listed upstream to downstream along the river. Land-use regions are broken into urban areas, primary and secondary coud forest, annual and permanent crops, and pastures for livestock (**Figure 5).** Much of the watershed is comprised of steeply sloping land that cannot be used for intensive crop production (**Figure 6).** My research partners and I stayed in Bajo Zúñiga, located at approximately 10°08.3N, 84°29.8W.

A Tour of the Watershed

To get to know the Río La Paz micro-watershed, let's imagine we are a drop of water in the Río La Paz making its way downstream (**Figures 2A, 3, and 5**). We begin at the top of the micro-watershed, at the springs (the *nacientes*—meaning birthplaces) of the river. We flow through large swathes of intact primary cloud forest covering the hills, tumble down sparkling waterfalls and catch glimpses of the unique fauna inhabiting this forest including spider monkeys and quetzals. We then flow through Bajo La Paz, the furthest upstream community, whose residents earn their living by offering activities to ecotourists and Costa Ricans such as horseback riding to waterfalls and trout fishing in ponds they have constructed themselves and stocked with fish. As we proceed downstream, we start to lose the protective covering of forest save a thin strip of trees directly above the river. We flow through small plots of sugarcane and coffee in La Paz, sighting subsistence and small-scale farmers working among their crops. Now we speed past more coffee and sugarcane, pastures with grazing cows and horses, and vegetable crops. Here we find the farmers of Piedades Norte working on their sugarcane and coffee plots and the farmers of Bajo Zúñiga tending to vegetable crops—huge green heads of lettuce, long rows of tomatoes, and fields of cilantro, celery, potatoes, green onions, and string beans. We also glimpse a couple of small-scale livestock operations with pigs (*chanchera*), chickens (*pollera*), and milking cows (*lechería*), and smell a sticky sweetness as we rush past a sugarcane mill (*trapiche*) that makes *dulce*, a densely-packed, caramel-colored cylinder of sugar used to make

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[54] CONSULTORES CENTROAMERICANOS EN INGENIERÍA S. A. (31 Enero de 2005). Estudio de la Situación y Propuestas de Mejoras para el Abastecimiento de Agua Potable en las Zonas de San Ramón y Palmares: Apéndice 6: Cuencas Hidrográficas. Instituto Costarricense de Acueductos y Alcantarillados. República de Costa Rica.
[55] USGS. (2003). "Drainage basins (watersheds)." USGS Hydrologic Help Retrieved 5/10/09, from http://ga2.er.usgs.gov/HydroHelp/drainagebasin.cfm.
[56] See note 54 above (Consultores 2005).

hot *agua dulce.* Finally, we flow through the community of La Esperanza, whose residents are busy working in more sugarcane, coffee, and vegetable fields, or tending to their families in their houses. Now we hear a rushing noise as we surge into the great Río Barranca, and if we chose to continue our journey, we would be carried straight to the Pacific Ocean.

Figure 2. Topographical map of the lower portion of the Río La Paz watershed. Río La Paz flows southeast through the communities of Bajo La Paz, La Paz, Piedades Norte, Bajo Zúñiga, and La Esperanza. It then joins the Río Barranca which flows west to the Pacific. The city of San Ramón which will take potable water from Río La Paz lies in the lower right-hand corner.

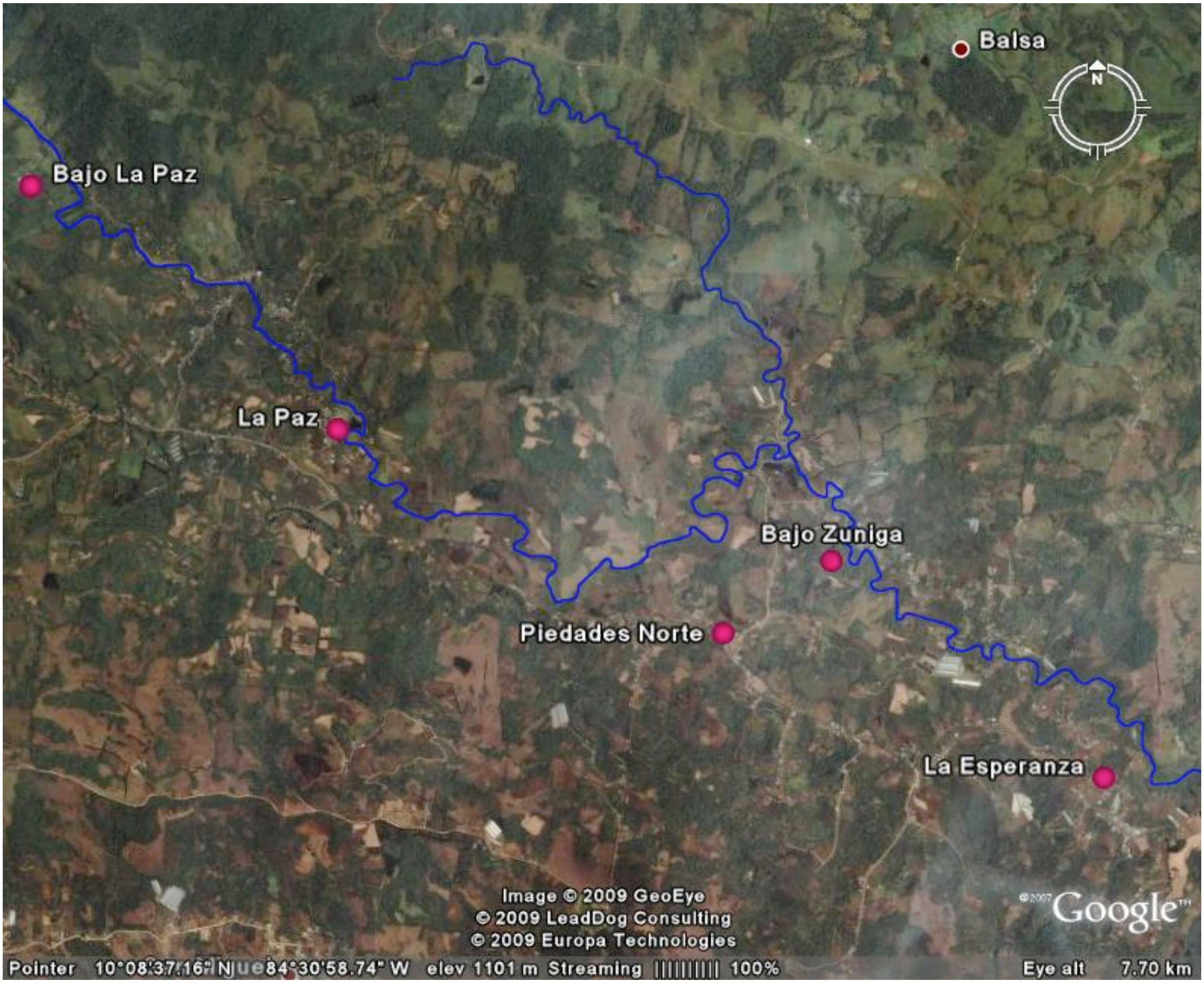

Figure 2A. Map of the lower portion of the Río La Paz watershed, showing Río La Paz and the five communities that rely on the river for domestic water and irrigation water, among other uses. The Quebrada Manco is the large stream in the upper-middle of the picture that flows into Río La Paz close to Bajo Zúñiga.

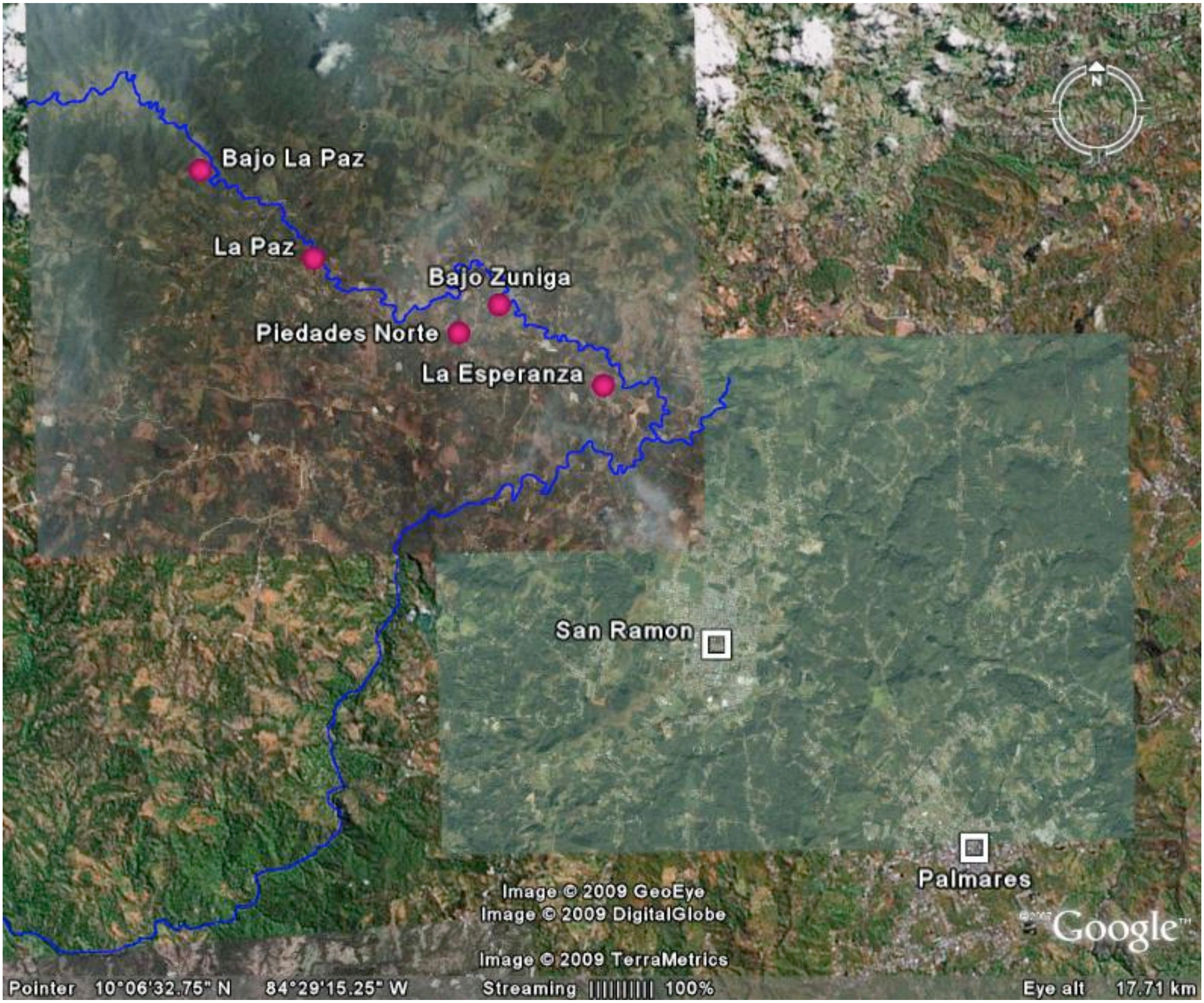

Figure 3. Map of Río La Paz watershed and Río Barranca. The five communities along Río La Paz are shown, with the downstream cities of San Ramón and Palmares. Río La Paz flows into Río Barranca downstream of La Esperanza, which in turn flows west to the Pacific ocean.

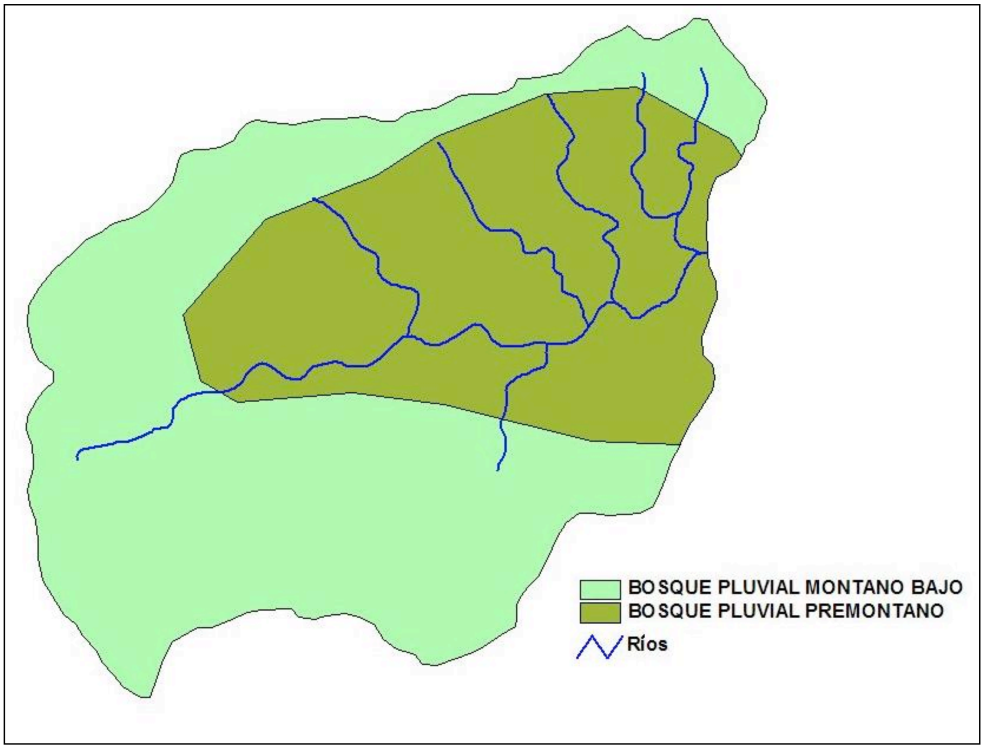

Figure 4. Map of upper-most portion of La Paz watershed, showing tropical lower montane rainforest in light green and tropical premontane rainforest in dark green. The lower montane forest is higher-elevation primary forest, while the premontane forest is lower-elevation, mostly secondary forest.[57]

[57] CONSULTORES CENTROAMERICANOS EN INGENIERÍA S. A. (31 Enero de 2005). Estudio de la Situación y Propuestas de Mejoras para el Abastecimiento de Agua Potable en las Zonas de San Ramón y Palmares: Apéndice 6: Cuencas Hidrográficas. Instituto Costarricense de Acueductos y Alcantarillados. República de Costa Rica.

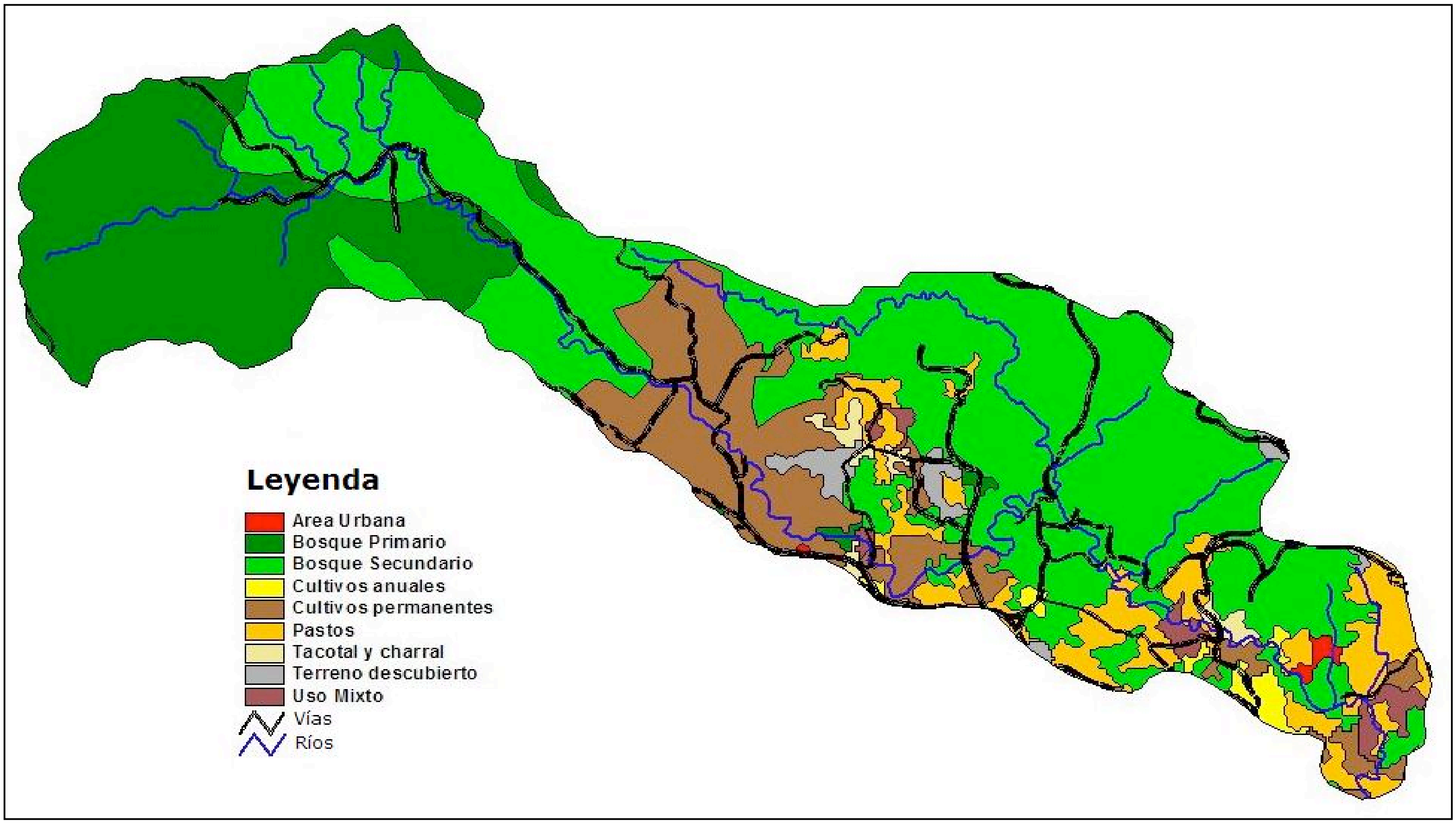

Figure 5. Land-use map of the La Paz watershed (1995). Legend: Río La Paz and its streams shown in blue, roads shown in black. Red—urban area. Dark green—primary cloud forest (mostly lower montane rainforest). Light green—secondary cloud forest (mostly premontane rainforest). Light yellow—annual crops. Brown—permanent crops. Orange—pastures fo livestock. White—shrubs. Lavender—open areas. Purple—mixed use.[58]

[58] See note 57 above (Consultores 2005).

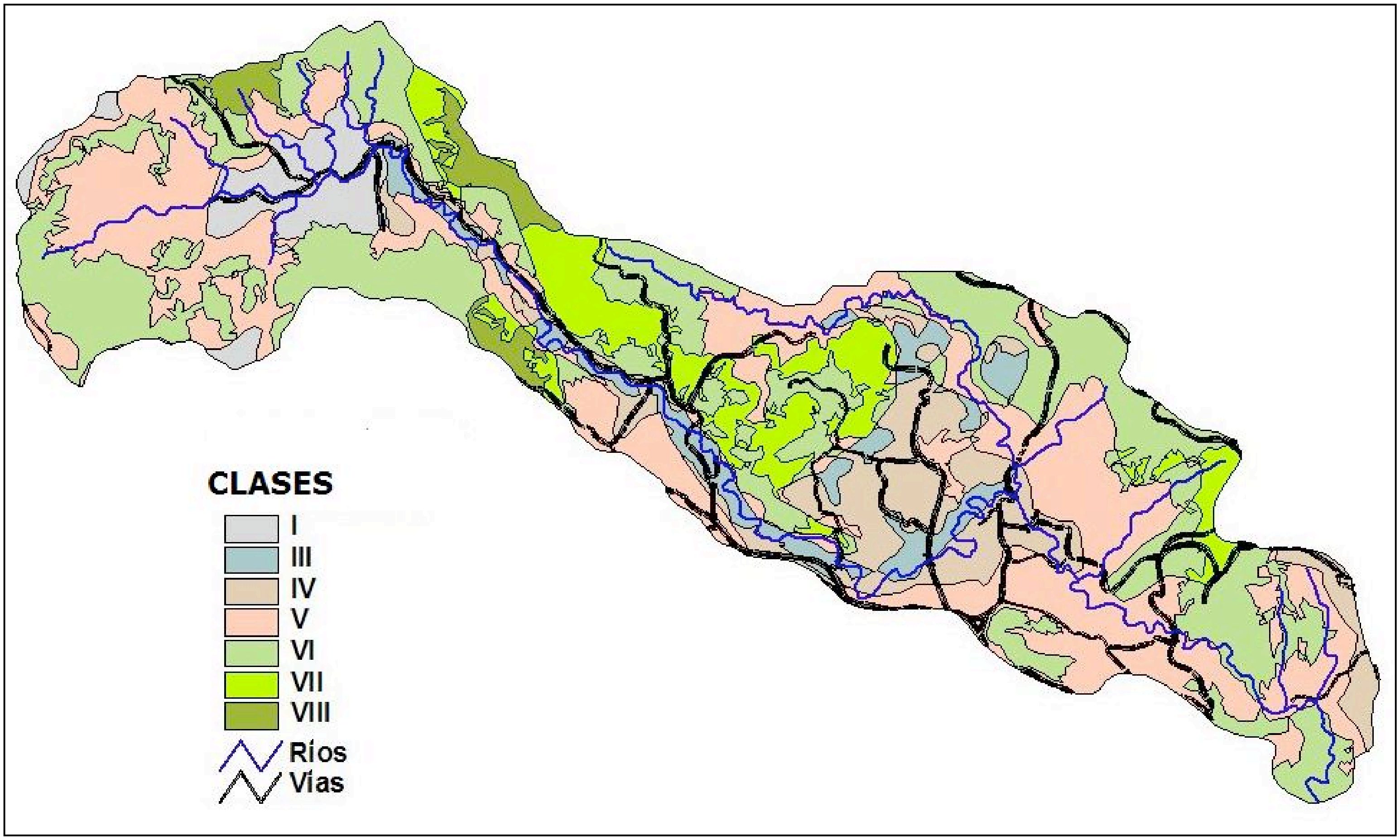

Figure 6. Map of La Paz watershed with Río La Paz and its streams in blue and roads in black. Land is split into potential uses of the land, according to the classification system below, regardless of actual use. (Uses 1995 information).[59]

Potential Use category	Description
I-III	Land suitable for all types of cultivation including annual and perennial, and pastures. Requires attention to soil conservation.
IV-VI	Land suitable for agroforestry (crops grown using the forested environment, such as shade-grown coffee), perennial crops (in this case, coffee or sugarcane), silvipasture (combining pastures with trees), or reforestation.
VII	Land only suitable for light forest management or natural regeneration of forests.
VIII	Land only suitable for forest protection, too difficult to manage.

[59] See note 57 above (Consultores 2005).

Ecological State of the Micro-watershed

Life Zones

The Holdridge Life Zone classifications split land into categories based on temperature, precipitation, and evapotranspiration.[60] According to the Life Zone system, the uppermost portions of the Río La Paz micro-watershed are comprised of tropical lower montane rainforest and tropical premontane rainforest (**Figure 4**), while the lower portions of the watershed are tropical premontane rain or moist forest (**Figure 5**).[61] These types of forests are better known as cloud forests and are classified by high annual rainfall and vegetation that collects water vapor from persistent low-lying clouds. The temperature ranges between 12 and 24ºC and average annual rainfall is around 4000mm. Agriculture and development in cloud forests can be difficult due to the high rainfall and consistently humid air.[62] Although Costa Rica has a wet season that lasts 6-7 months (winter: approximately April to November) and a dry season lasts 5-6 months (summer: approximately November to April), in the La Paz and other cloud forests, the air is humid throughout the dry season and rain is still frequent. While the lower montane forest is mostly primary, the premontane forest is mostly secondary, having been cleared in the past for livestock pastures and then left to regrow.[63]

Biodiversity

Although information about biodiversity specific to the Río La Paz watershed is not available, nearby Juan Castro Blanco National Park harbors biodiversity representative of the upper Río La Paz watershed, in the mountainous cloud forest. The national park offers protection to at least 57 species of mammals, such as tapir, ocelots, sloths, and howler monkeys, at least 233 species of birds, both resident and migratory, and at least 22 species of bats.[64] Endangered and threatened species such as the quetzal, curassow, red brocket deer, and Black Guan live within the park. Unique vegetation includes lancewood and yayo trees.[65]

Hydrology

Río La Paz forms from multiple streams high in the cloud forest of the Tilarán mountains. Each stream is spring-fed. Water from one of these streams is diverted through the AyA treatment plant north of Bajo La Paz, that adds chlorine to the water to kill any pathogens and pipes the water through the aqueduct system to the communities along Río La Paz. After passing through households, graywater from the aqueduct runs out of separate pipes into drainage ditches on the sides of the road, into holes dug in

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[60] United Nations Environment Programme GRID. (2004). "Holdridge Life Zones (Ecological Zones)." Retrieved 5/10/09, from http://www-cger.nies.go.jp/grid-e/gridtxt/grid3.html.
[61] See note 57 above (Consultores 2005).
[62] Ibid.
[63] Rodriguez, F. (5-20-2008). Personal comm. Hydrology. A. Gulley. Bajo La Paz, Costa Rica.
[64] Wikipedia. "Juan Castro Blanco national park." Retrieved 1/11/09, from http://en.wikipedia.org/wiki/Juan_Castro_Blanco_National_Park.
[65] Central America.com. (2008). "Juan Castro Blanco national park." Retrieved 1/11/09, from http://www.centralamerica.com/cr/parks/mojuancastro.htm.

people's land, or back down to the river. This graywater contains household chemicals, detergents, dish soap, and contributes to the contamination in the river.

More major streams join Río La Paz further downstream, the most major one being the Quebrada Manco, which doubles the streamflow in the river. Eventually Río La Paz reaches Río Barranca, which flows straight west to the Pacific ocean.

Streamflow

According to a 2005 study conducted for the government water agency AyA, the average monthly streamflow in Río La Paz is 840 liters/sec, though this volume decreases significantly during the dry season to less than 300 liters/sec (**Table 1**). The further downstream, the greater the streamflow of the river (**Pictures 1 and 2)**. Furthermore, extreme streamflow events are important to monitor or estimate, since droughts or unusually dry seasons frequently occur in Costa Rica and further reduce the volume of water remaining in the rivers. The study estimates that every 2 years, an extreme event will occur that reduces the upstream flow to less than 100 liters/sec, and every 25 years, the river will be reduced to only about 50 liters/sec upstream and 200 liters/sec downstream (**Table 2**). 50 liters/sec is only .05 cubic meters/sec, an extremely small flow. Furthermore, climate change is most likely decreasing flow volumes in general (see Climate Change section below), and some estimate that the streamflow has decreased by 40L/sec in the past year alone.[66]

Table 1. Average monthly streamflow values in Río La Paz (liters/sec), annually and for dry season months.[67]

Monthly average for year	March	April	May
840	251	208	273

Table 2. Estimated minimum streamflows in each of 2, 5, 10, or 25-year time periods, at an upper point and lower point of Río La Paz.[68]

Period of Return (years)	Minimum streamflow (l/sec)	
	Far upstream point of river	Furthest downstream point of river
2	94,08	360,01
5	77,16	295,27
10	66,76	255,50
25	53,91	206,29

[66] Mora, S. (5-18-2008). Personal comm. AyA and water management. A. Gulley. AyA office, San Ramon, Costa Rica.

[67] CONSULTORES CENTROAMERICANOS EN INGENIERÍA S. A. (31 Enero de 2005). Estudio de la Situación y Propuestas de Mejoras para el Abastecimiento de Agua Potable en las Zonas de San Ramón y Palmares: Apéndice 7: Hidrologia. Instituto Costarricense de Acueductos y Alcantarillados. República de Costa Rica.

[68] Ibid.

Water quality

As a part of the diversion plan to provide potable water to San Ramón and Palmares from Río La Paz, the Laboratorio Nacional de Aguas (del AyA) sampled two points on the river for various water quality parameters, including fecal coliform, conductivity, pollution tolerance of macroinvertebrates, and various nutrient levels (Table 5). The study should not be considered conclusive, since only two points were sampled on a single day (January 15, 2005) during the beginning of the dry season; nutrient loads, water levels, turbidity, and other parameters change significantly depending on the season.

The lab's fecal coliform measurements indicate "good" water quality (Table 3), though a signficant increase in fecal coliform colonies was detected at the downstream sampling site compared to the upstream site. Conductivity, a measure of the amount of electricity the water can conduct, increases from the upstream site to the downstream site. Conductivity increases with an increasing level of ions, which can be added to the water through erosion and sedimentation, agricultural run-off, and urban run-off such as road salt and sewage.[69] The lab also collected macroinvertebrates and used them to assess the pollution levels in the river according to the Biological Monitoring Working Party modified for Costa Rica (BMWP') index (Table 4). They found a normal level of water quality at the upstream site, indicating eutrophication and moderate contamination, and a bad level of water quality at the downstream site, indicating high contamination (Table 5). Again, this test should not be considered conclusive, since many different procedures for sampling macroinvertebrates and indices for calculating pollution tolerance levels exist, each producing differing results.

Table 3. Fecal coliform classification system[70]

Classification of water quality	Fecal coliform (CF/100ml)
Excellent	< 20
Good	20-1500
Regular	1501-6000
Bad	>6000

Table 4. Water quality classification system using the Biological Monitoring Working Party modified for Costa Rica (BMWP') index.[71]

Level of water quality	BMWP'	Color code
Excellent	> 120	Blue
Good, not contaminated or altered in a perceptible way	102-120	Blue
Normal, eutrophication, moderate contamination	61-100	Green
Bad, contaminated	36-60	Yellow
Bad, very contaminated	16-35	Orange
Very bad, extremely contaminated	<15	Red

[69] Water on the Web. (2004). "Electrical Conductivity." Retrieved 2/5/08, from http://www.waterontheweb.org/under/waterquality/conductivity.html
[70] See note 67 above (Consultores 2005).
[71] Ibid.

Table 5. Selected water quality parameters for two sampling points on Río La Paz, conducted on Jan 15, 2005 by the Laboratorio Nacional de Aguas del AyA.[72]

Variable	Units	Río La Paz upstream	Río La Paz downstream
Macroinvertebrate results		Green	Orange
Fecal coliform	CF/100ml	150	430
E. coli	NMP	150	400
True color	U Pt/Co	8	11
Turbidity	UNT	1.4	2.5
Suspended Solids Sed.	ml/l/hr	0.1	0.1
Conductivity	µS	22	27
Smell		Negative	Negative
pH		7.49	7.36
Saturation pH		8.83	9.11
Index of saturation		-1.34	-1.75
Alkalinity (phenolphthalein)	mg/l	0	0
Total alkalinity	mg/l	8	12
Total hardness	mg/l	14	17
Hardness from calcium	mg/l	7	7
Hardness from magnesium	mg/l	7	10
Sulfides	mg/l	2	2
Chlorides	mg/l	4	4
Fluorides	mg/l	0.05	0.05
Sodium	mg/l	3.5	2.0
Potassium	mg/l	1.0	1.0

Overall it is clear that the downstream site is more contaminated than the upstream site. This is expected since the upstream site is located in a primary cloud forest in the mountains, removed from most human activities. The downstream site is located within a matrix of secondary forest patches, agricultural fields, pastures where livestock graze, and residential areas. Contaminants that enter the river in this area include pesticide and fertilizer run-off, animal manure, road run-off, household graywater, and household trash. There is also significantly more erosion downstream than upstream, as the upstream point has a high level of forest cover, no roads that pass across the river, and few human constructions and no agricultural fields nearby. The ability of the river to filter out and absorb this pollution without debilitating impact on its ecosystem service functions and aquatic life is unclear. We do know that the fish and shrimp that populated the river in past decades no longer exist.[73] Their disappearance could be due to increasing contamination and sedimentation, decreasing water levels, or most likely both.

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[72] Ibid.
[73] Cachu (5-20-2008). Rio La Paz. A. Gulley. RyM, Bajo Zuniga, Costa Rica.

Picture 1. Río La Paz in Bajo Zúñiga, in the middle section of the watershed.

Picture 2. Río La Paz in the cloud forest, in the upper part of the watershed.

Socio-Economic State of the Micro-watershed

Census Information

According to the latest census,[74] the population of the Río La Paz watershed in 2007 was 3,625, with an approximately equal number of males (48.8%) and females (51.2%). With a total of 978 households, the average number of people per household was 3.7. A significant Nicaraguan population lives within the watershed, with 47 or 4% of households reporting Nicaraguan nationality. The majority of the population has received a primary-level education, either complete or incomplete, while significant portions of the population have also obtained a secondary-level or university-level education (Table 6). It appears that women have a slightly higher education level than men, with a greater percentage of women having attended secondary school or university. The literacy rate is very high, with only 2.5% of male adults and 1.4% of female adults reporting illiteracy. Again, this points to a higher average education level of females.

Table 6. Percentages of male and female adults in the RLP watershed having obtained a primary, secondary, or university level education in 2007.

Education Level	Male	Female
Primary	57.9	57.4
Secondary	21	23.8
University	4	4.9
Not reporting	17.1	13.9
Total	100	100

Most people in the watershed are permanently employed (mostly small-scale and subsistence farmers), are housewives, or are students (Table 7). Others work occasionally, many in construction. A small unemployment rate of 3.2 percent was reported.

Table 7. Percentage of people with various laboral conditions in the RLP watershed in 2007.

Permanent	Occasional	Unemployed	Pensioned	*Ama de casa*	Student	Unreported
20.2	13.6	3.2	3.6	22	18.8	18.5

Finally, of the 978 households in the area, 728 are provided potable water by AyA through the aqueduct system. Another 131 in Bajo Zúñiga are provided with water from their own aqueduct system through their ASADAS organization. 119 households do not rely on the aqueduct service and provide themselves with water: 12 households pump water from a well, 97 get water from a spring or other natural source that they own, and 10 households get water from a natural source, most likely a stream or the river (Table 8).

[74] **Note on the census**: I compiled and summarized census information for the communities of La Paz (including Bajo La Paz), Piedades Norte, Bajo Zúñiga, and La Esperanza. I did not include data on Ángeles Norte or Ángeles Sur because only portions of the communities fall within the RLP watershed and time was limited. Information on Bajo Zúñiga was obtained from: Caja Costarricense de Seguro Social (2006-2007). Census. Sector: Los Angeles. San Ramon, Costa Rica. Information on the other communities was obtained from: Caja Costarricense de Seguro Social (2007). Census. Sector: Los Trapiches. San Ramon, Costa Rica.

Table 8. Types of potable water provision in the watershed (number of households)

Aqueduct	**Aqueduct**	**Own**	**Own**	**Neither**
AyA	ASADAS	Spring	Well	Natural source
728	131	97	12	10

Economic Activities and Markets

The majority of the adult male population living within the watershed are subsistence or small-scale farmers, while the majority of the adult female population are *amas de casa* (heads of the household). Farmers in the upper watershed are mainly involved in sugarcane (*caña)* and coffee (*café*) production. Many farmers in the lower watershed who used to grow sugarcane and coffee have switched to vegetable production within the past decade because of varying reasons such as the low profitability, lack of market availability, and large amount of labor required. Vegetables (*hortalizas*) grown by these farmers include lettuce, tomatoes, cilantro, celery, potatoes, and green onions. Many farmers also raise animals, including chickens, cattle, and pigs, or sell their cows' milk locally. There is one ecological *dulce* factory (*trapiche)* in the watershed, that makes caramel from sugarcane grown by the local farmers, using methods that do not contaminate the river and generate most of the energy needed to run the factory. Other people work as teachers, construction workers, students, trout farmers (who stock ponds with trout and charge people to fish for them or eat them at the restaurant), and convenience store owners. Many people living in La Esperanza, the furthest downstream community, commute to work in San Ramón each day and do not grow any crops.

Farmers distribute their produce locally, in San Ramón, and nationally. Many vegetable farmers drop off their produce daily at a distribution center called R&M in Bajo Zúñiga. Workers at the center wash and package the produce and then bring it to supermarkets all over Costa Rica. Other farmers choose to vend their produce themselves at the organic market in San Ramón, the nearest large city about 20 minutes away by car.

Governing and social institutions

AyA (*Acueductos y Alcantarillados*, Aqueducts and Sewage systems) is in charge of potable water provision. An aqueduct pipes potable water from the top of the watershed downhill through the communities, and residents pay a monthly bill to AyA proportional to the amount of water they use. MINAE (*Ministerio de Ambiente y Energía*, Ministry of the Environment and Energy)[75] is the national government branch in charge of managing the river, but their actual day-to-day operations are scant, mainly including minimal protection against illegal logging and deforestation in the upper watershed. Bajo Zúñiga is located in a different "sector" than the rest of the communities, according to how the government chose to split up the land, so they have an ASADAS, a rural organization for water management. The ASADAS is held accountable to AyA, but it fund-raises and manages the aqueduct that provides potable water to the community themselves (see Organizational Framework above fore more information).

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[75] MINAET. (2007). "Ministerio de Ambiente, Energia, y Telecomunicaciones." Retrieved 1/12/09, from http://www.minae.go.cr/.

A school and church in each community comprise the center of community life. Parent organizations at the school give input into decisions, and managing committees at the church run the operations. In addition, Community Development organizations (*Desarrollo Comunal)* are part of the local governance in each community to manage the community's funds, upkeep roads and sidewalks, run the school and the common hall, and search for solutions to environmental problems. They get their funds from the Commission of Emergencies and the Natural Resources sector of the municipality, as well as fund-raisers. The Bajo La Paz *Desarrollo Comunal* is typical and includes 4 women and 4 men who meet every two weeks.[76] They often discuss water-related issues, but to my knowledge minimal action has resulted. Additional Water Boards (*Juntas de Agua)* have organized within the communities to fight the diversion plan and offer more concentrated efforts towards protecting the river. To my knowledge, the Water Boards have led productive discussions that have shifted the awareness of RLP residents towards protecting the river, but little organized action has resulted.

Knowledge and information

Knowledge about agricultural practices has been passed down through multiple generations. While the previous generation (parents of middle-aged people) of the watershed practiced only coffee and sugarcane production, much of the newer generation has moved to vegetable production and has needed to obtain information outside the family. Neighbors share information to varying degrees, discussing the relative effectiveness of their practices.

INA (Instituto Nacional de Aprendizaje, National Institute of Learning) contains an agricultural extension service that tours communities and offers courses related to agriculture and the environment. In the RLP watershed, they have taught 15-day and longer courses on use of chemical pesticides and fertilizers, organic farming and marketing, maintenance of machinery, use of irrigation systems, milk production, and so on.[77] Similar classes are taught within the communities by companies that manufacture agricultural products.[78] Engineers come to the farmer's fields to take soil samples and give an analysis of the health of the soil and what crops and practices would be best suited for their soil.[79]

An additional source of general environmental awareness is the television. Commercials about protecting the environment are shown by the national government and possibly other organizations. Since television is watched frequently in this area, commercials and programming may be an effective way to raise environmental awareness.[80]

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[76] Arias, I. A. a. H. A. A. (5-17-2008). Personal comm. Desarrollo Comunal operations. A. Gulley. Bajo La Paz, Costa Rica.

[77] Interviews: Hilberto Castro, 12/16/08, house in Piedades Norte; Marco, 12/17/08, fields in Bajo Zúñiga; farmer in La Esperanza, 12/19/08.

[78] Interview, 12/17, house in La Paz.

[79] Interview, 12/18, farmer at house in Bajo La Paz.

[80] Interview, farmer in La Esperanza, 12/19/08; personal observation.

Overview of Water Issues

The Río La Paz micro-watershed, in the province of Alajuela, can be seen as a microcosm of the world in the freshwater challenges it faces.[81] Water distribution problems, contamination, pressures from urban expansion, and the prevalence of upstream *water-impacting* activities that affect downstream *water-dependent* activities form the basis of social-ecological challenges confronted by human populations throughout the world.[82] The water in Río La Paz is experiencing dropping water levels due to climate change and overuse of irrigation water, increased contamination from the surrounding farms, livestock operations, and household trash, and a potential governmental diversion plan to redirect a significant percentage of the river water to downstream cities. These cities, San Ramón and Palmares, have run out of potable water due to poorly-controlled urban expansion and population growth.[83]

External forces affecting the watershed

Climate Change

Although difficult to monitor, most people agree that climate change is responsible for the decreasing water levels in the river and streams over the past 10 years or more, as well as the more variable amounts of rain. This year, in 2008, the rainy season was extended by multiple weeks—it usually stops raining in November but it rained every day until mid-December. It is likely that climate change will continue to affect the watershed by making the dry seasons even drier (resulting in lower water levels), including more drought events, and the wet seasons more variable, including more flooding events.

Evidence of climate change can be seen from minimum and maximum streamflow data taken from two nearby watersheds from 1954-1992 (**Table 9**). Two stations were used because the first was destroyed by a flood in 1977, but the two watersheds have equal areas and similar rivers, so the data can be used together.[84] In general, the minimum streamflow registered in the dry season appears to be decreasing over time, while the maximum streamflow registered in the wet season appears more variable over time, with two flooding events recorded in the last two years of 1990-1991 and 1991-1992.

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[81] Weihoff, T. L. (5-17-2008). Personal comm. CAFTA and water advocacy. A. Gulley. Bajo La Paz, Costa Rica.

[82] Falkenmark, M. (2003). "Freshwater as Shared between Society and Ecosystems: From Divided Approaches to Integrated Challenges." Philosophical Transactions: Biological Sciences **358**(1440): 2037-2049.

[83] Mora, S. (5-18-2008). Personal comm. AyA and water management. A. Gulley. AyA office, San Ramon, Costa Rica.

[84] See note 67 above (Consultores 2005).

Table 9. Minimum average daily streamflow and maximum instantaneous streamflow (cubic meters/sec) registered at stations 80-2201, Nagatac and 80-2202, Guapinol.[85] One cubic meter/sec is equal to 1000 L/sec.

Year	Name and number of the station	Streamflow (m^3/s)		Area of watershed (Km^2)
		Minimum	Maximum	
1954 - 1955	80-2201 Nagatac	2,1	712,1	195
1955 - 1956		3,04	235,3	
1956 - 1957		1,9	253,7	
1957 - 1958		2,08	552,5	
1958 - 1959		2,07	480	
1959 - 1960		2,14	286,5	
1960 - 1961		1,14	451,45	
1961 - 1962		1,14	440,05	
1962 - 1963		2,13	304,34	
1963 - 1964		2,9	553,53	
1964 - 1965		1,65	486,4	
1965 - 1966		1,29	330	
1966 - 1967		2,07	483,1	
1967 - 1968		2,15	502,9	
1968 - 1969		2,75	364,2	
1969 - 1970		2,14	900	
1970 - 1971		3,54	573	
1971 - 1972		2,27	983	
1972 - 1973		2,26	386	
1973 - 1974		2,06	441	
1974 - 1975		2,28	ND	
1975 - 1976		1,95	275	
1976 - 1977	80-2202 Guapinol	1,62	205	203,1
1977 - 1978		1,84	377	
1978 - 1979		ND	ND	
1979 - 1980		2,22	435	
1980 - 1981		1,72	169	
1981 - 1982		1,27	833	
1982 - 1983		1,72	268	
1983 - 1984		1,51	515	
1984 - 1985		1,44	399	
1985 - 1986		1,44	365	
1986 - 1987		1,19	281	
1987 - 1988		1,19	527	
1988 - 1989		1,68	567	
1989 - 1990		1,58	666	
1990 - 1991		1,79	1310	
1991 - 1992		1,79	1080	

[85] Ibid.

The diversion plan

The government organization in charge of potable water distribution, AyA, has decided on Río La Paz as the future source of potable water for the cities of San Ramón (population 42,000)[86] and the smaller city of Palmares (Figure 2, Figure 2B). These cities currently use 200L/sec of potable water from 14 wells that tap into various aquifers in nearby Piedades Sur and Bajo Barranca. However, these cities are some of the fastest-growing small cities in Costa Rica;[87] San Ramón is expected to have 71,000 people in 2030 compared to 42,000 people in 2008, and Palmares is expected to have 42,000 people in 2030 compared to 25,000 people in 2008 if the current growth rate continues. This tremendous increase in population will require an additional 70-100L/sec potable water provision by 2015.

To determine where this potable water would come from, AyA hired a consulting company (CONCESA, Consultores Centroamericanos en Ingenieria S.A.) to conduct an investigation. They considered many different springs and rivers but problems such as sedimentation, existing use, and proximity limited their selection to two alternatives: Río Barranca, or Río La Paz, either upstream near the springs that feed the river or downstream near its confluence with Río Barranca. They proceeded with an extensive study to determine which alternative would be best considering current land uses, existing infrastructure, water quality, vulnerability to extreme weather events and contamination, and costs including equipment, chemical treatment, purchase of land and rights for infrastructure, and energy to pump the water.

They initially concluded that taking water near the springs of Río La Paz would be the best option. One of the main reasons is that the water quality of the spring-fed streams of Río La Paz is classified as primary, compared to quaternary water quality in the Río Barranca. Using water from the Río Barranca would require constructing and maintaining an expensive and energy-intensive water treatment plant.[88] However, they have since changed their mind and now plan on constructing a water treatment plant at the bottom of Río La Paz near its confluence with Río Barranca, because of the decreasing water levels in Río La Paz. Moreover, the construction plans have been suspended due to the economic crisis.[89] If the original timetable holds up, in 2015 AyA will begin diverting 70L/sec of Río La Paz water to San Ramón during the dry season from November-May, and an additional 30L/sec to Palmares during the wet season from May-November, for a total of 100L/sec. These are high levels considering the average dry season flow of about 200-280L/sec and wet season flow of about 840L/sec (Table 1). The plan would require construction of a water treatment plant and piping infrastructure that would allow the water to flow by gravity to the cities.[90]

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[86] Diversion plan somewhere CONSULTORES CENTROAMERICANOS EN INGENIERÍA S. A. (31 Enero de 2005). Estudio de la Situación y Propuestas de Mejoras para el Abastecimiento de Agua Potable en las Zonas de San Ramón y Palmares: Informe Principal. INSTITUTO COSTARRICENSE DE ACUEDUCTOS Y ALCANTARILLADOS. República de Costa Rica.; Caja Costarricense de Seguro Social (2000). Census. San Ramon.

[87] Villa, L. (4-24-2008). Personal comm. Discussion of water provisioning with Nectandra Institute. A. Gulley. San Ramón, Costa Rica.

[88] Mora, S. (5-18-2008). Personal comm. AyA and water management. A. Gulley. AyA office, San Ramon, Costa Rica.

[89] Mora, S. (2-3-2009). Personal comm. The Diversion Plan. A. Gulley. Email.

[90] See note 86 above (Consultores 2005).

Internal forces affecting the micro-watershed

Decisions made by individuals within the watershed affect the quality and quantity of the freshwater in the Río La Paz and its affluent streams. Some decisions only affect the quality of water and not the quantity. However, many decisions that affect water quantity will also alter the quality, so it is hard to separate the two. For example, using aspersion irrigation—overhead sprinkler irrigation—to deliver much more water than necessary to a tomato crop will increase the amount of run-off (including pesticides, fertilizers, animal manure, and so on) into the river (**Picture 3**). In contrast, using drip irrigation uses less water, reduces erosion, requires the use of less chemicals, and in some cases reduces the occurrence of insect and other plagues (**Picture 4).** Control of illegal logging and protection of the forests sheltering the springs and upper portion of the watershed also affects the quantity and quality of water remaining in the river. Deforestation on the borders of the river degrades the integrity of the river channel and causes flooding. Deforestation of areas upstream of the river increase erosion and run-off, depositing more sediment and agricultural pollutants into the river and decreasing soil health and fertility.

Picture 3. Gilberto showing us his aspersion irrigation system in Piedades Norte.

Picture 4. A more water-efficient drip irrigation system

Chavez, W. (2008). Personal comm. with head engineer of the Diversion Plan. A. Gulley. AyA office, San Ramon, Costa Rica.

Factors affecting water quality

Among point-source pollution affecting the RLP freshwater system are household trash bags thrown directly into the rivers and streams, and livestock excreting into the water. Non-point sources are much more prevalent and include sediment from erosion, agricultural run-off containing pesticides, fertilizers, and animal manure, graywater from households, and urban run-off such as grease and oil from roads. During the rainy season, large-scale erosion of roadways and agricultural land occurs, and hours of rain each day wash anything on the surface of fields and pastures into the rivers and streams.

Many decisions made by individuals living in the watershed affect the quality of the rivers and streams. Farmers decide what crops they will grow, what fertilizers and pest control measures they will use (chemical versus natural and organic), how they will manage their livestock including what they will do with manure, where they will graze the animals, and how they will avoid soil compaction, and what soil conservation techniques they will use to decrease erosion and preserve soil fertility. The land in the watershed is mountainous, so farmers use techniques to grow crops on steep slopes such as terracing, windbreaks, and mulching.

Amas de casa and household members decide how to dispose of household trash (burning it, burying it, throwing it in the river, paying for service to collect it), what types of cleaners, detergents, and dish soap they use, and how to dispose of graywater from sinks, showers, and washing machines. There is no infrastructure for disposal of graywater, so graywater from houses becomes run-off after it is piped to roadside ditches or over the land.[91]

Industries in the watershed also release pollutants that impair the water quality of the river. The vegetable distribution center R&M washes vegetables with water and iodine, piping the used water containing pesticides into the river.[92] A large-scale chicken operation that sells meat chickens to a national company may emit manure and graywater into the river. Pig farms and milking operations may also contaminate the river with manure. Construction of houses, roads, and other projects contributes to erosion and increases soil compaction, resulting in higher levels of run-off that would otherwise be held in the soil.

Forces affecting water quantity

Farmers decide what crops they grow (how water-intensive they are), how much water they use on their crops, the source of their water (river or stream, perforated well, rain, or aqueduct), what irrigation system they use (gravity, aspersion, or drip irrigation), what time of day they irrigate, and whether they use water conservation methods such as tanks that collect rain water during the rainy season. *Amas de casa* decide how much water they consume for cleaning, washing clothes, cooking, showering, and so on. The average amount of water consumed by a household in Piedades Norte is 19.6 cubic meters per month.[93]

Industries in the area such as the chicken operation, pig farms, milk operation, and distribution center also consume water. There used to be about a dozen *trapiches* on the

[91] Mora, S. (5-14-2008). Personal comm. Water management. A. Gulley. Email.
[92] Mendez, M. (4-14-2008). Personal comm. and tour of RyM produce distribution center. A. Gulley. RyM, Bajo Zuniga, Costa Rica.
[93] See note 89 above (Mora 2008).

river that processed the sugar cane from local farmers, consumed incredible amounts of water, and contaminated the river with waste from old tires that they burned for fuel. However, degradation of the river and/or profit maximization led the management to destroy all of these *trapiches* and replace them with a single "ecological *trapiche*" that recycles the water it uses and uses sugarcane waste and water vapor given off in one stage of the process for energy.[94]

[94] Tour of Ecological Trapiche, April 2008; Interview with Ecological Trapiche owner. 4/18/08, house in Bajo Zúñiga.

Concept map

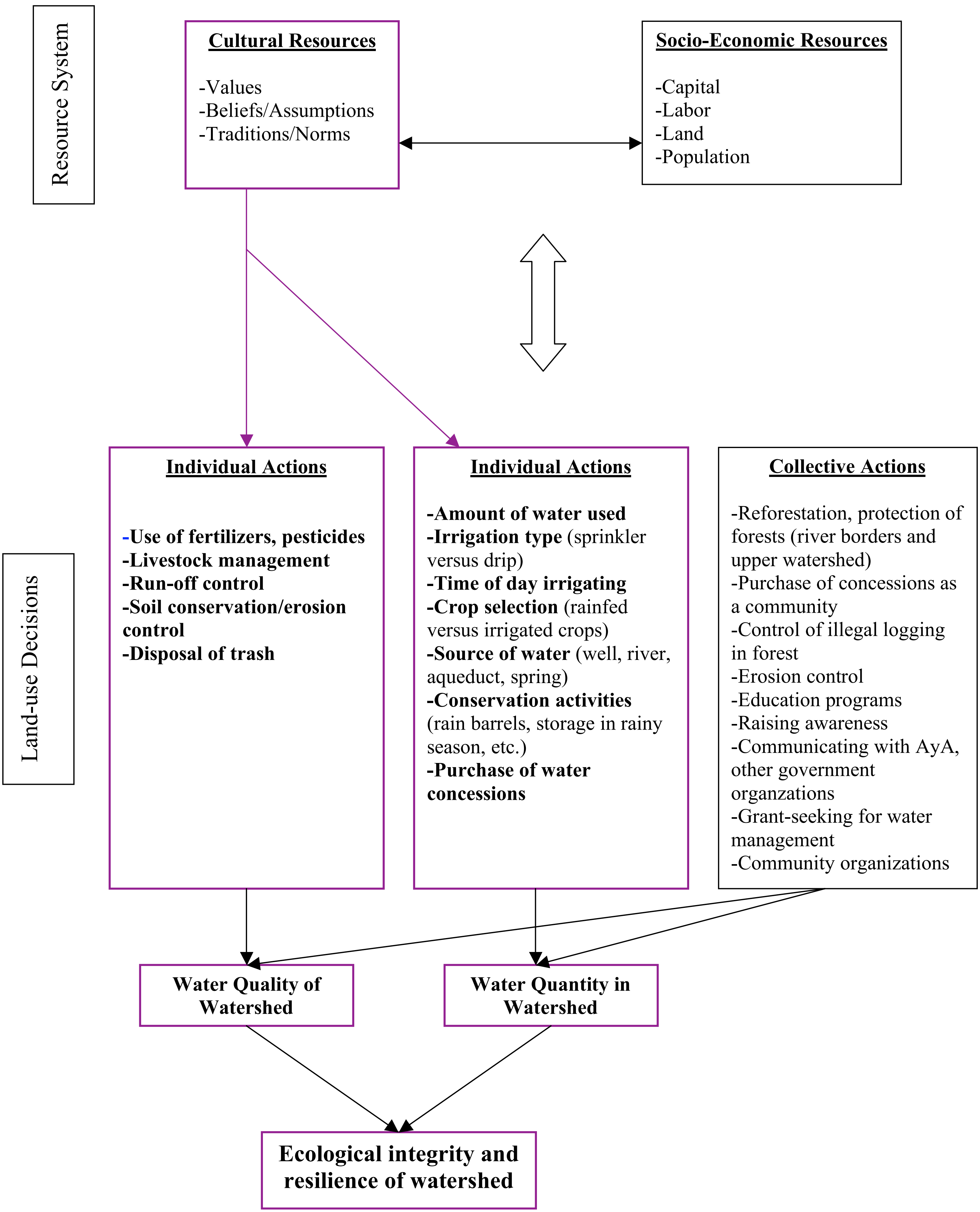
Throughout my investigation, I used the concept map below to organize my research. I developed this concept map based on Pickett, and developed the culture categories based on Davis et al and Toupal.[95] Outlined in purple is the research path I followed. My broad, overall research question is: How do cultural variables affect those land-use decisions made by individuals that alter the water quality or quantity of the Río La Paz microwatershed?

Starting at the bottom of the chart, I am interested in striving towards a watershed with ecological resilience and integrity (or preserving these qualities if they already exist). To accomplish this end, I split up human impacts on the watershed into water quality and water quantity impacts. Moving up on the chart, I decide to investigate how *individual* farmers and watershed residents were affecting the water quantity and quality, and brainstormed the individual actions that are most responsible. I choose to ignore collective actions that also have a large impact on the watershed, in addition to larger-scale policies and governmental programs.

I then follow Pickett in asking what "resources" individuals use to make water-impacting decisions, and find that the majority of literature focuses on socio-economic resources—for example, farmers may use chemical pesticides that degrade water quality because they are cheaper than organic pesticides. However, I decide to investigate whether cultural resources were also important—for example, a farmer may use chemical pesticides because his family has always used them or because a discourse that chemicals do not contaminate the river runs through the community. I narrow these cultural resources down to shared traditions, values, and beliefs or assumptions that affect people's relationship to the natural environment.

[95] Pickett, S. T. A., William R. Burch, Jr., Shawn E. Dalton and Timothy W. Foresman, J. Morgan Grove, Rowan Rowntree (1997). "A conceptual framework for the study of human ecosystems in urban areas." Urban Ecosystems **1**: 185-199.; Davis, S. A., Lawrence R. Shaffer, and Julie H. Edmister (2003). Sustainability of aquatic systems and the role of culture and values. Achieving sustainable freshwater systems. M. M. Holland, Elizabeth R. Blood, and Lawrence R. Shaffer.; Toupal, R. S. (2003). "Cultural landscapes as a methodology for understanding natural resource management impacts in the western United States." Conservation Ecology **7**(1): 12.

CONCEPT MAP


Resource System
Cultural Resources
-Values
-Beliefs/Assumptions
-Traditions/Norms
Socio-Economic Resources
-Capital
-Labor
-Land
-Population
Land-use Decisions
Individual Actions
-Use of fertilizers, pesticides
-Livestock management
-Run-off control
-Soil conservation/erosion control
-Disposal of trash
Individual Actions
-Amount of water used
-Irrigation type (sprinkler versus drip)
-Time of day irrigating
-Crop selection (rainfed versus irrigated crops)
-Source of water (well, river, aqueduct, spring)
-Conservation activities (rain barrels, storage in rainy season, etc.)
-Purchase of water concessions
Collective Actions
-Reforestation, protection of forests (river borders and upper watershed)
-Purchase of concessions as a community
-Control of illegal logging in forest
-Erosion control
-Education programs
-Raising awareness
-Communicating with AyA, other government organzations
-Grant-seeking for water management
-Community organizations
Water Quality of Watershed
Water Quantity in Watershed
Ecological integrity and resilience of watershed

Methodology

I conducted research in three separate visits to the study site, in April, May, and December 2008. In April, I stayed for a week in the Río La Paz area with seven other students, a professor, and a research assistant from my Spring 2008 study abroad program in Atenas. I returned to the area with Gretchen Grebe[96] for three weeks in May, after our study abroad program had ended. Finally, I returned to the area for ten days in December with Gretchen and another friend to conduct final interviews. I statistically analyzed results from interviews conducted with farmers in April and May 2008, and qualitatively analyzed more in-depth interviews conducted with farmers in December 2008. Here I will describe each of these activities in greater detail.

April 2008

The Research Team

During the week of April 17-24, 2008, seven students[97] led by our research advisor Francisco Rodriguez and research assistant Mary Solie from the School for Field Studies' Center for Sustainable Development (*Centro Para Desarollo Sostenible)* in Atenas, Costa Rica[98] conducted initial fieldwork in the Río La Paz area. We stayed in a lodge in the Bajo Zúñiga area and spent our days conducting interviews and leading workshops with Río La Paz residents, attending meetings with pertinent institutions, taking GPS points for the creation of a GIS map of the microwatershed, and testing the water quality in the streams and river. During this week, we gained a familiarity with the area and began to learn the history of the area, the issues most strongly affecting the people, and the heterogeneity of the communities.

Rapid Rural Appraisal

We used the Rapid Rural Appraisal (RRA) methodology when conducting interviews and meetings with residents. According to the World Bank, there are five key components of an RRA: *participation, teamwork, flexibility, optimal ignorance, and triangulation.*[99] In our fieldwork, we encouraged the *participation* of a diverse group of Bajo Zúñiga farmers and residents in the management of the watershed through interviews and workshops. The tenet of *teamwork* deals with avoiding biases in research. In our study, we worked to avoid biases by interviewing residents with diverse occupations, including farmers, students, construction workers, *amas de casa,* and

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[96] Gretchen Grebe, Bates College, ggrebe@bates.edu

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Megan Hepner, Allegheny College
Ian Howes, University of Vermont
Emma Kravet, Weslyan University
Erin McMahon, Colombia University

[98] School for Field Studies. (Atenas, Costa Rica). from http://www.fieldstudies.org.

[99] World Bank. "Participatory Rural Appraisal." Retrieved 3/15/08, from http://www.worldbank.org/wbi/sourcebook/sba104.htm.

owners of tourism operations. Interviewees spanned a wide range of income levels, education levels, and ages. We practiced *flexibility* by interviewing community members at their convenience, usually in their homes, and allowing community members to take charge of discussions during the community workshops. We exercised *optimal ignorance* by trying to only gather information from the community that was pertinent to our research and collecting it in a time-efficient manner. Finally, we used *triangulation* whenever possible by consulting at least three people with varying perspectives when gathering qualitative information from community members.

Resident Interviews

We interviewed 50 residents (out of the total population of 3625) of the Río La Paz area during the week of April 17-April 24 2008 using a semi-structured interview we created as the basis for our conversations (See Appendix A for interview instrument). After some initial observations of the area during a one-day tour of farms and businesses, we developed interview questions about a wide variety of water-related issues in consultation with our advisor Francisco: water use and costs, irrigation practices, residents' familiarity with water-related institutions, knowledge about concessions for water, awareness of water contamination, and opinions about water conservation.

In pairs, we walked along main roads and side roads, knocking on doors of houses until someone answered. We then told them that we were university students from the Center for Sustainable Development in Atenas, we were doing a project on water and the river, and we would like to ask them some questions for about thirty minutes. If they agreed to talk to us, they usually invited us inside and we read them the questions on the interview sheet, writing down their answers as they spoke. We did not use tape recorders. We would ask all of our pre-determined questions and would often ask follow-up questions to keep the flow of the conversation.

We coded our survey results, compiled them into an Excel database, and analyzed them using means, medians, correlations, and ANOVA statistical analyses using the MiniTab software.

Potential Sources of Interview Error[100]

Many potential sources of error were introduced during our interviewing. First, sampling error exists since we did not interview enough people to draw any statistically significant conclusions from our data. For example, we interviewed 19 farmers (out of most likely a couple hundred farmers in the watershed) who irrigate their crops and found that the majority of them use sprinkler irrigation (**Picture 3)**, but this sample is not large enough to draw conclusions about the type of irrigation used by all farmers in the microwatershed. Coverage error was a problem, since our sampling population was misrepresentative of the overall population in many ways. Since we found our respondents by knocking on doors, we only sampled people who lived on easily-accessible main or side streets. We also interviewed different numbers of people living in each of the five communities, many more men than women, and more farmers than people with other occupations.

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[100] Dillman, D., and P Salant (1994). How to conduct your own survey. New York, John Wiley and Sons, Inc.

Measurement error could have easily arisen since eight different people conducted interviews, so the wording of the questions they asked could have varied slightly, impromptu follow-up questions differed, respondents could have reacted differently and volunteered different amounts of information depending on how comfortable they felt with the interviewer, and the interviewers' varying levels of Spanish inevitably resulted in some inaccuracies in translation and varying amounts of detail of responses recorded.

Despite these sources of error, the interviews provided a good opportunity to gain invaluable background knowledge about the residents in the study area, including the types of crops they grow, their uses of aqueduct and river water, their familiarity with institutions and water concessions, their views on protection of the river, and their cultural practices (including usually offering us delicious home-grown coffee or homemade desserts!).

Resident Workshops

As a part of the Rapid Rural Appraisal method, we held two participatory diagnostic workshops. The purpose of the workshops was to encourage dialogue among a diverse group of residents about problems with their river and water supply, to get a feel for the variation in residents' opinions surrounding the issues, to foster leadership among the residents, and to brainstorm solutions together. The first workshop was held on the night of April 21 in Bajo Zúñiga, attended mainly by residents of Bajo Zúñiga, and the second was held on the night of April 22 in Bajo La Paz, attended mainly by residents of the other four communities.

During the workshops, we first introduced ourselves and our purpose to the community members, and then broke up into smaller groups of four to eight people to discuss and visualize specific issues, including contamination of Río La Paz, water concessions, and the proposed diversion plan. One or two students facilitated each small group by asking leading questions and encouraging community members to brainstorm and organize their own ideas on paper. Some community members drew a map of how they remember that Río La Paz looked in the past, how it currently looks, and how they expected it to look in the future if they protected it better. Other community members drew a map of the watershed, or wrote lists of the major points discussed. After the small group work, we reconvened and each group presented their work to the others and discussed the issues with everyone.

Meetings with Institutions

We met with various institutions to gather necessary background information about watershed management in Costa Rica. We met with Álvaro Ugalde, co-founder of the Nectandra Institute[101] and major contributor to the design and financing of SINAC, Costa Rica's National Park System, who told us about the current state of water provisioning in Costa Rica and the conflicts between rural aqueduct organizations (ASADAS) and the governmental water institution (AyA). We also talked to various members of the Nectandra Institute in San Ramón, including Randal Varela, Luis Villa, and Evelyn. They shared their experiences as members of an NGO working to preserve intact patches of forest in Costa Rica and to empower rural communities to take control of the protection of their watersheds. We talked to Ronald Sánchez, head of the Programa

[101] Instituto Nectandra. (2008). Retrieved 5/10/09, from http://www.nectandra.org/.

para Desarollo Sostenible at the University of Costa Rica-San Ramón[102], who taught us how to sample for macroinvertebrates in streams and rivers to assess water quality. We also met with Zaida Mora at the AyA office in San Ramón[103], who spoke to us about the current state of the Río La Paz diversion plan from the government's perspective.

May 2008

The Research Team

For three weeks, from May 10-29 2008, Gretchen Grebe[104] and I stayed again at the lodge in Bajo Zúñiga to conduct further fieldwork. We administered surveys to 117 residents of the Río La Paz area, gathered census information on the five Río La Paz communities plus San Ramón and Palmares, met with pertinent institutions, and held one workshop for residents at the end of our stay with the help of our research advisor Francisco Rodriguez.

Resident Surveys

We handed out around 150 surveys to residents of the Río La Paz area, which they filled out themselves—while we waited to answer any questions—and handed back to us (See Appendix B for survey instrument). We decided to use a survey instrument for logistical reasons, to more easily gain responses from a large number of residents. Therefore, we had to write simple questions that could be answered by circling or writing a number, which limited the depth of the responses.

In some cases (no more than 15 surveys), residents said they had forgotten their glasses or had poor eyesight, so we read the surveys aloud and we recorded their answers on the survey forms as they dictated them. We administered the surveys in five different locations: On May 11, we collected 34 surveys from people attending a fair in La Esperanza complete with a soccer game, BINGO, tamales, and lemonade. On May 12, we collected 13 surveys from farmers dropping off their produce at the distribution center in Bajo Zúñiga or shoppers buying produce at the supermarket there (R&M). On May 17, we attended mass in La Paz and gathered 29 surveys from people as they were leaving mass. Before the mass, we asked the priest to announce our intentions of conducting a survey at the end of his service, which he graciously did. Also on May 17, we gathered 8 surveys from people leaving a night mass in Bajo Zúñiga. Finally, on May 18, we attended mass in Piedades Norte with the same priest who again announced our survey, enabling us to collect 32 surveys.

The survey allowed us to gather information on residents' socio-demographics, uses of water, land-use practices, their perceptions of how the river has changed in the last ten years, and their willingness to contribute to efforts of protecting the river. Results were coded, compiled into an Excel database, and analyzed statistically for means, medians, correlations, t-tests, chi-square tests, and ANOVA tests using the JMP software.

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[104] Gretchen Grebe, Bates College, ggrebe@bates.edu

Potential Sources of Survey Error

As with the interview, many potential sources of error arose in our surveying efforts, although we tried to reduce errors that we had discovered while interviewing in April. First, we surveyed 117 people throughout the study area, which reduced sampling error by providing a much larger sample size. Nonetheless, the statistical significance of tests for relationships between variables must be determined on a case-by-case basis.

Second, we attempted to minimize some forms of coverage error, although others arose instead. Except for Bajo La Paz, we surveyed a relatively equal number of people from each of the five communities, although some respondents reported living on the border of Piedades Norte and La Esperanza: 7 from Bajo La Paz, 23 from La Paz, 21 from Bajo Zúñiga, 31 from Piedades Norte, 12 from Piedades Norte/La Esperanza, and 18 from La Esperanza. We surveyed a relatively equal number of females and males: 49 females, 59 males, and 9 people who didn't report their gender. Reported education level of respondents was varied: we surveyed 50 people with a primary-level education, 25 with a secondary-level education, and 24 with a university-level education. One substantial form of coverage error could have arisen because we surveyed at masses, a fair, and the produce distribution center, so our sample population was limited to people attending these events. Although weekly mass and special fairs are all widely attended by community members, attendees may not be representative of the general population.

Third, we minimized measurement error from respondents' reactions to interviewers and the recording problems of interviewers by using written surveys instead of face-to-face interviews. However, respondents could have misunderstood the wording of certain questions or misinterpreted questions that asked respondents to rank their perceptions on a scale of 0-5. In addition, we experienced huge problems with respondents not completing all portions of the survey. We would often ask them to complete any sections they had not filled out, but many sections were still left blank.

Fourth, we encountered non-response error as we never got back some of the surveys we handed out (probably less than 5%), which could have led to a misrepresentative sample of the general population. For example, illiterate people were probably less likely to complete the survey by seeking help from someone else, and this sector of the population could have different land-use practices and opinions about water problems than the literate sector of the population.

Meetings with Institutions

We again met with Randal Varela from the Nectandra Institute in his office in San Ramón, who inspired us with the programs he started to empower rural communities to protect their aqueducts and watersheds, and the capacity of communities to self-organize and make positive changes. We met with Zaida Mora at the AyA office in San Ramón again, who spoke to us about the bureaucratic problems surrounding water management in Costa Rica. We also talked informally with the president of the Community Development organization of La Paz and her husband, who told us about how the organization runs, their goals for the future, and residents' anger over the diversion plan. We also met with a passionate, semi-retired water rights advocate, who spoke to us about the looming Central American Free Trade Agreement (CAFTA) and the implications for the privatization of water in Costa Rica.

Finally, we met with William Chavez, the engineer in charge of the Río La Paz diversion plan, in the AyA office in San Ramón. He gave us invaluable information on the diversion plan, including the motivations, alternatives, evaluation methods of alternatives, and the exact proposal. At the end of the meeting he presented us with a CD containing the diversion plans, evaluation of alternatives, and final recommendations.

Resident Workshop

Before we left Costa Rica in May, we held a final workshop in the Bajo Zúñiga communal space on May 26, 2008, to report on our findings from our research projects for the School for Field Studies and to brainstorm solutions to the water-related problems discovered by the residents and our research team. The meeting was attended by 12 residents of Bajo Zúñiga and Piedades Norte, 3 women and 9 men. First, our advisor Francisco Rodriguez asked the residents to rate the top three water-related problems they saw in their communities, and they shared their results. Next, we informally presented brief summaries of the results of the research papers written by the seven School for Field Studies students based on the research we conducted in April. Finally, we opened the discussion up to the residents, and one woman who is an active community organizer and advocate for water rights within the community dominated the discussion by relaying her frustrations with the communities' inability to effectively organize to confront water problems, the lack of communication between the government and the communities, and the resources she thought the communities needed to protect their watershed in the future. The meeting ended on a bit of a somber note as rain pounded against the metal roof and the meeting had focused on frustrations rather than solutions.

December 2008

The Research Team

From December 14-24, 2008, Gretchen Grebe, my friend Aaron Schwartz, and I stayed in the lodge in Bajo Zúñiga to conduct final interviews with farmers living in the five communities. While Gretchen worked with the NGO Nectandra in San Ramón each day, Aaron and I walked throughout the communities to talk to farmers.

Farmer Interviews

We interviewed 15 farmers in total using a 40-minute semi-structured interview (See Appendix C for interview instrument): 6 from Bajo La Paz/La Paz, 6 from Piedades Norte/Bajo Zúñiga, and 3 from La Esperanza. I had originally planned on interviewing 40 farmers, and performing statistical analyses on their responses—this would allow a more quantitative investigation of relationships between land-use decisions, perceptions of the environment, and social variables such as age, education level, and place of residence. However, I had to adjust my plan soon after I arrived in Bajo Zúñiga. Aaron and I spent the first couple of days walking aimlessly through the area trying unsuccessfully to locate farmers who were not busy at work—their schedules usually involve work in the fields from around 6am to 4pm. We ended up only finding farmers available to talk between 4pm and 6pm, either in their homes or finishing up work in their fields. This limited the total number of interviews that we could conduct, so I decided to switch my methodology from a statistical investigation to a qualitative anthropological one based on case studies.

Viewing each interview as a case study worked well, as our interviewees represented a diverse range of social characteristics and land-use practices.

We walked from door to door in each community, either together or separately, introducing ourselves as university students conducting a study on farming practices and asking where we could find farmers. When we found a farmer, we would ask if they would be willing to help us with a 40-minute interview to help us learn more about their farming techniques. If they agreed, we usually asked if we could record their interviews to remember what they said. We used digital tape recorders to record 10 of the 15 interviews, since two farmers said they didn't want us to record and we felt more comfortable not recording with three other farmers.

Interview Development

To create the interview instrument I used in December 2008 (Appendix C), I started by defining my interview population as farmers (who are all male in this region), since farmers make the majority of the day-to-day land-use decisions that affect the watershed. Of course women's knowledge and perceptions of the watershed are equally important and may affect many of the decisions made by farmers, but due to the narrow time scope of this project, I focused on farmers.

I then defined the specific socio-economic factors, cultural factors, and land-use decisions I wanted to focus on. First, I identified 3 land-use decisions made by farmers in the watershed that affect water quality, and 5 land-use decisions that affect water quantity:

Individual actions affecting water quality
1. Use of fertilizers and pest control methods
2. Run-off control (fertilizers, pesticides, and livestock manure) and soil conservation
3. Household trash disposal
Individual actions affecting water quantity
1. Type of irrigation
2. Time of day irrigation takes place
3. Crop selection
4. Amount of water used
5. Water conservation methods

Next, I developed a more specific list of actions within each of the eight decision categories in order to gather more information on specific land-use decisions affecting water quantity and quality. I formed my interview around these specific aspects:

Both: Source of water (Aqueduct, river, spring, or well)
Individual actions affecting water quality
1. Use of fertilizers and pest control methods A) Type (natural vs. chemical)
2. Run-off control (fertilizers, pesticides, and livestock manure) and soil conservation to prevent erosion

A) Type of irrigation (see below) B) Crop selection (see below) C) Construction of terraces or use of other techniques (mulching, reforesting land close to river, using agroforestry, etc) D) Livestock control (keeping them away from river, disposing of manure appropriately)
3. Waste disposal method A) Burning vs. River vs. Landfill B) Composting habits
Individual actions affecting water quantity
1. Type of irrigation A) Drip vs. Sprinkler vs. Gravity
2. Time of day irrigation takes place A) Night vs. Day
3. Crop selection A) Rainfed (coffee, sugarcane) vs. Irrigated (vegetables) B) Water needs of crops C) Soil conservation potential of crops
4. Amount of water used A) Monthly water use (from aqueduct bill or pumping estimates)
5. Water conservation methods A) Use of conservation techniques such as rain barrels, storage tank for rainy season water, etc.

Finally, I inquired about key aspects of the "human social system," including the social order and social institutions based on Pickett 1997, that are most relevant to my study. I have not included gender or occupation because I only interviewed male farmers.

Key Factors in Human Social System	
Social Order	1. Age
	2. Years spent farming
	3. Income
	4. Place of residence A) Community B) Placement along river (upstream to downstream)
Social Institutions	5. Education level (none, primary, secondary, university, post-grad)
	6. Community governance (level of participation in community groups on a scale of 1-3, such as school board, Community Development group, church organization, "water board," etc.)

After I wrote the interview, I practiced it by interviewing Don Zasada, a farmer at Caretaker farm near Williams College. He gave me some valuable insight and led me to modify many of my interview questions. When I arrived in Costa Rica, I went through the interview with a farmer I knew from May, asking him to correct any Spanish errors and provide some specific farming vocabulary used in the region. I corrected the errors and made copies of the interview in San Ramón.

Potential Sources of Interview Error

Since we did not statistically analyze the interview results, we did not have to worry as much about sampling and coverage errors. We interviewed farmers from each of the five communities, covering the entire microwatershed. We discovered that no clear spatial boundaries exist between the communities of Bajo La Paz and La Paz, and Bajo Zúñiga and Piedades Norte, so we focused on separating our interview locations as much as possible. The farmers represented a diverse range of social variables, including primary, secondary, and university education levels, ages 24 to 78, family sizes of 1 to 10 people, no participation to a high level of participation in community organizations, and from 5 years to a lifetime of farming experience.

We minimized measurement error by asking the same set of open-ended interview questions to all the farmers. However, some measurement error could still remain because we could not write down every word said by farmers who we did not digitally record, and some portions of the digital recordings proved unintelligible upon reviewing them. It is also possible that the farmers who we did not digitally record viewed the interview in a more casual manner, while recorded farmers perceived the interview more professionally. Indeed, we tended to get shorter, more matter-of-fact answers from non-recorded farmers and more detailed, thought-out answers from recorded farmers.

Literature Review

Recent water management literature focuses on the development of frameworks that support *sustainable water use*. Paralleling the famous definition of sustainable development from the 1987 World Commission on Environment and Development[105], Gleick defines sustainable water use as "the use of water that supports the ability of human society to endure and flourish into the indefinite future without undermining the integrity of the hydrological cycle or the ecological systems that depend on it".[106] To reach this goal, many authors have developed criteria for *sustainable* or *adaptive water management plans.* Their management plans take integrative approaches to solving water quantity and quality problems, combining social, ecological, and economic dimensions of sustainability and encouraging the use of social and hard sciences.[107] Here I summarize and paraphrase the important criteria in their management frameworks:

1. **Social sustainability.**
    a. **Establish a Basic Water Requirement for human health.** Requirements for human consumption and domestic use are tiny (about 20 cubic meters/person/year) and should be prioritized over all other water uses.[108]
    b. **Involve all actors in planning, decision-making, implementation, and monitoring.** Developing linkages between national, regional, and local governments, community residents, NGOs, and other organizations is crucial. Many authors have emphasized the need for bottom-up management in cooperation with top-down management, highlighting the special role of small-scale and community organizations.[109] Indigenous and traditional knowledge should be incorporated into management strategies.[110]
    c. **Ensure open, free, equitable information flow.** Use appropriate media and technology to share information on water quality and quantity

[105] United Nations General Assembly (1987). Report of the world commission on environment and development. 96th plenary meeting.
Their definition of sustainable development: "meeting the needs of the present without compromising the ability of future generations to meet their own needs."
[106] Gleick, P. H. (1998). "Water in Crisis: Paths to Sustainable Water Use." Ecological Applications **8**(3): 571-579.
[107] **For example**, Kammerbauer et al. 2001, Gleick 1998, Andrade 2007, Falkenmark and Folke 2002.
[108] Wallace, J. S., M. C. Acreman, et al. (2003). "The Sharing of Water between Society and Ecosystems: From Conflict to Catchment-Based Co-Management." Philosophical Transactions: Biological Sciences **358**(1440): 2011-2026.
Rijsberman, F. R. (2006). "Water scarcity: Fact or fiction?" Agricultural Water Management **80**(1-3): 5-22.
[109] **For example**: Lee, R. G. e. a. (1994). Integrating sustainable development and environmental vitality: a landscape ecology approach. Watershed Management: Balancing sustainability and environmental change. R. J. Naiman, Springer.; Freeman, R. E. and R. O. Ray (2001). "Landscape ecology practice by small scale river conservation groups." Landscape and Urban Planning **56**(3-4): 171-184.; Gleick, P. H. (1998). "Water in Crisis: Paths to Sustainable Water Use." Ecological Applications **8**(3): 571-579.
[110] **For example**: Nare, L., D. Love, et al. (2006). "Involvement of stakeholders in the water quality monitoring and surveillance system: The case of Mzingwane Catchment, Zimbabwe." Physics and Chemistry of the Earth, Parts A/B/C **31**(15-16): 707-712.

justly.[111] Planners should strive to prevent “information flow pathologies” that restrict people’s ability to adapt to ecological change, such as the social and physical distance between water managers and the actual communities they are managing and the often short time periods spent observing the water flows.[112]

2. **Ecological sustainability.**
   a. **Allocate water needs to the ecosystem.** A “Basic Water Requirement” for ecosystem health should be incorporated into management plans. This means a certain percentage of freshwater flows should be set aside for ecosystems.[113] For example, South Africa’s 1998 National Water Act establishes specific quantities of water for human health (25 L/day/person) and aquatic ecosystems (11-28% of median annual flow).[114] Water for ecosystems should be considered indirect water for humans.
   b. **Develop a holistic systems approach to freshwater ecosystems.** Land-water relationships, blue and green water connections, ground water and surface water connections, and upstream-downstream interactions should be investigated.[115] Ecological knowledge should be incorporated into organizational and institutional frameworks.[116]
3. **Economic sustainability.**
   a. **Place economic values on ecosystem goods and services, including water and watershed services.[117]** The Payments for Ecosystem Services (PES) program offers a model for paying individual land owners to protect forests and freshwater systems that provide the society with ecosystem goods and services.[118]
   b. **Internalize social costs.** Governments should create policies that offer incentives for private users of water resources to reduce or internalize the negative externalities that generate social costs, such as contamination and erosion.[119]
4. **Plan for variability and uncertainty**. In light of climate change, globalization, and other powerful forces, unpredictable events that stress water quality and

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[111] See note 105 above (Gleick 1998).
[112] Lee, R. G. e. a. (1994). Integrating sustainable development and environmental vitality: a landscape ecology approach. Watershed Management: Balancing sustainability and environmental change. R. J. Naiman, Springer.
[113] See note 105 above (Gleick 1998).
Richter, B. D. (In Press). "Ecologically Sustainable Water Management: Managing River Flows for Ecological Integrity." Ecological Applications.
[114] Falkenmark, M. (2003). "Freshwater as Shared between Society and Ecosystems: From Divided Approaches to Integrated Challenges." Philosophical Transactions: Biological Sciences **358**(1440): 2037-2049.
[115] Ibid.
[116] Folke, C. Ibid."Freshwater for Resilience: A Shift in Thinking." 2027-2036.
[117] Daily et al. 2000. Daily, G. C., * Tore Söderqvist, Sara Aniyar, Kenneth, P. D. Arrow, Paul R. Ehrlich, Carl Folke,, et al. (2000). "The value of nature and the nature of value." Science **289**(5478): 395-396.
[118] Jimenez, J. J., Francisco Alpizar Campos, Guillermo Navarro (2004). Experiencias de pago por servicios ambientales en cuencas en Costa Rica. Semana cientifica 2004. CATIE.
[119] Arrow et al. 1995. Arrow, K., B. Bolin, et al. (1995). "Economic growth, carrying capacity, and the environment." Ecological Economics **15**(2): 91-95.

quantity should be expected. Therefore, we should focus on increasing the *resilience* of freshwater systems in responding to stressors and the *adaptive* capacity of governments and communities.[120] One definition of ecosystem resilience is "the magnitude of disturbances that can be absorbed before a system centered on one locally stable equilibrium flips to another."[121] Using scientific methods to evaluate physical, chemical, and biological water parameters, including monitoring water quality, will be crucial in developing a sustainable management plan that is also resilient.[122]

As evidenced by this framework, the economic, sociopolitical, and ecological aspects of water management are well-represented in the literature. However, in order to uphold the integrity of the world's freshwater supply, I argue that communities all over the world must develop management approaches that also consider cultural dimensions.[123] In this study, I follow Davis et. al. and Toupal to narrow culture to shared traditions, values, and beliefs or assumptions that affect people's relationship to the natural environment.[124] It seems evident that the modern Western reliance on capitalism and science as its driving forces has left little room for consideration of people's traditions, values, and beliefs. Watershed management is a clear example of a scientific- and economically-minded discipline that mirrors the overarching Western model of progress.

For example, one theoretical framework for a more integrated type of management has been called adaptive co-management.[125] The framework uses the

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[120] **Resilience**: Folke, C. (2003). "Freshwater for Resilience: A Shift in Thinking." Philosophical Transactions: Biological Sciences **358**(1440): 2027-2036.; Marten, G. G. (1988). "Productivity, Stability, Sustainability, Equitability and Autonomy as Properties for Agroecosystem Assessment." Agricultural Systems **26**: 291-316.; Meyer, J. L. (1997). "Stream Health: Incorporating the Human Dimension to Advance Stream Ecology." Journal of the North American Benthological Society **16**(2): 439-447.

Adaptive management: Folke, C. (2003). "Freshwater for Resilience: A Shift in Thinking." Philosophical Transactions: Biological Sciences **358**(1440): 2027-2036.; Falkenmark, M. (2003). "Freshwater as Shared between Society and Ecosystems: From Divided Approaches to Integrated Challenges." Philosophical Transactions: Biological Sciences **358**(1440): 2037-2049.; Jury, W. A. and H. Vaux, Jr. (2005). "The Role of Science in Solving the World's Emerging Water Problems." Proceedings of the National Academy of Sciences of the United States of America **102**(44): 15715-15720.

[121] See note 118 above (Arrow, K., B. Bolin, et al. (1995). "Economic growth, carrying capacity, and the environment." Ecological Economics **15**(2): 91-95.

[122] Folke, C. (2003). "Freshwater for Resilience: A Shift in Thinking." Philosophical Transactions: Biological Sciences **358**(1440): 2027-2036.; Richter (ecologically sustainable water management). Richter, B. D. (In Press). "Ecologically Sustainable Water Management: Managing River Flows for Ecological Integrity." Ecological Applications.

[123] Andrade Pérez, Á. e. (2007). Aplicación del Enfoque Ecosistémico en Latinomérica. CEM - UICN. Bogotá, Colombia.

[124] Davis, S. A., Lawrence R. Shaffer, and Julie H. Edmister (2003). Sustainability of aquatic systems and the role of culture and values. Achieving sustainable freshwater systems. M. M. Holland, Elizabeth R. Blood, and Lawrence R. Shaffer.; Toupal, R. S. (2003). "Cultural landscapes as a methodology for understanding natural resource management impacts in the western United States." Conservation Ecology **7**(1): 12.

[125] See note 121 above (Folke 2003), See note 113 above (Falkenmark 2003).

watershed (also known as a catchment) as a management unit, allowing for integration of social and ecological systems. As Falkenmark states, "the basic challenge in a catchment can be summarized as managing the water flowing down a catchment while orchestrating for compatibility between land use/water, humans/ecosystems, upstream/downstream and present/future generations…the management has to incorporate four basic perspectives: the social, the ecological, the economic and the resource perspectives, respectively."[126] Within these four perspectives, culture has little room. While it seems that culture could be subsumed under the social perspective, Falkenmark emphasizes the participation of all stakeholders rather than examining cultural factors in the social dimension.

An even more striking absence of culture can be seen outside of the academic literature, in texts designed to aid watershed managers or policy developers. For example, the 2007 book *Integrated Watershed Management: Connecting People to their Land and Water*, lists three key principles of integrated watershed management: ecological—focusing on the ecology of watersheds, institutional—fostering dialogue among all stakeholders and giving more authority to local communities, and economic—improving market-based approaches and incentives.[127] Cultural considerations such as the valuation of water, traditional methods of water management used by watershed residents, and residents' perceptions of water quality and quantity problems do not appear in the publication.

Culture is also absent from the blossoming field of sustainability indicators and indices, which attempt to generate lists of easily-monitored criteria that will reveal how degraded or resilient a river or watershed is. The indices focus on ecological aspects of the watershed that can be monitored by scientific means, and may also include certain socio-economic indicators. For example, one typical index called the "wetland disturbance axis" includes indicators for land use and habitat fragmentation (average buffer width, surrounding land use ratios, and distance of nearest fragment), hydrology (type of water source, extent of hydrological modification), and water quality (conductivity, level of contamination).[128] A simple, commonly-used index is Falkenmark's "water stress index" that indicates a country's water stress based on the renewable water supply per capita—for example, less than 500 cubic meters/person/year is considered absolute water scarcity.[129] A more complex index that attempts to determine water scarcity and access of communities, regions, or countries, the Water Poverty Index (WPI) considers resources, access, capacity, use, and environment indicators.[130] Cultural considerations are absent from this index that is gaining in popularity for water planners.

Nonetheless, some academics focused on water issues have identified culture as an important consideration in water management. For example, Davis et al. acknowledge the necessity of cultural change in the formation of sustainable water management plans. They discuss three levels of culture—artifacts, values, and basic assumptions—and the

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[126] See note 113 above (Falkenmark 2003).

[127] Gregersen, H. M., P.F. Ffolliott, and K.N. Brooks (2008). Integrated watershed management: connecting people to their land and water, CABI.

[129] Falkenmark 1989, cited in:
Rijsberman, F. R. (2006). "Water scarcity: Fact or fiction?" Agricultural Water Management **80**(1-3): 5-22.

[130] Lawrence, P., Jeremy Meigh and Caroline Sullivan (2002). The water poverty index: an international comparison, Keele University.

characteristics of cultural change.[131] Goulder and Kennedy start from the assumption that in order to make choices about how to use their natural environment, people need to know what services can be provided—in the realm of fact—and decide what those services are worth—in the realm of culture. They examine the philosophical foundations of valuing the environment, including anthropocentric perspectives and intrinsic rights.[132]

It is clear that the academic and watershed planning literature is heavily scientific and economic. I argue that culture is important partly because it affects people's reception of new knowledge, including scientific information or government policies, and their willingness and ability to change.[133] Although humans are more adaptive than other species to change, they are constrained by social and cultural processes.[134] For example, even if free, equitable information flow is accomplished (criteria 1c), people's ideological beliefs or assumptions may restrict them from responding to new information: if someone believes that water is a renewable resource, they may dismiss as irrelevant a graph showing dropping water levels in their nearby river for the last 10 years.[135] If these cultural responses are realistic, then planning for sustainability will require much more attention to culture in the water management process.

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[131] See note 123 above (Davis et al.)
[132] Goulder, L. H. a. D. K. (1997). Valuing ecosystem services: philosphical bases and empirical methods. Nature's Services: Societal dependence on natural ecosystems. G. C. Daily, Island Press.
[133] See note 123 above (Davis et al.)
[134] See note 111 above (Lee 1992)
[135] Ibid.

Results and Discussion, Part 1: Interview and Survey Data

April 2008 Interviews[136]

We interviewed fifty residents of the Río La Paz watershed during the week of April 17-April 24, 2008 using a survey we created as the basis for our conversations (Appendix A). We used the survey to obtain information on basic demographics, water use and costs, and irrigation practices, and to gauge residents' familiarity with water-related institutions, knowledge about concessions for water, awareness of water contamination, and opinions about water conservation. We also held two participatory diagnostic workshops using Rapid Rural Appraisal methodology, and met with various people and organizations (see Methodology section for details).

Interviews with Watershed Residents

We interviewed fifty people, 34 men and 16 women, including farmers, construction workers, housewives, students, and store owners (See Appendix A for interview instrument). 8% had no formal education, 71% attended primary school, 16% attended secondary school, and 4% attended a university. The average age was 47, the youngest being 16 and the oldest being 75. About one-third of people interviewed said they participate in an organization dealing with water issues, including the Community Development organization (*Desarollo Comunal*), ASADAS, Association for Sustainable Development (*Asociación de Desarollo Sostenible*), AyA, or a Water Board (*junta de agua)*.

Sources of drinking water

Almost half of people interviewed get their drinking water supplied by AyA (table 1). AyA gets the water for the aqueduct from Río La Paz springs in the mountains; the water is treated with chlorine and then piped throughout the communities. Most of the rest get their drinking water directly from a spring of Río La Paz (**Table 1**).

Table 1. Sources of drinking water of interviewees

Where do you get your drinking water? (49 people)	**Number of people**
Aqueduct (AyA)	23
Spring of Rio La Paz	19
Downstream Rio La Paz	4
Well	3

Sources of irrigation water

Of the twenty people interviewed that irrigate crops, 80% get their water directly Río La Paz, either from a spring or downstream (**Table 2**).

[136] **This section from:**
Gulley, A. (2008). "Working Towards Adapative Co-management of Freshwater Systems: A Case Study from the Río La Paz Watershed, Costa Rica." School for Field Studies Directed Research paper.

Table 2. Sources of irrigation water

Where do you get your irrigation water? (20 people)	Number of farmers
Aqueduct (AyA)	2
Spring of Rio La Paz	7
Downstream Rio La Paz	9
Another river	1
Well	1

Water problems

Four main questions assessed residents' awareness of water issues in the Río La Paz area: Are there problems with water in the area? Is there contamination in the river? Do you know about the diversion plan? Do you think there is less water in the river now than in the past?

62% of respondents said there were problems with water in the Río La Paz area, while 38% said there were no problems. When asked what these problems were, the most frequently cited answer was contamination of the river, followed by water scarcity (**Table 2**). When asked directly if there is contamination in Río La Paz or another stream in the watershed, 57% of the interviewees said there is contamination and 35% said there is no contamination. The most frequently cited source of contamination was trash from households, followed by agricultural run-off or chemicals (**Table 3**). 66% of interviewees said they knew about the Río La Paz diversion plan. Finally, when asked if there was a difference in the amount of water available in the river compared to the past, 77% said yes and 23% said no.

Table 2. Problems with water cited by interviewees

What are the water problems?	Number of people:
Contamination	18
Trash thrown in the river	5
Other types of contamination (agricultural, trapiches, livestock)	6
Water shortage	9
Diversion Plan	5
Deforestation	5
Chlorine in tap water	2
Need to improve consciousness	2
Endangered aquatic life	1
Climate change	1
Distribution	1
Water is too cheap	1

Table 3. Sources of contamination in Río La Paz cited by respondents

What are the most important sources of contamination in Río La Paz?	Number of people:
Trash from households	12
Agrochemicals/agriculture	8
Pig farms *(chancheras)*	8
Milk factory (*lechería)*	6
Livestock *(Ganado)*	2
Trapiche	2
Trash from outsiders	1

There is no statistically significant correlation between education level, occupation, salary, or source of water and answers to the previous questions. However, there is a statistically significant correlation between gender and age and answering affirmatively to the questions: male respondents and older respondents were more likely to say that there are problems with water, that the river is contaminated, that they know about the diversion plan, and that there is less water now than in the past.

There are a couple of statistically significant correlations between community of residence (Bajo La Paz, La Paz, Bajo Zúñiga, La Esperanza, Piedades) and answers to the previous four questions. When La Esperanza—the most downstream community—is compared with the other four communities combined, people in La Esperanza are more likely than the other communities to answer negatively to the questions—that there are no problems with water, that the river is not contaminated, that they do not know about the diversion plan, and that there is not less water now than in the past. When all communities are considered separately, there is a trend that people in Bajo La Paz—the most upstream community—are more likely to answer affirmatively to the questions.

Water Conservation and Protection

Almost half (49%) of respondents said they knew one or more methods to avoid water contamination; the most frequently cited method was not throwing trash into the river. When asked if they knew any methods of water or watershed conservation, three respondents cited avoiding cutting trees or reforestation and three respondents said that education or a change in consciousness was necessary (**Table 4**). One person said that water quality testing could help water conservation.

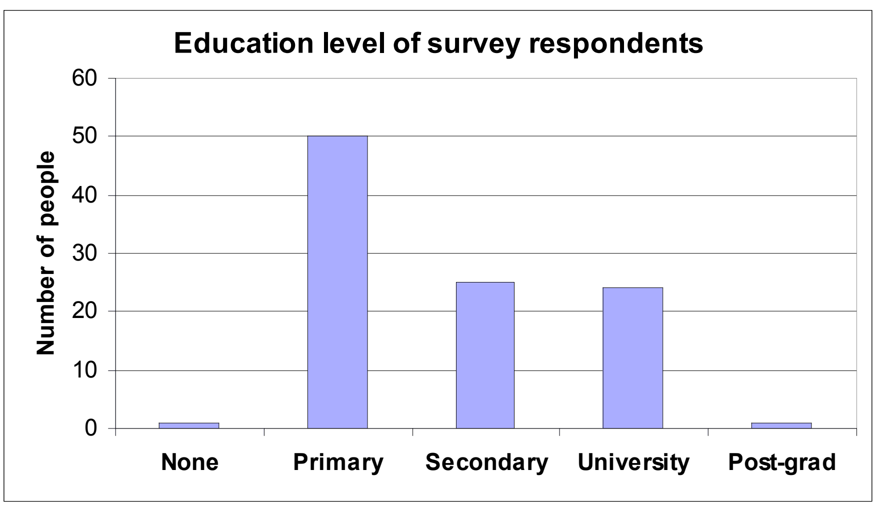
Table 4. Water conservation methods cited by respondents

Do you know or practice any water conservation methods?	**Number of people:**
Don't cut trees/plant trees	3
Education/consciousness	3
Don't throw garbage	2
Go organic	1
Do water quality testing	1
Drip irrigation	1
Dispose trash in San Ramon	1

May 2008 Survey

We surveyed 112 watershed residents (See Appendix B for survey instrument). The average age was 40 and the average number of family members was 5. The average monthly family income was 185,566 colones (about $4282/year), extremely close to the national average income ($4590/year in 2005).[137] We surveyed about the same number of men and women (59 men, 49 women, 9 unidentified). Most respondents had a primary-level education (Graph 1).

Graph 1.



Water Use. The vast majority of residents use water from the aqueduct to drink and wash. However, 7% of respondents get their drinking water only a well and 6% get their drinking water from the river. Residents pay on average 3849 colones/month for their aqueduct water (about $7/month). Of the 39 people that reported using water to irrigate, 44% said they get their water from the aqueduct, 59% from the river or stream, and 5% from a well. Most of the

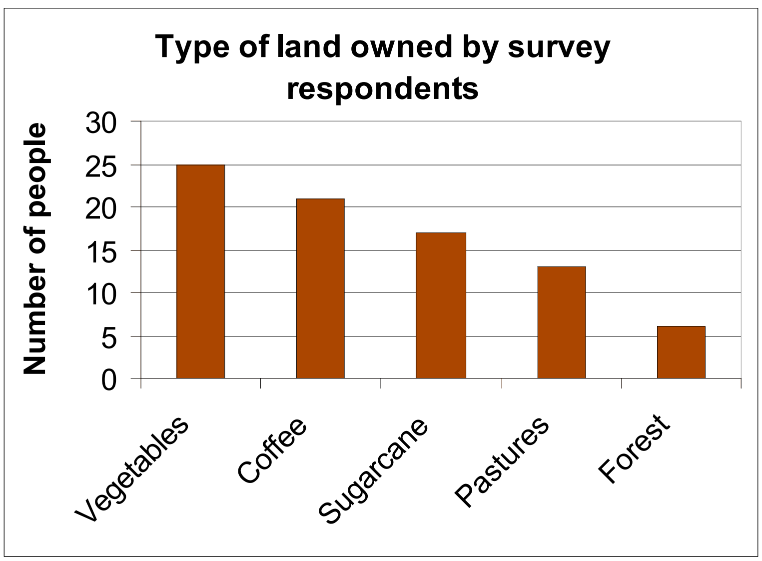
[137] UNICEF. (2007). "Draft country programme document: Costa Rica." Retrieved 5/10/09, from http://www.unicef.org/about/execboard/files/07-PL45-Costa_Rica.pdf.

23 people that use water from the river or a stream to irrigate do not pay for the use of this water.

Sewage disposal. The vast majority of residents reported using septic tanks for their sewage. However, 4 respondents reported using a hole dug in the ground for their sewage, and 3 said they used the river for sewage disposal.

Land use. Watershed residents use the land for crops, pastures, and forests (**Graph 2.**) The farmers in the watershed are small-scale, growing an average of 2.7 hectares (3.9 *manzanas*) each. Only six people claimed they own forested land, and the average area of this land is only 1.0 *manzana*, less than one hectare. Pastures take up the most land, averaging 3.0 *manzanas* per pasture owner, followed by sugarcane that averages 2.3 *manzanas* per farmer, while the least amount of land is used for coffee, .93 *manzanas* per farmer. Only 2 people said they owned pigs, with 3 pigs each. Cows or cattle were reportedly owned by 19 people, with an average of 9 cows each.

Graph 2.



Most farmers only irrigate vegetables, although 2 irrigate coffee and 4 irrigate pastures for livestock (**Table 4.5**). The vast majority reported using fertilizers on coffee, sugarcane, and vegetable crops, but not pastures. Slightly fewer people reported using pesticides on coffee, sugarcane, and vegetable crops.

Table 4.5. Number of people responding to Yes/No land-use questions on May 2008 survey.

Land Use		Irrigate?	Fertilizers?	Pesticides?
Coffee	Yes	4	18	13
	No	16	1	6
Sugarcane	Yes	0	14	12
	No	16	2	4
Vegetables	Yes	18	20	18
	No	3	3	4
Pastures	Yes	4	4	2
	No	8	7	10
Forests	Yes	0	0	0
	No	4	4	4

Changes in the Watershed. Watershed residents responded to the question "With respect to the following factors how have things changed in the last 10 years?" as follows (**Table 5).** While residents thought much change had occurred in general, we did not ask *how* things had changed, so the question was relatively useless. For example, residents could have thought that water levels had actually increased a lot in the past 10 years and still registered a high number. Nonetheless, it is interesting that "willingness to do something and protect the water" ranked the lowest, potentially indicating that people think others do not want to help protect the river, their frustration that more people don't or more isn't being done, or their desire for more people to join the effort. For example, one person wrote on the survey "we need to do more." Since the "quantity of people using the waters of Río La Paz" ranked the highest, the population in general or the quantity of farmers must have substantially increased in the recent past (it is unlikely that people thought the number of users had decreased since the population is growing[138]).

Table 5. Survey responses to "With respect to the following factors how have things changed in the last 10 years?"

Factor	Average number (0 indicates no change and 5 indicates a lot of change)
Quantity of water in Río La Paz	4.51
Quantity of rain	4.07
Availability of wood to cook with	4.23
Dirtiness in streams	4.26
Dirtiness in Río La Paz	4.20
Quantity of people using the waters of Río La Paz	4.89
Willingness to do something and protect the water	3.96

Willingness to participate. The surveys indicated a high level of willingness to participate in water-related issues (**Table 6**). In addition to these questions, half of respondents said they were interested in joining a group about water issues early in the survey (32% said "yes" and 18% said "maybe"). The responses to these questions indicates a potential for strong

[138] Caja Costarricense de Seguro Social (2006-2007). Census. Sector: Los Angeles. San Ramon, Costa Rica.; Caja Costarricense de Seguro Social (2008). Census. Sector: Los Angeles. San Ramon, Costa Rica.

community participation and adaptive co-management of the watershed. The question about concessions scored the lowest, suggesting that more education on the concession process is needed in the communities and/or the national concessions model needs to be reformed to be more easily completed by ordinary, small-scale users.

Table 6. Survey responses to questions about the willingness to participate in water issues

Action	**Average number (0 represents you don't want to do anything and 5 indicates that you would participate a lot in seeing how to resolve the problem)**
In the future I will be ready to form part of groups about water issues	4.21
I will obtain a concession to continue using the water I need	4.19
I will support those who protect water in the community	4.84

December 2008 Interviews

Fifteen farmers from the five RLP communities were interviewed in December about their land-use practices, irrigation practices, agricultural traditions, and perceptions of the watershed (See Appendix C for interview instrument). A summary of the results obtained is described here.

Social Variables

The farmers represented a diverse range of social variables, including community of residence, education level, age range, family size, level of participation in community organizations, and years of farming experience.

We interviewed 6 farmers from Bajo La Paz/La Paz, 6 from Piedades Norte/Bajo Zúñiga, and 3 from La Esperanza. The average age of the farmers was 48 (**Figure A**). Ten of the farmers have been farming their whole lives, four have farmed for 15-20 years, and one has farmed for five years. All the farmers had completed some schooling, most having completed primary school (**Figure B).** Family sizes ranged from one to ten members, with a median of four members. Farmers participated in an average of one community organization (**Figure C).**

Figure A.

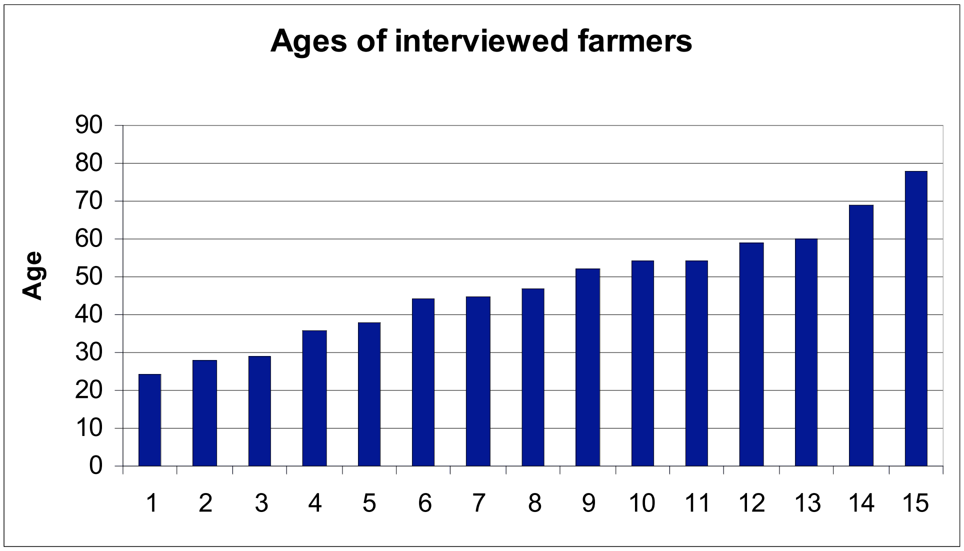


Figure B.

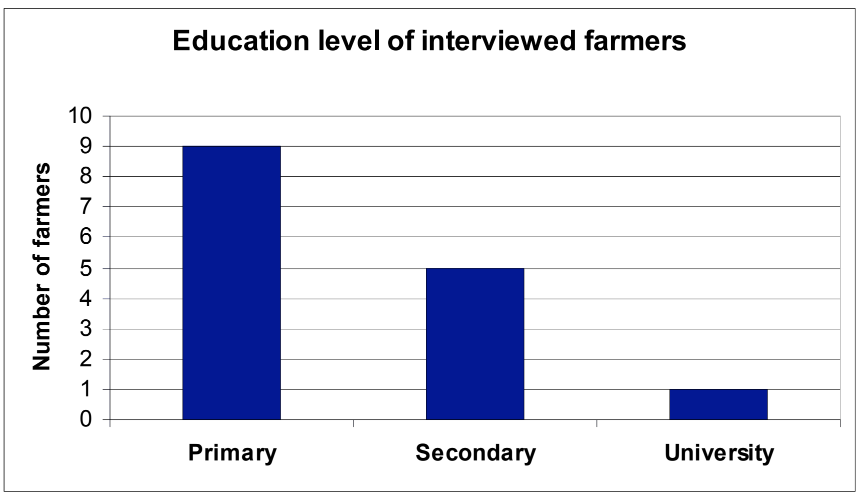
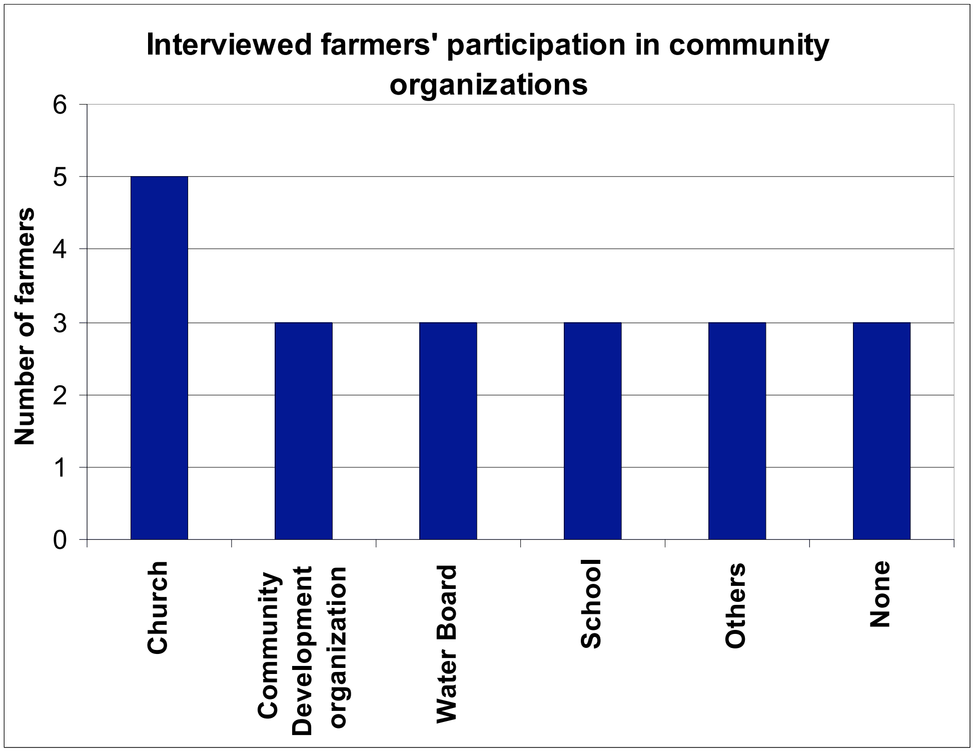


Figure C.

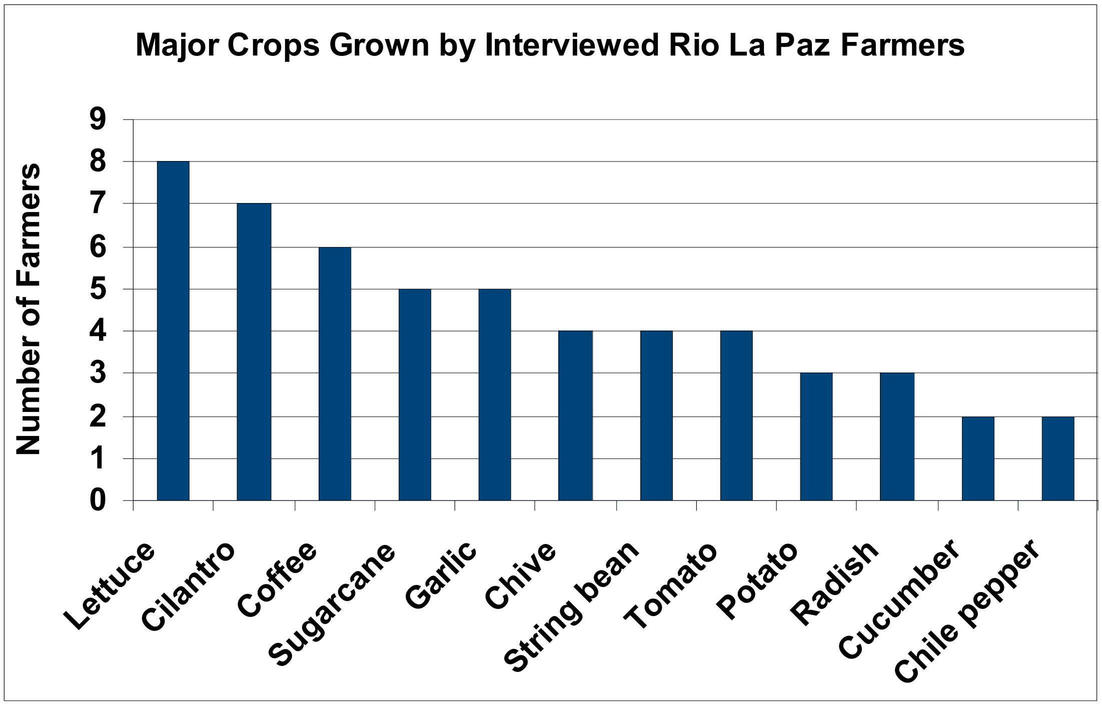


Land-Use Practices (Questions 1-8)

Question 1: What do you grow? How many *manzanas* of each crop do you have?

The interviewed farmers grow a wide variety of crops (**Figure 1, Picture 5**). Three farmers grow exclusively sugarcane, one exclusively coffee, and five exclusively vegetables. The other six farmers grow multiple types. One additional farmer grows only a small amount of fruit—blackberries, passion fruit, and *granadilla.*

Figure 1. Crops grown by two or more interviewed farmers in the RLP watershed.

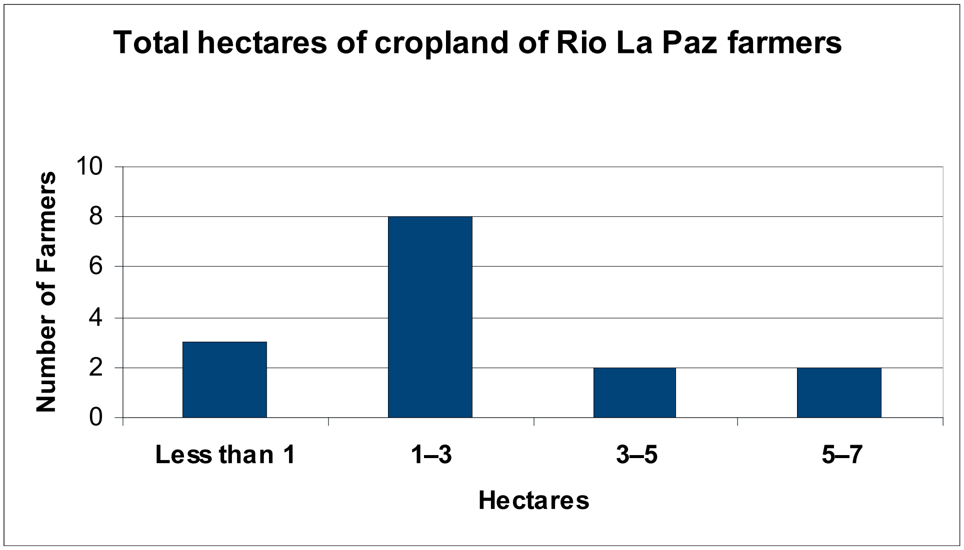


Picture 5. Gilberto showing us his varieties of lettuce

The farmers in the RLP watershed are very small-scale farmers: the average amount of cropland in cultivation by each farmer is 2.6 hectares, converted from *manzanas* (**Figure 2**).

On average, the greatest amount of land is used to grow sugarcane (an average of 3.2 hectares per farmer), followed by coffee (1.6 hectares) and finally vegetables (1.4 hectares).

Figure 2. Total hectares of cropland in cultivation by interviewed RLP farmers

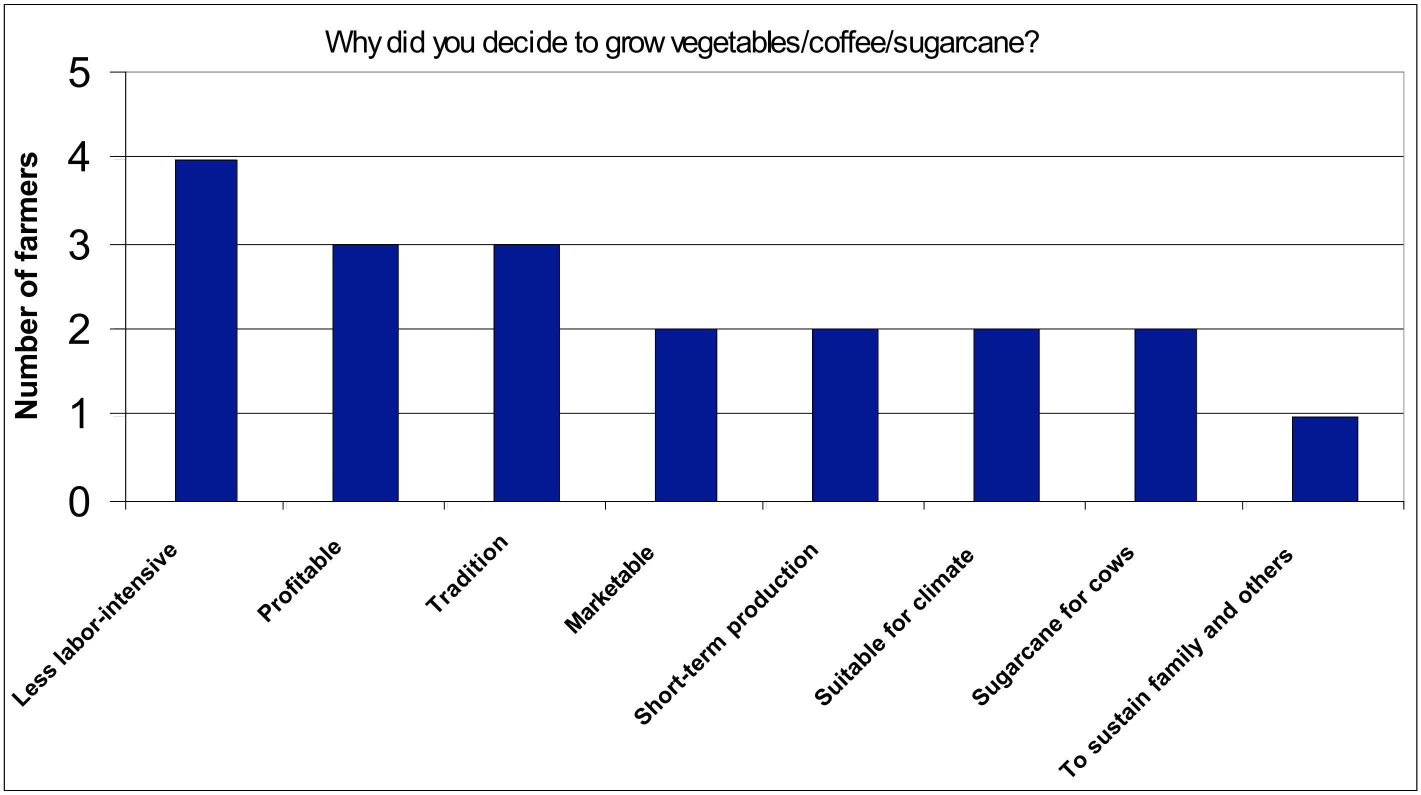


Question 2. Why did you decide to grow [vegetables/sugarcane/coffee]? Are there any advantages to growing these crops? If yes, what? Are there any disadvantages to growing these crops? If yes, what? Have you ever considered growing other crops? Why or why not?

The amount of water needed to irrigate varies widely depending on the type of crop. Furthermore, rainfed crops such as sugarcane and potentially coffee do not need to be irrigated at all. Crop selection also alters the amount of harmful pesticides and fertilizers needed.

Farmers mostly cited economic or logistical reasons for their crop selection—they said their crops of choice are more profitable, less time-consuming, more marketable, or easier to grow than others (**Figure 3**). Five vegetable farmers cited crop losses from insect or fungus plagues and adverse weather conditions as a disadvantage to growing vegetables. The farmers explained that they experience high crop losses due to the high amount of precipitation, cold fronts, and windy conditions. A sugarcane farmer highlighted this point when he said an advantage to growing cane was enjoying less plagues than vegetables. Two vegetable farmers cited an additional disadvantage to growing veggies: the necessity of using chemicals; A sugarcane farmer said an advantage of growing cane was being able to use less chemicals. In contrast, sugarcane farmers said the disadvantages to growing sugarcane were the profitability and the amount of labor required. Vegetable farmers cited profitability and amount of labor required as advantages to growing veggies, as well as market availability. The farmer growing exclusively coffee did not state any advantages but said disadvantages included the profitability, market availability, and amount of labor required. Although not many farmers growing only coffee still exist in the RLP area, the area used to be dominated by coffee—seven out of the fifteen interviewed farmers used to grow coffee and six more still grow a small amount of coffee.

Figure 3. Reasons cited by interviewed RLP farmers for growing their crop(s)



However, three farmers also cited one cultural aspect—tradition—as being important in determining crop selection. The first, a vegetable farmer, stated, "it is the manner in which we live." The second, a sugarcane and coffee farmer, said he has always lived by cane and coffee and it is his family's sustenance. The third, a coffee farmer, said he planted the coffee many years ago and it would cost too much to switch crops, which seems like an economic as well as cultural response.

Question 3. Do you fertilize your crops?
***If yes*: How? Where do you get them? What crops do you use them on? Why do you fertilize in this way? Are there any advantages to fertilizing in this way? If yes, what? Are there any disadvantages to fertilizing in this way? If yes, what?**
***If yes or no*: Have you ever considered fertilizing by [using chemicals/a natural method]? Why or why not?**

The farmers I interviewed use a wide variety of fertilizers, including chemical and organic fertilizers (**Figure 5**). Fourteen use natural methods, although all but one use chemical fertilizers as well (**Figure 4**). Half of these farmers insisted they use more organic fertilizer or manure than chemicals. Only one farmer uses only chemicals. The organic fertilizers make creative use of materials that would otherwise be considered wastes, and many are produced in the area. Although they are safer for humans and most likely healthier for the aquatic ecosystem, natural fertilizers like animal manures can still contaminate the river due to their high concentrations of nitrogen. The most common organic or natural fertilization method was chicken manure, which most of the farmers purchase from the chicken farm in La Esperanza that raises 70,000 meat chickens for sale to PolloRey, which distributes the meat throughout the country.

Figure 4. Numbers of interviewed farmers using chemical and organic fertilization methods in RLP area

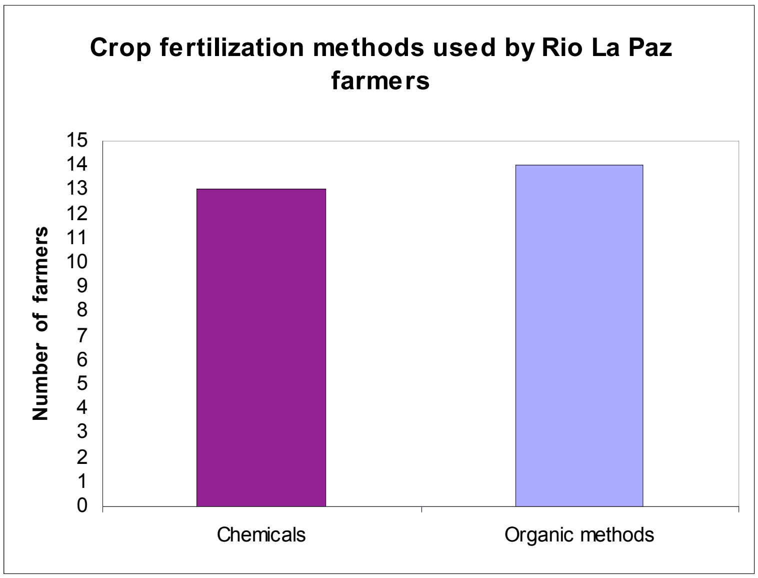
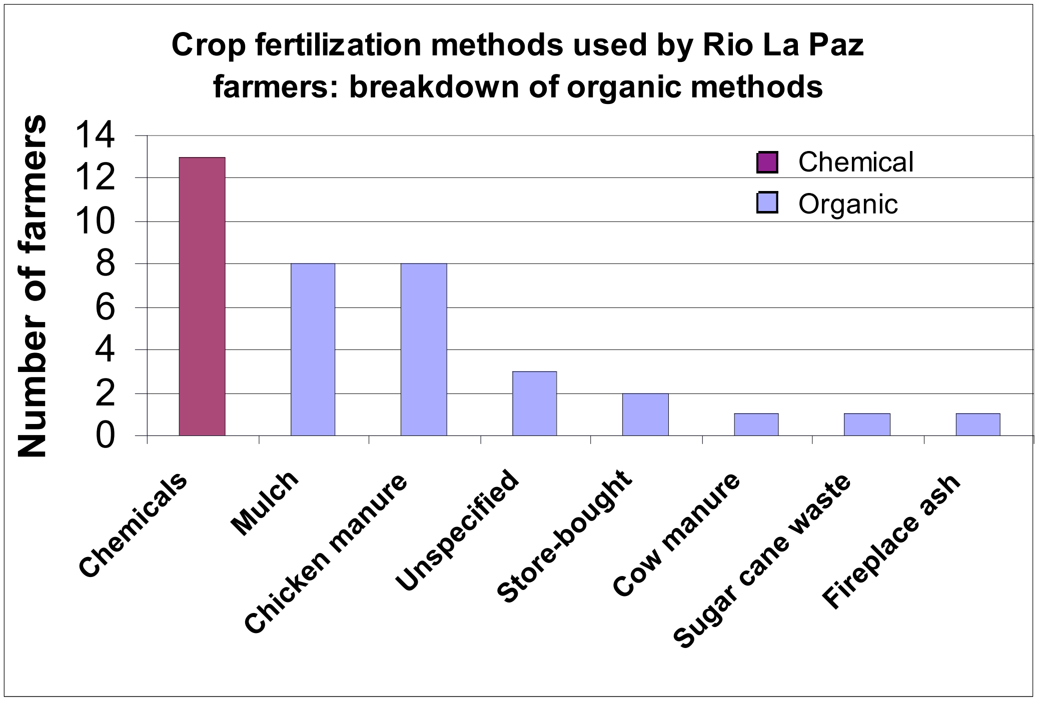
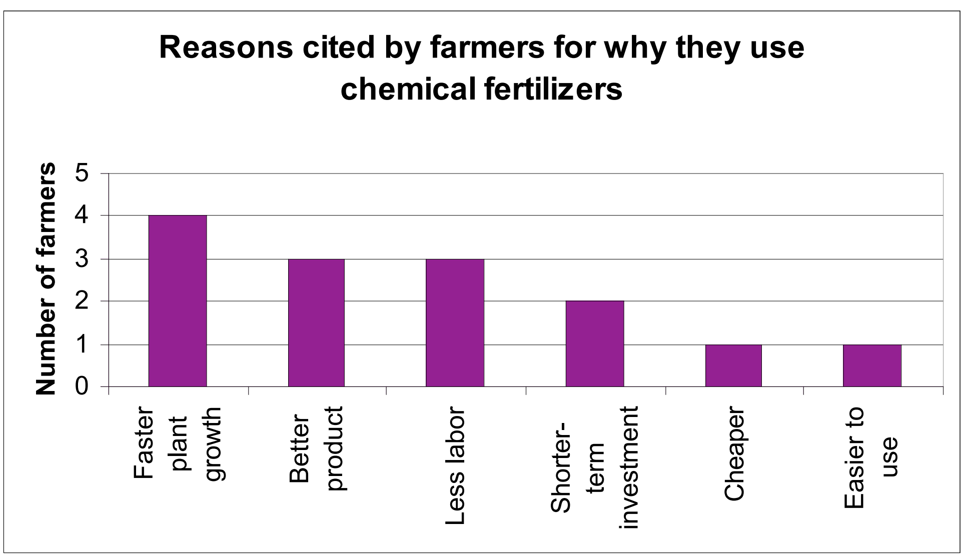


Figure 5. Types of fertilizers used by RLP farmers, including a break-down of all the organic/natural methods.



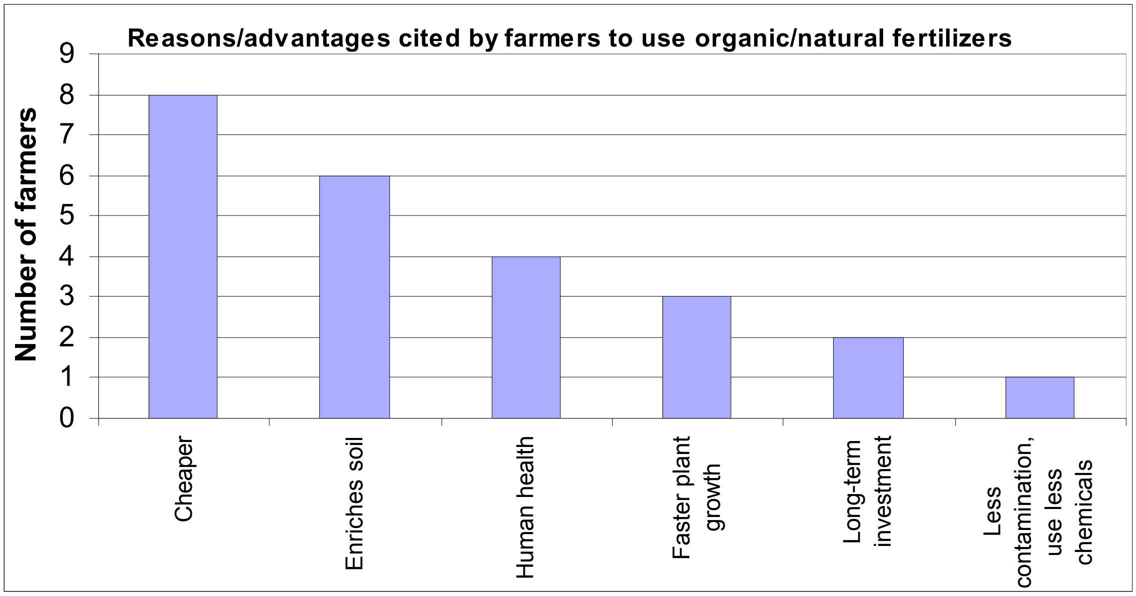
When farmers explained why they use *chemical* fertilizers, they only cited economic reasons, generally saying it helped the plants grow faster or led to a higher-quality product (**Figure 6**).

Figure 6.



Most farmers also gave economic responses when queried about why they use *natural* fertilizers (**Figure 7**). However, non-economic reasons were also provided. Four farmers mentioned human health as either a disadvantage of using chemical fertilizers or an advantage of using organic fertilizers. As a disadvantage to chemicals, another farmer stated bluntly that chemical fertilizers contaminate.

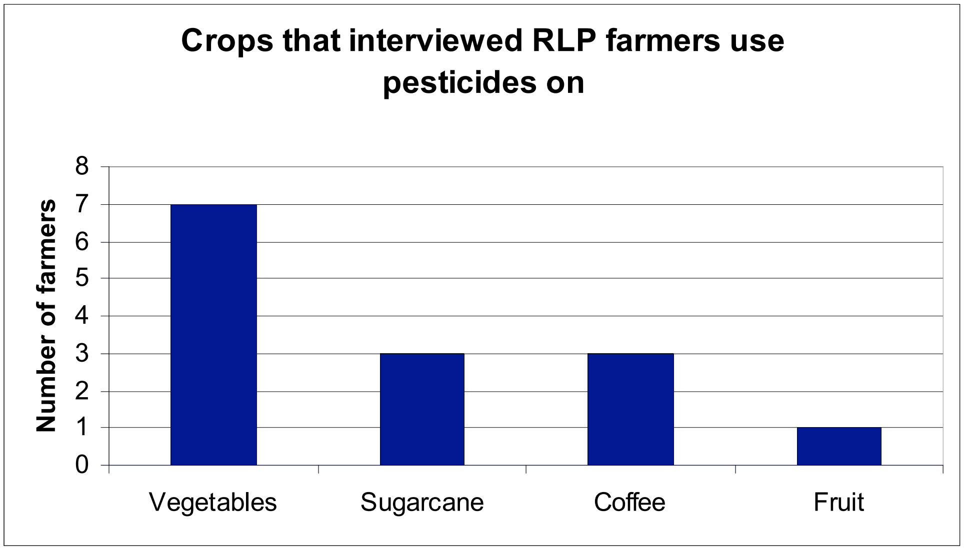
Figure 7.



Question 4. Do you use any pest control methods?
***If yes*: Could you describe them (e.g. pesticides, insecticides, fungicides, diversifying crops, mulching)? Where do you get them? What crops do you use them for? Are there any other advantages to using these pest control methods? Are there any disadvantages?**
***If yes/no*: Have you ever considered using [chemical pesticides/using natural pest control methods such as diversifying crops, mulching]?**

Farmers used pest control methods more frequently on vegetable crops than other crops (**Figure 8),** supporting their previous statements that a disadvantage to growing veggies was the prevalence of insect or fungal plagues, while an advantage to growing sugarcane was a lack of plagues.

Figure 8.



Unlike their fertilization methods, more farmers use chemical pesticides than natural pest control methods (**Figure 9**), although a variety of creative natural pest control methods are in use that do not endanger the riparian ecosystem or human health (**Figure 10).** For example, three farmers use large sheets of sticky insect paper distributed throughout their fields that attract insects with their yellow color and then capture them. Two farmers use living fences or barriers, such as *caña india,* that attract the insects away from the crops.

Figure 9.

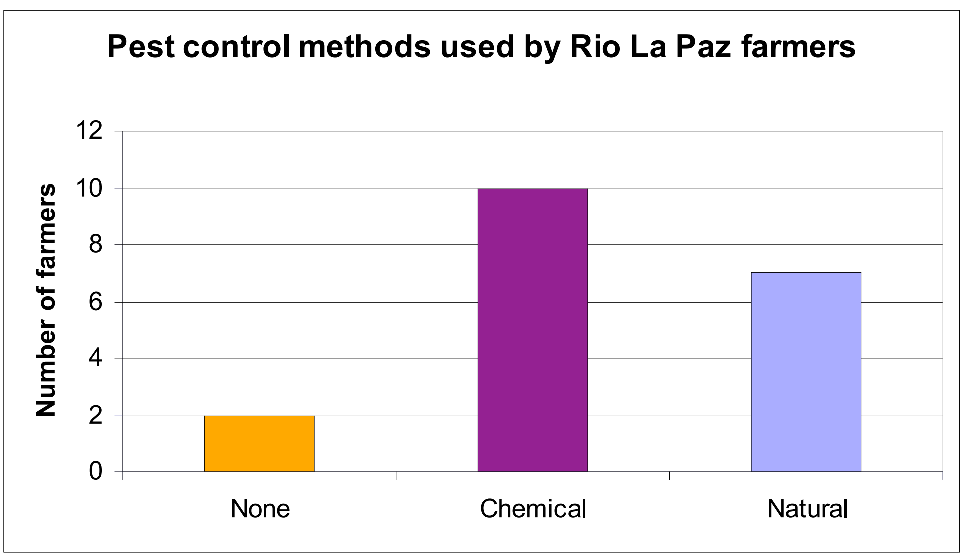
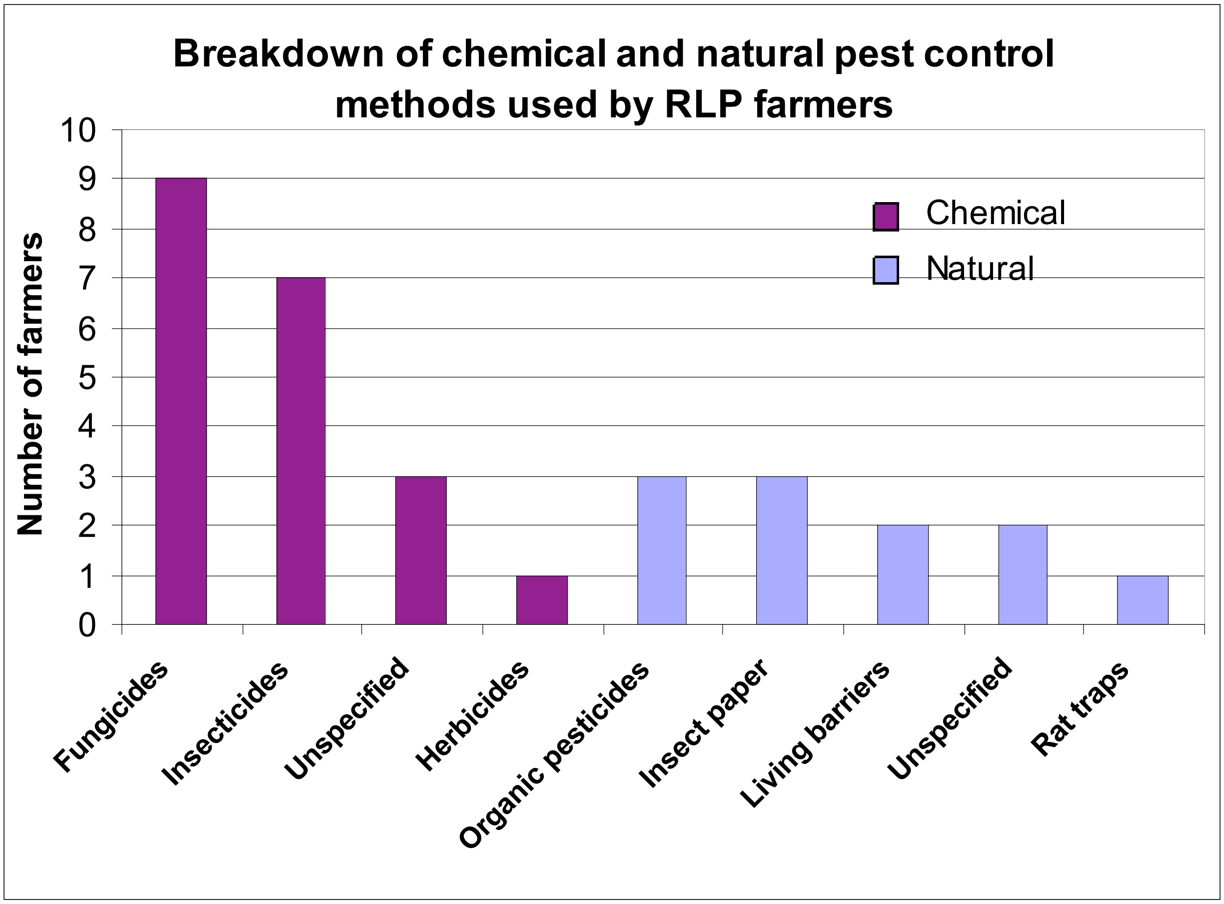


Figure 10.



Various economic reasons were given for using chemical pesticides, and one farmer said he has worked with chemicals for many years and isn't used to natural methods (Tradition, **Figure 11)**. Similar to organic fertilizers, many farmers said natural pest control methods were cheaper than chemicals (**Figure 13**). Again, many farmers using natural pest control cited non-economic reasons or advantages, including concerns about human health and environmental contamination (**Figures 12 and 13).**

Figure 11.

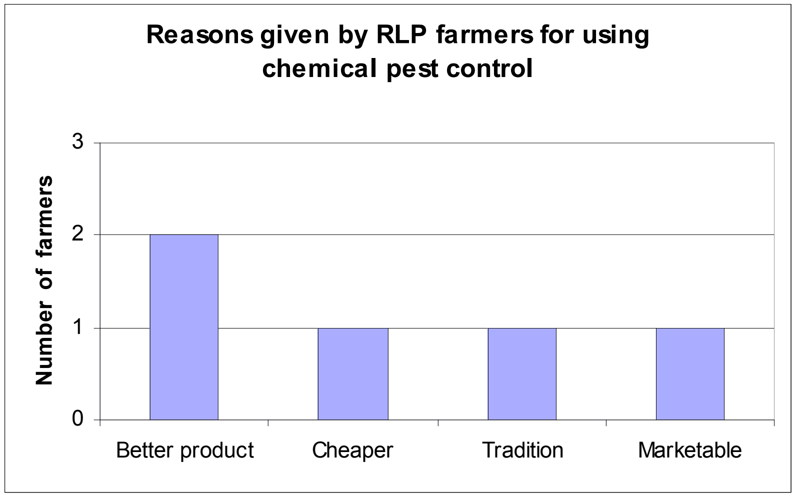


Figure 12.

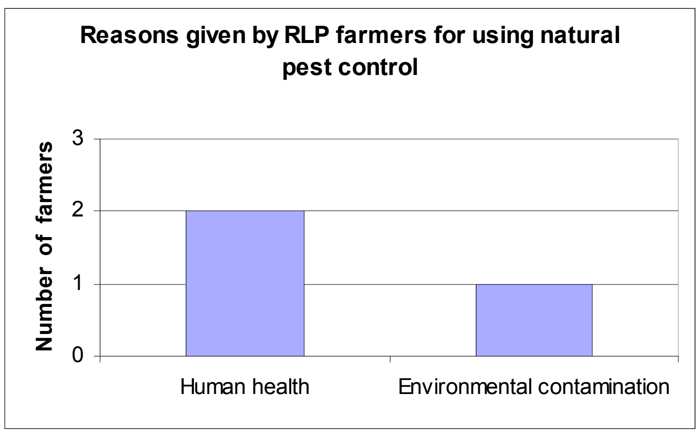
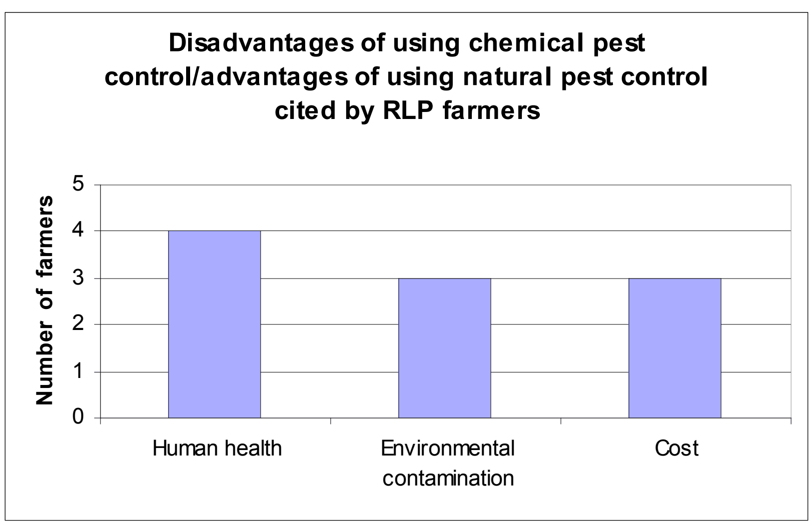


Figure 13.



Question 5. Do you use terracing?
***If yes:* Why do you use terracing? Are there any other advantages to terracing? Are there any disadvantages to terracing?**
***If no:* Have you ever considered terracing? Why or why not?**

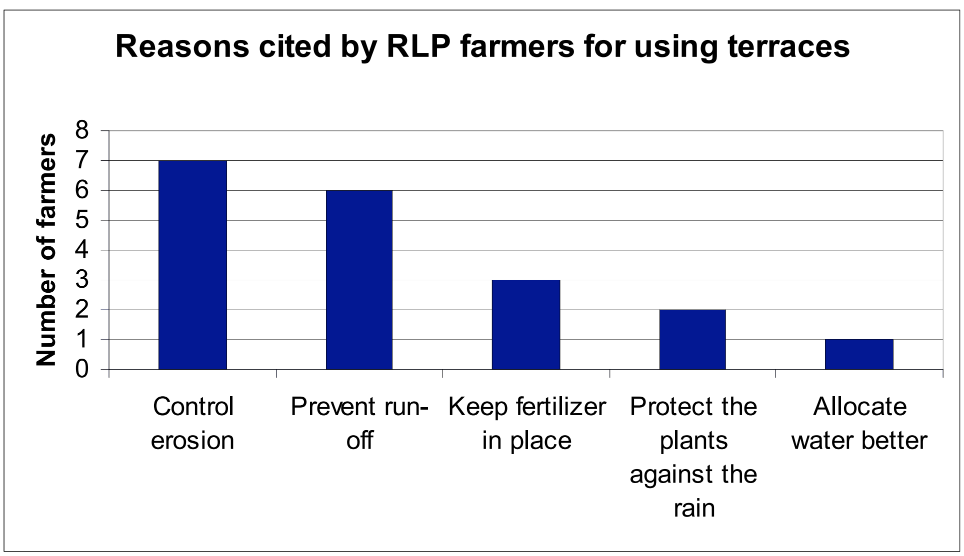
Twelve farmers use terracing on their fields. Terraces are used all over the world to grow crops effectively on sloped land (**Picture 6)**. Sugarcane farmers are less likely to use terracing since most sugarcane is grown on flat land, but all the coffee and vegetable farmers use terracing. However, some sugarcane farmers cause damage to the river if they don't practice soil conservation methods and grow their crop to the edge of the river (**Picture 7).** The farmers mentioned many obvious and less obvious reasons for terracing (**Figure 14).** Only one farmer cited a disadvantage to terracing, which he said was the labor involved.

Picture 6.[139] Terraced fields.

[139] Treehugger archives, http://www.treehugger.com/terrace-farms.jpg

Picture 7. A sugarcane field growing up to the edge of the river in Piedades Norte, causing soil erosion and pesticide and fertilizer run-off into the river. This practice is illegal.

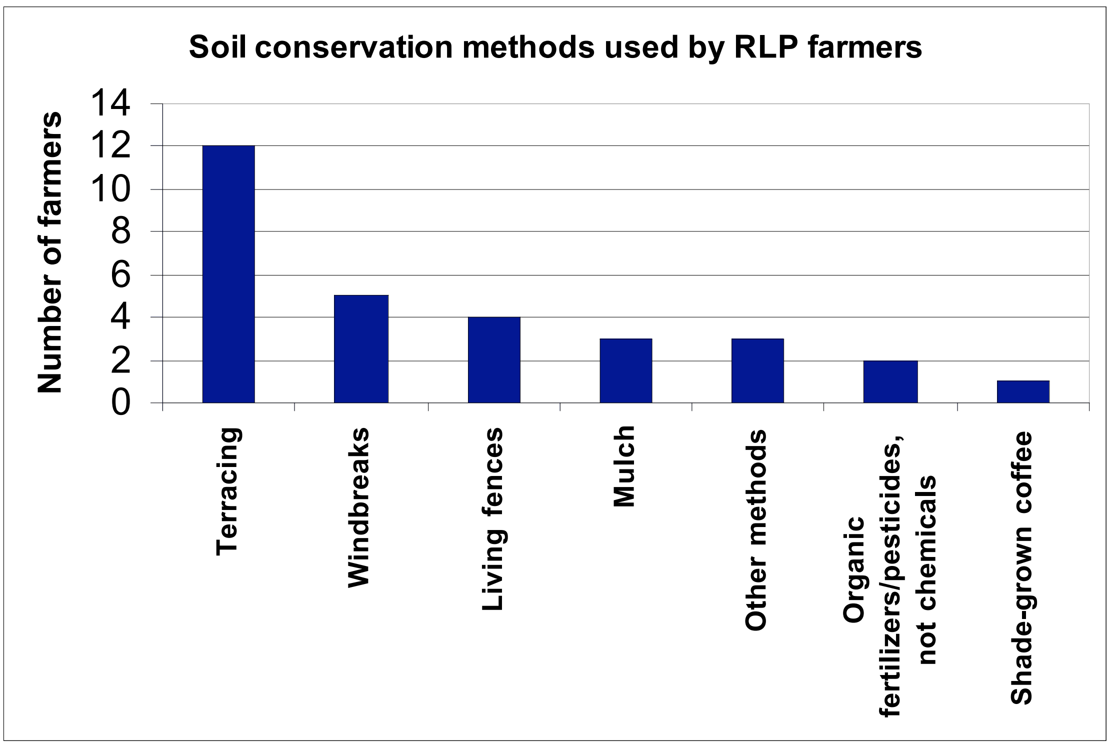
Figure 14.



Question 6. Do you use any other methods to conserve soil?
If yes: **What method(s)? Are there any other advantages to this method? Are there any disadvantages to this method?**
If no: (suggest mulching, reforestation) **Have you ever considered a soil conservation method? Why or why not?**

Besides terracing, twelve farmers use another kind of soil conservation method (**Figure 15**). Two farmers use sugarcane leaves and other wastes left over from sugar production as organic mulching material. One farmer explained that he doesn't burn the sugarcane in order to keep the leaves to produce organic material, protect against erosion, and protect the soil from sun exposure. Another farmer uses *caña india* plants as living fences and as windbreaks to prevent sugarcane from snapping in the wind. Similarly, a vegetable farmer uses corn as windbreaks and as pest control to attract insects away from his crops. Another farmer explained the benefits of mulching—it improves the soil, the production, and the quality of his products, and reduces erosion.

Figure 15.



Question 7. Do you have pigs, cows, or other animals?
***If yes:* How many? What do you do with the manure? Where do you keep them/do you keep them near the river?**

Nine farmers do not own animals and six farmers do. Five have cows, one has bulls for plowing the sugarcane fields and pigs, and one has chickens. Five out of the six farmers use their animal manure as organic fertilizer. The chicken owner has 70,000 meat chickens that he sells to PolloRey which then distributes the meat throughout the country. He keeps his chickens in long, enclosed barns and uses the manure for fertilizer which he sells to local and perhaps non-local farmers.

Question 8. What do you do with your house's trash?
Do you compost your food waste? Why do you dispose of your trash in this way? Are there any other advantages to disposing trash in this way? Are there any disadvantages to disposing trash in this way?

Burning trash releases toxic chemicals into the atmosphere that get carried by the wind, inhaled by people and animals, and deposited onto the land elsewhere. Burying trash can also be harmful to humans and the environment, as chemicals and wastes can leak into the surrounding soil and get washed into river systems. Transporting recyclables and trash to a center in the city impacts the watershed and probably the environment in general the least.

Most of the farmers burn their plastic trash and make fertilizer out of their organic wastes, such as peels, rinds, and other food wastes (**Figures 16 and 17).** Responses varied when farmers were asked why they dispose of their trash in this way. Farmers disagreed about whether burning trash or burying trash was more harmful: Two farmers said they burn their trash because it's easier, though one said a disadvantage was the contamination from the smoke of the burned plastic. Another farmer said he burns his trash because there is no other way, nowhere to take it, and "we don't have a well-developed culture of recycling." However, others thought that burning was the cleanest method—one farmer said he burns his trash because it's clean and so it doesn't rot. Another farmer said everything plastic should be burned or it will contaminate. Two farmers said burning was better because buried trash stays in the ground. Two farmers who bury wastes say it maintains the trash in one place. Two farmers who both burn and bury their wastes said that there is no impact from their actions.

Figure 16.

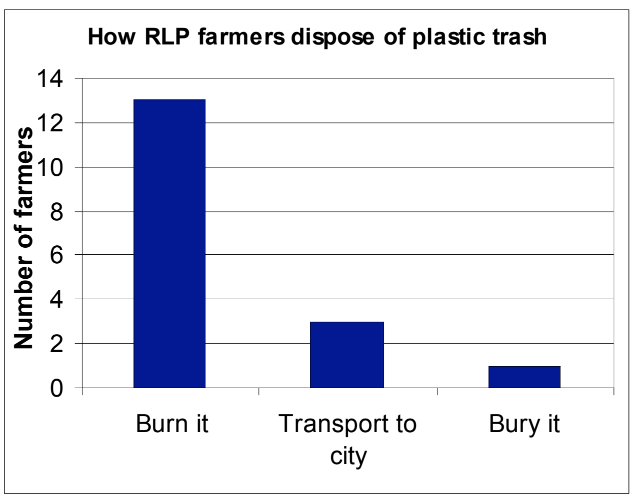
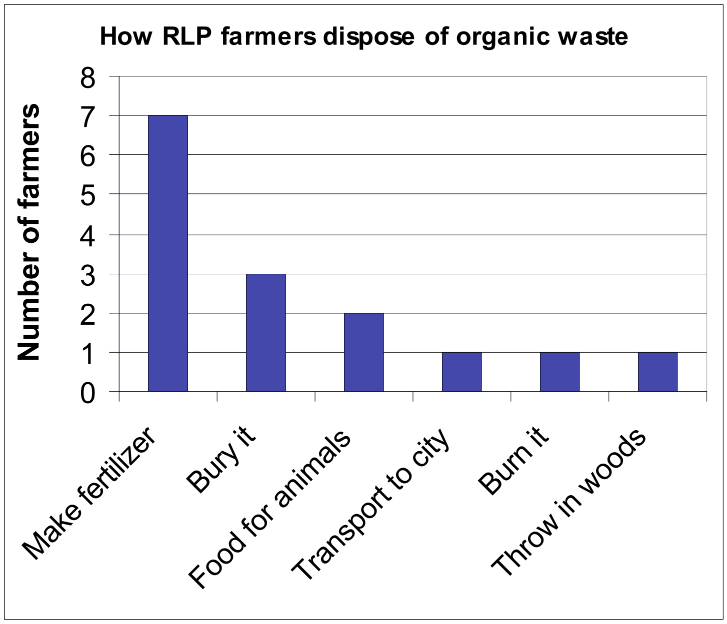


Figure 17.



Other wastes
One farmer said he brings his agrochemical waste to recycle at the factory, and another said he buries his agrochemical waste in a hole far from the river. Another farmer said he buries his glass waste. Two farmers said they recycle their cans in the city, and one farmer buries his cans.

Have you ever considered [*throwing it in the river/burning it/getting it picked up*]? Why or why not?
None of the farmers said they have considered throwing any of their wastes in the river. Five farmers said the trash would contaminate the river or the water, another said we need to protect the ecology of the river, and another said we all use the river so we need to protect it.

None of the farmers use a trash disposal service, which consists of a truck that passes through the communities and picks up trash. Three farmers said the service was not available, but four said the service was available but they didn't use it. Two said it was too expensive.

Three farmers who do not consider burying their trash said that the trash remains in the ground for a long time. One said buried trash contaminates. Another farmer who recycles his agrochemicals by bringing them back to the factory said buried agrochemicals affect the environment.

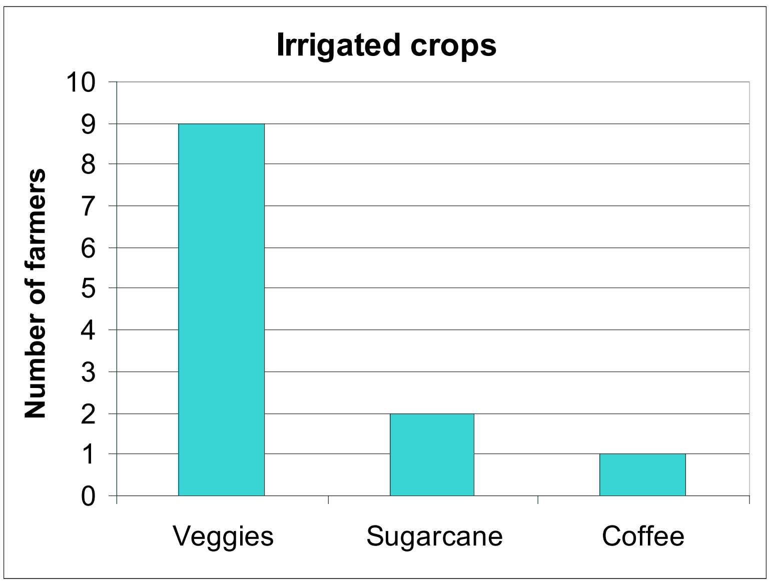
When asked if he had considered burning his trash, one farmer said he hadn't because of chemicals and the planet. Similarly, another said he buries his plastic because it stays in the earth, but if you burn it the chemicals affect the environment.

Irrigation Practices (Questions 9-14)

Question 9. Do you irrigate any of your crops? Which ones? ***If no, skip to question #15. If yes, continue with this section.***

Three sugarcane or coffee farmers do not irrigate at all, relying solely on the rain. The other twelve farmers irrigate vegetables, sugarcane, and coffee (**Figure 18**). The fruit farmer is extremely small-scale, using a small amount of water from a hose attached to his house to water the fruit plants. Eight farmers said they only irrigate during the summer, the dry season.

Figure 18.

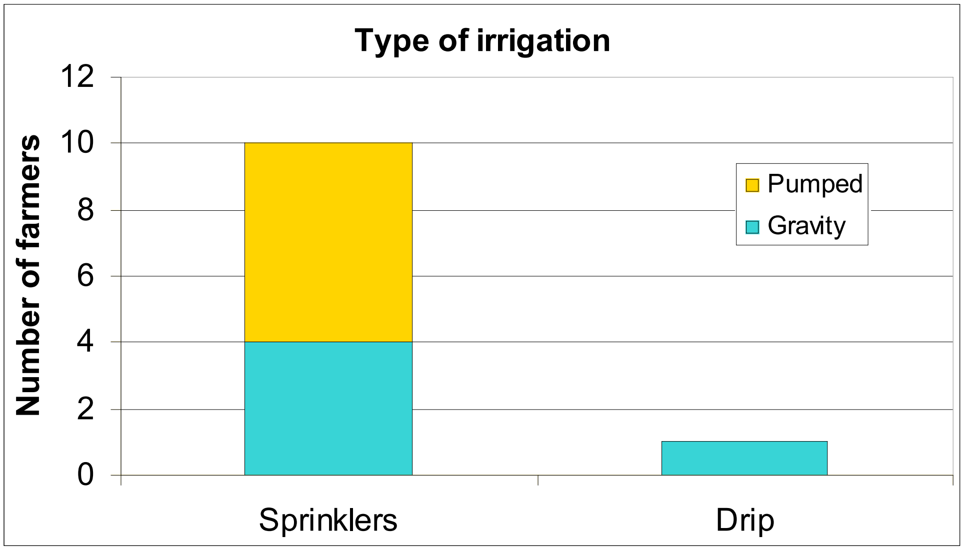


Question 10. What type of irrigation system do you use? Why do you use this type of irrigation system? Are there any other advantages to this type of irrigation system? Are there any disadvantages to this type of irrigation system? Have you ever considered [*circle one: sprinkler/gravity/drip*] irrigation? Why or why not?

By far, the most common irrigation system was aspersion, with 10 farmers using some type of this system (**Figure 19**). Aspersion is an overhead irrigation system that uses sprinklers to distribute the water. Two of these farmers use "mariposas," or butterflies, which are larger sprinkler fixtures that use a greater amount of water to wet the soil in less time—one farmer said sprinklers were more expensive and required more watering time than butterflies. Only one farmer uses drip irrigation, in which water is delivered directly to the root of each plant through small piping run along each row of plants. Drip irrigation conserves water, reduces erosion, and often reduces the occurrence of plagues and requires less chemical pesticides and fertilizers.

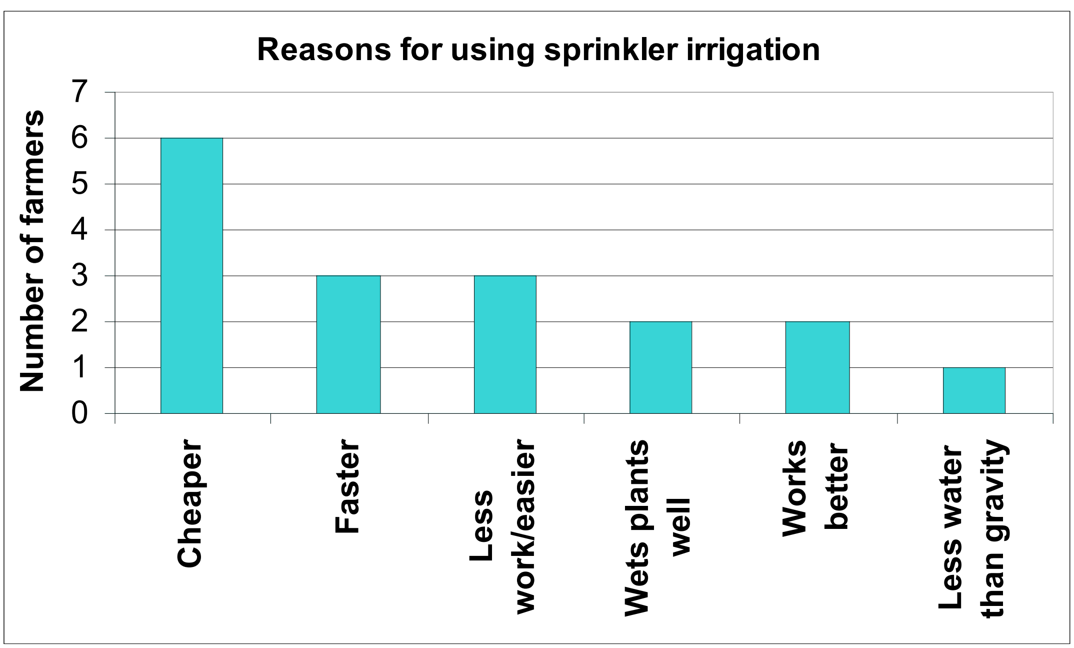
Five of the farmers use gravity-fed sprinkler or drip irrigation systems, in which water flows downward from a higher-elevation spring or stream (**Figure 19**). The other six farmers pump their water from the river, a stream, or a well.

Figure 19.



Farmers cited many economic reasons for using sprinkler irrigation, and one farmer said it used less water than pure gravity irrigation, where water flows downhill onto the crops without using any type of water distribution system (**Figure 20).** Farmers listed many disadvantages to sprinkler systems: water losses from evaporation, the decreased amount of water available at the end of the summer, a limit to the amount of sprinkler heads that could be feasibly used with the system, the effect on the soil health, the difficulty of maintaining the system and the amount of labor required compared to drip irrigation, and the need to use more energy and spend more money to wet the soil compared to drip irrigation.

Figure 20.



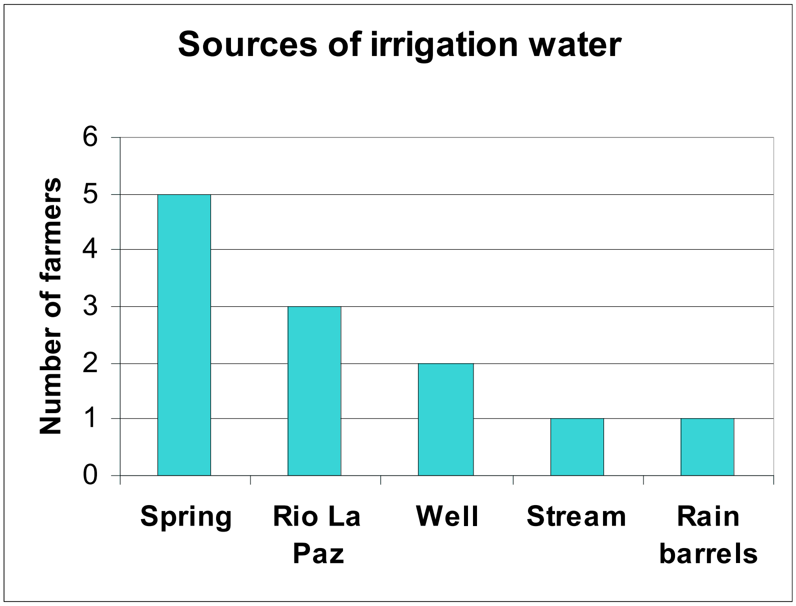
The farmer using drip irrigation said he uses his system because it uses less water, works better, and is healthier for the plants. He said other advantages were that it was cheaper, very easy to maintain, simple to use, and requires less chemicals. He said that aspersion irrigation wilts the plants and leads to more plagues, but is necessary for some crops like lettuce.

Many other farmers had considered drip irrigation but said it was too expensive (four farmers), it was not suitable for sugarcane (one farmer), it was made for short-term crops (one farmer), it took more time to water the crops (one farmer), and each plant needed its own hose (one farmer).

Question 11. Where do you get your irrigation water?
a) Aqueduct
How much is your *monthly* water bill in the summer/winter?
b) River, Stream, Spring, Well
Do you have a concession for the water you use?
How much does energy for pumping the water cost *each month* in the summer/winter?
How much water do you use *per day* to irrigate in the summer/winter?

Farmers get their water from a variety of sources within the watershed, although no farmer said he gets his water from the aqueduct (**Figure 21).** Many farmers said it was illegal to get irrigation water from the aqueduct, since it was only built to supply the amount required for domestic uses. Surprisingly, many farmers have access to springs owned by themselves or their neighbors. Other farmers pump water from Río La Paz or one of its streams, or pump water from their own wells. One farmer said he uses rain barrels.

Figure 21.



Concessions.
A concession is a legal document that entails its owner to use a specified amount of water for a specified purpose. The process of obtaining a concession is lengthy and bureaucratic, taking between one and two years to complete. Two farmers said they have concessions for the water they use. One of these farmers gets his water from a spring, and the other gets his water from a well and says he pays 1500 colones/month (about $3). Seven other farmers said they do not have concessions.

Energy costs.
Three farmers volunteered the amount they spend each month on electricity to pump water from the river, stream, or well (**Figure 22)**. All use sprinkler irrigation without the larger "butterflies" and only grow vegetables.

Figure 22.

Colones/month	Approx. hectares	Colones/hectare/month	Dollars/hectare/month
35000	2.8	12500	$25.00
5000	0.3	14300	$28.60
7000	1	6670	$13.40

Amount of water used.
The majority of farmers did not know how much water they used per day or per month. Three farmers said the daily amount of water required depends on the climate or the soil.

Question 11, continued. Why do you get your irrigation water there? Are there any other advantages to getting your irrigation water there? Are there any disadvantages to getting your irrigation water there? Have you ever considered getting your irrigation water from the [aqueduct/river/well]? Why or why not?

Wells.
The two farmers using a well as their water source said it is the only option—the river is too far from their fields and they don't own a spring. One farmer said he also uses it because he constructed it years ago; the other says it's easier and there is always water available. Both said there were no disadvantages.

Springs.
The five farmers using springs all use gravity-fed irrigation, avoiding energy costs for pumping water uphill from the river, a stream, or a well. Four of the five farmers recognized the cost issue, saying they would not consider pumping water from the river or well because of energy costs. When asked why they use springs, two farmers said that their neighbor lets them use a spring they own. Another said it was something he started many years ago and it was the easiest and cheapest way to irrigate. None of the farmers mentioned any disadvantages; one said the spring produces water all day, and another said the water would flow to the river anyway so there was no disadvantage in his use of it.

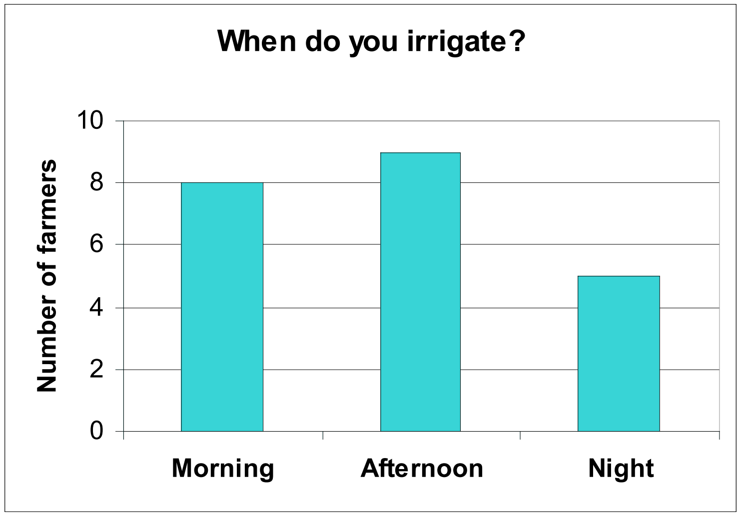
River or stream.
Four farmers pump water up to their fields from Rio La Paz or one of its affluent streams. Two farmers said they use this method because it's easier, and another said it is the only option but if he had access to a spring that would be better. One farmer said he had considered constructing a well because of the water shortages in the river, especially in the summer. Another said he had also considered building a well but it is expensive and difficult.

Rain barrels.
The small-scale sugarcane farmer with about two hectares of cane uses a combination of Rio La Paz water and rainwater he captures in barrels. He says there are difficulties with the rain barrels—they take three days to fill up with rain (in the rainy season), and there are mosquitoes and other insects. However, he said well water is not as clean as rainwater and the well he would use is far from his fields.

Question 12. What time of day do you irrigate and for how many hours? Why do you irrigate at these times? Are there any other advantages to irrigating at this time? Are there any disadvantages to irrigating at this time? Have you ever considered irrigating during the [day/night]? Why or why not?

The farmers irrigate throughout the entire day, but more irrigate during the morning and afternoon (**Figure 23).** Four farmers said it benefits the plants to water during the cooler hours of the day. A couple of farmers said they need to move around their sprinklers, one every six hours and another every hour.

Figure 23.



Responses varied about irrigating at night—one farmer said he only irrigates during the day because plants watered at night get sick with plagues. Another farmer said it would be better to water during the night because it wets the plants twice as much for the same amount of electricity, and the plant can breathe and suck up the water better. Another farmer agreed that watering at night uses water more effectively, but he says he is not working at night.

Farmers said they water for varying amounts of time, from two to twelve hours per day. The farmer using drip irrigation only waters for two hours each morning. He says drip irrigation allows watering at any time, but he waters in the morning when the ground is not so hot.

Question 13. Do you use the same quantity of water for all your crops?
***If no*: Which crops require the most water? Which crops require the least water?**

Most farmers said the quantity of water they use depends on multiple factors—the crop type, the plant age, the climate that day, the slope of the land, the humidity, and the sun. Three farmers said more water is needed for younger crops. Only one vegetable farmer said he uses the same amount of water for all his crops. Farmers mentioned lettuce and onion as crops requiring the most water.

Question 14. Do you use a water conservation method such as a rain barrel or storage tank for your irrigation water?
***If yes*: Which ones? Why do you use these water conservation methods? Are there any other advantages to using these methods? Are there any disadvantages to using these methods?**
***If no*: Have you ever considered using a water conservation method for your irrigation water? Why or why not?**

Eight farmers said they do not use a water conservation method while two said they do. These include the rain barrels used by the sugarcane farmer and a hose to direct additional water from a water collection tank on "the mountain," presumably from a spring, used by a veggie farmer. The drip irrigation farmer said he does not use another water conservation method because there is a large quantity of water available and it is very easy to access.

Agricultural traditions (Questions 15-18)

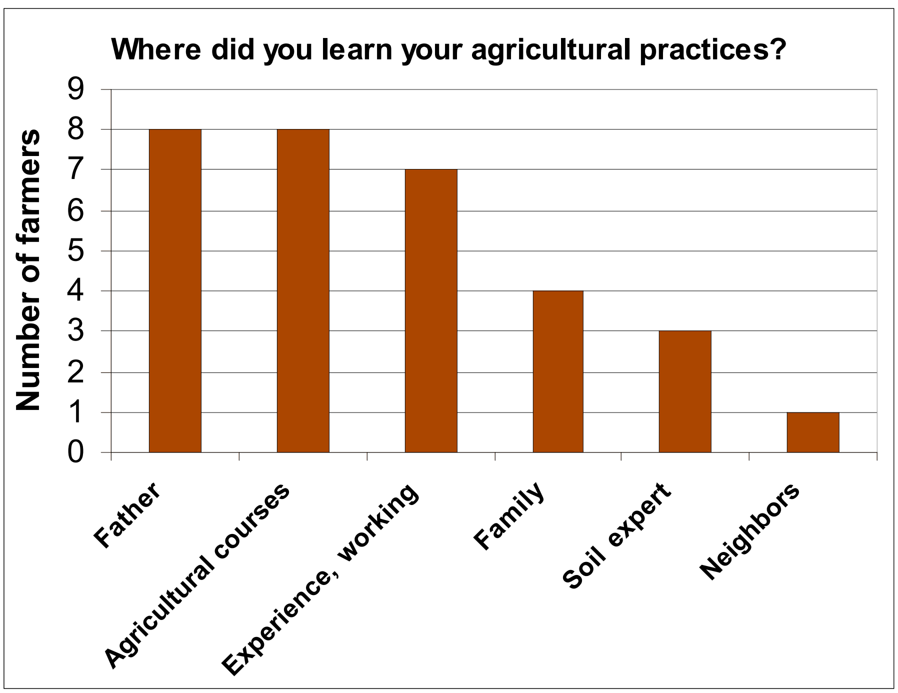
Question 15. How many years have you been farming?

Ten of the farmers have been farming their whole lives. Four more have farmed for 15-20 years. Only one has farmed for only five years.

Question 16. Where did you learn your farming techniques?

Farmers said they learned their farming techniques from a variety of sources, but most commonly family members (**Figure 24).** Farmers spoke of a wide selection of agricultural courses they had taken and learned from, offered by the agricultural extension service (INA--National Institute of Learning) and other companies such as agrochemical companies. Course topics included the management of agrochemicals and irrigation systems, pasture planting, maintenance of agricultural machinery, production of milk, and organic agriculture.

Figure 24.



Question 17. Are any of your agricultural practices different from those of your family? If yes, how?

While six farmers said their agricultural practices did not differ from those of their family, five farmers said they did. Three farmers said their fathers worked in coffee and two said their fathers worked in sugarcane—they work in other crops. One of the farmers said his family raised chickens but he does not.

Question 18. Are your agricultural practices different than your neighbors'? If yes, how?

Seven farmers said that everyone has different ideas or practices while seven other farmers said that everyone's practices are more or less the same. In addition, while four farmers claimed that neighbors discuss their agricultural practices and decide which ones work the best, one farmer said there is not much communication and decision-making between neighbors.

A farmer who said practices are all the same said that what one person doesn't know he asks of another, so practices end up similar. In the words of another farmer, "we all work under the same understanding [of agricultural practices]."

Another farmer said that friends work differently, because the variable local climate affects pests—and therefore chemical use—and crop selection. A sugarcane farmer explained that practices vary depending on the type of sugarcane and the terrain. Another sugarcane farmer said he is unique among cane growers in his use of terracing and living fences.

Perceptions of the Watershed (Questions 19-25)

Question 19. Is Río La Paz important to you? Why or why not?

Every farmer said the river is important to him. However, the farmers provided a wide variety of reasons (**Figure 25).** Their reasons help reveal how the farmers perceive themselves in relation to the river and the natural environment, and how they value nature. The majority of the farmers' statements are anthropocentric and resource-based: they portray the river as a source of goods and services for humans. These goods and services include water for human consumption (numbers 10, 14), water for the consumption of livestock that humans raise (1, 8), irrigation water (1, 2, 4, 6, 8), water for industry as in the sugarcane factory (15), the ability to fish for recreation (8), and the opportunity for jobs (8). Many responses are anthropocentric even if they do not explicitly contain a resource-based approach, explaining the river's importance in terms of its effect on humans (2, 3, 5, 6, 10). A few responses indicate a more ecocentric perspective that sees nature as a holistic system with intrinsic value; in other words, the environment is not just important because it provides resources to humans (7, 12, 13). For example, one farmer says the river is where water collects, suggesting he values the river as part of a larger ecosystem. Finally, one farmer describes our duty to protect the river because it has always existed, suggesting he values the river not for its explicit benefit to humans but because it existence, another example of intrinsic value (9). For further discussion, see the Value Paradigms section in the Discussion section below.

Figure 25. All farmers' responses to "Why is Rio La Paz important to you?"

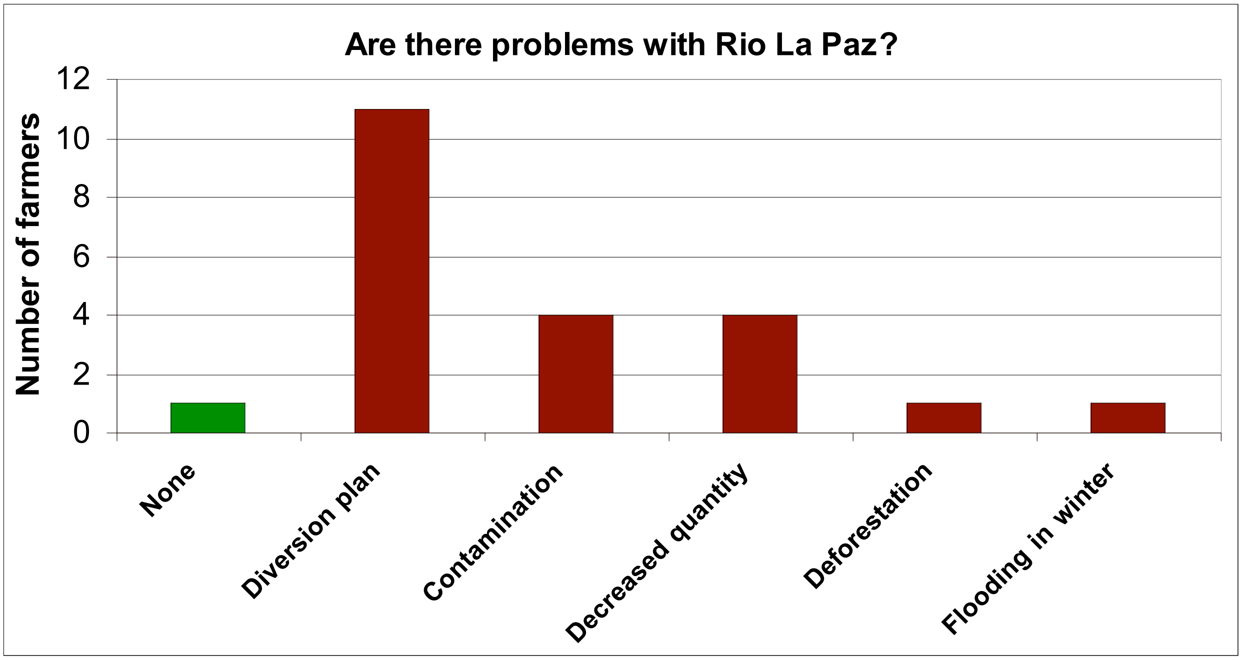
1. For the water, for every use--irrigation, animal consumption.
2. It's important to this region because we grow a lot of crops. It passes by all of us.
3. We depend on the river for almost everything.
4. The majority of people use it to irrigate crops.
5. The river can give a lot of help to our future.
6. People use it for irrigation. Everyone will leave if it disappears.
7. For irrigation and nature.
8. It is used for a source of water, to irrigate vegetables, for cows, to fish for recreation. The river gives various alternatives for work.
9. It has always been there. We must take care of it and protect it.
10. A benefit for the whole community. And it is the same water as the aqueduct.
11. For me the most important things are the waters […explanation of the river system hydrology and geography…]. We must take care of them more.
12. Where water collects. It is very important.
13. Water is life. And it is a pure and pretty river.
14. It provides potable water.
15. It gives us water [that makes it possible] to burn [sugarcane in the factory] and everything; the sugarcane factory is of the river.

Question 20. Are there any problems with Río La Paz?
***If yes:* What? What will happen if these problems continue?**

Fourteen farmers mentioned problems with the river while only one said there are no problems (**Figure 26)**. Eleven farmers mentioned the diversion, which may be due to sampling error: since my group worked on raising awareness about the diversion plan in April, some of the farmers recognized me and may have thought I wanted them to talk about the diversion plan. Seven farmers mentioned problems besides the diversion plan: one farmer said the river is very low in the summer, another said the river has much less water in the winter, another said outsiders contaminate the river with trash, and another said sometimes when the river rises, about 20 kids can't get to school because of a flooded bridge.

When asked what will happen if the problems continue, many farmers expressed uncertainty, three farmers saying they didn't know and one farmer saying that everyone will leave if the water disappears. Two said the farmers could build wells. One farmer said the water will stop being potable and marine life such as fish and shrimp will disappear.

Figure 26.



The diversion plan.
Eleven farmers gave responses that had to do with the plan to divert Río La Paz water to San Ramón and Palmares (**Figure 27**).

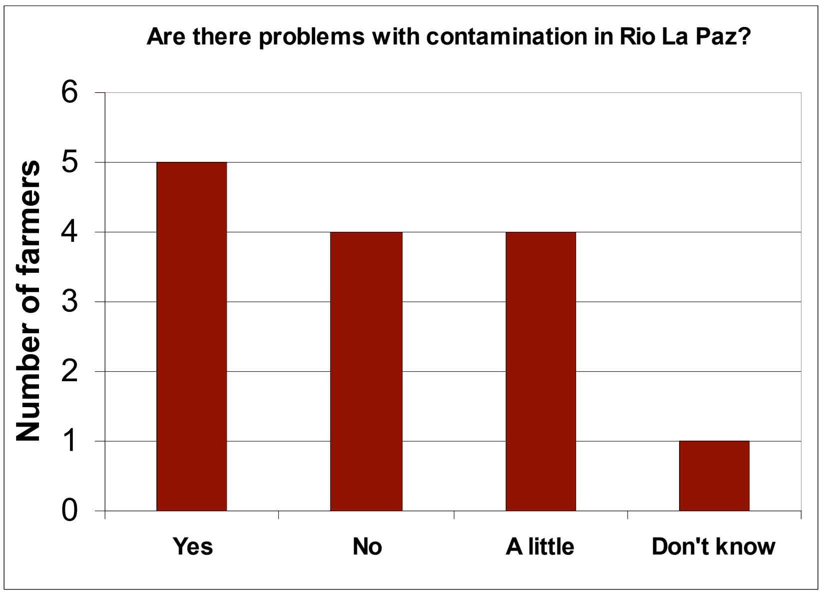
Figure 27. What are the problems with Rio La Paz? All farmers' statements on the Diversion Plan.
They want to take the water and leave about 20% of it for the communities--it's very little water for a lot of things.
A few years ago AyA wanted to capture almost all of the water for human consumption up there, [at the springs]. And because human consumption is given priority, it was a little difficult for the groups that are trying to get them not to take the water from up there. There is very little water left in march or april for such a large project like they want to do. Such a large investment in piping for not having the water they want. **What will happen if the project happens?** The farmers will not know what to do. Some will adapt with a perforated well, because here the water tables are relatively shallow, at about 80 meters. But the wells are expensive.
I have heard commentaries that there are certain institutions and certain parts of the government that are fighting for part of this water, more than the river has.
A water pipeline to Palmares; I don't know exactly.
Taking the water for human consumption to Palmares. **What will happen if the problems continue?** The people oppose it.
The diversion plan will leave the community without water, especially in the summer.
Here there are people that want to take the water to places that had water but stopped taking care of it--they contaminated it with trash and bad things.
They want to take the water.
I have heard that they want to take the water for human consumption, but nothing concrete.

Question 21. Are there problems with contamination in the Río La Paz? Why or why not?
The most significant probable contributors to water contamination in the watershed are pesticides, chemical fertilizers, animal manure, and soil that erodes and washes into the river. Pesticides and chemical fertilizers contain chemicals toxic to aquatic biota and harmful to humans if consumed or in some cases even handled. Chemical fertilizers and manure contain high concentrations of nitrogen that lead to imbalances in the chemistry of the aquatic system

and eutrophication. Rain or irrigation water can wash livestock excrement or natural fertilizers made of animal manure into the river. Erosion causes increased sedimentation in the river, increasing the water temperature, decreasing the amount of sunlight that can penetrate into the water, and harming aquatic life.

There was no consensus among farmers as to whether the river was contaminated (**Figure 28**). Answers ranged from not at all to very much—one farmer said the people have a lot of awareness; the river is clean, while another farmer listed five contamination sources. Three farmers said the river was clean or only a little contaminated because people protect it, while another farmer said he didn't know if there were problems with contamination but he protects it.

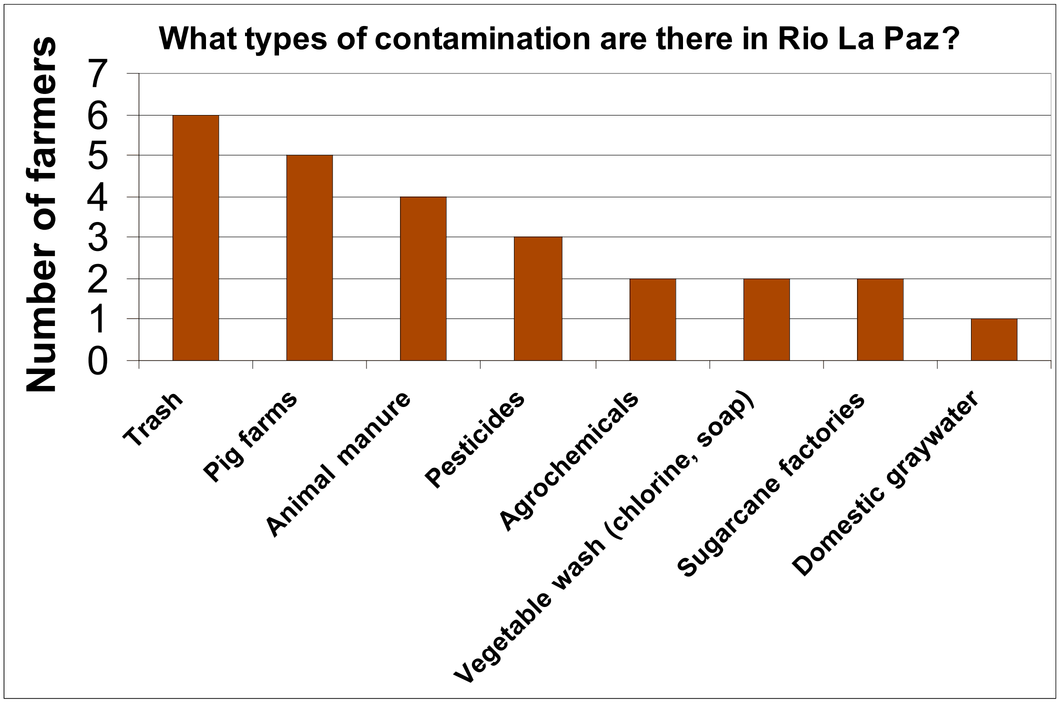
Figure 28.



If yes: **What types of contamination are in the river? Where does the contamination come from? Who or what contaminates the river the most (for example, houses, trapiches, lecherías, chancheras, agricultures)? Do you think anything can be done to improve the water quality of Río La Paz? If yes, what?**

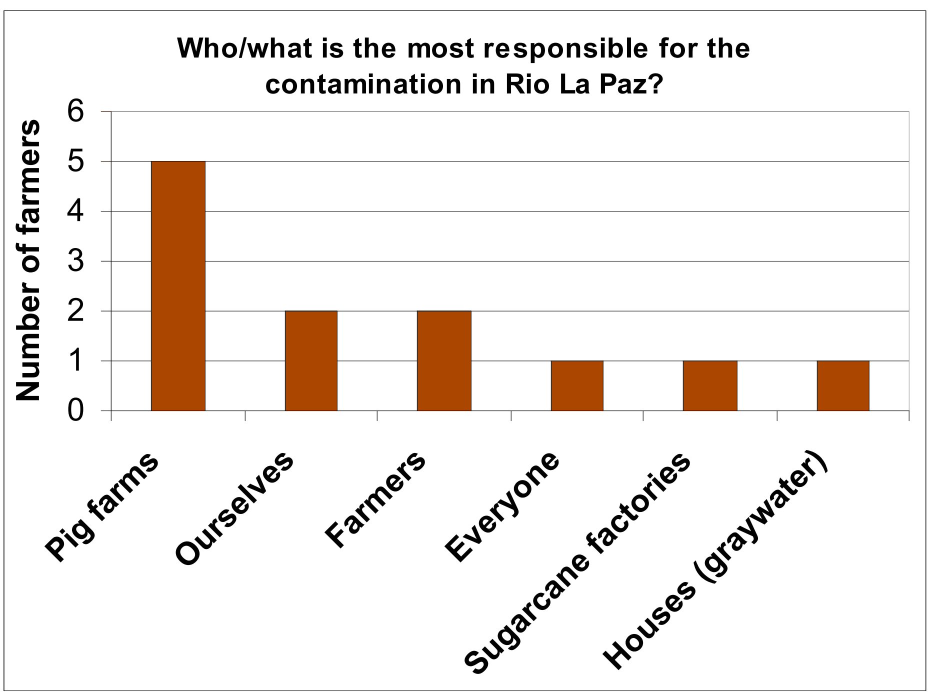
Farmers cited eight types of contamination in Rio La Paz (**Figure 29).** When asked about the origin of the contamination, three farmers said people throw trash in the river, such as bottles and cans. Two farmers said pig manure at pig farms runs into the river—one said it's not intentional but rather produced naturally. One farmer explained that companies like the produce distribution center RyM wash vegetables with soap and chlorine, which end up in the river. Another farmer said that herbicides are applied on farms bordering the river, while a different farmer said pesticides originated from "the same crops that I grow here."

Figure 29.



Farmers blamed the pig farms the most for the contamination in the river (**Figure 30).** One farmer said everyone has a part in the contamination, but then states that "some people don't take care of the river but I don't do that."

Figure 30.

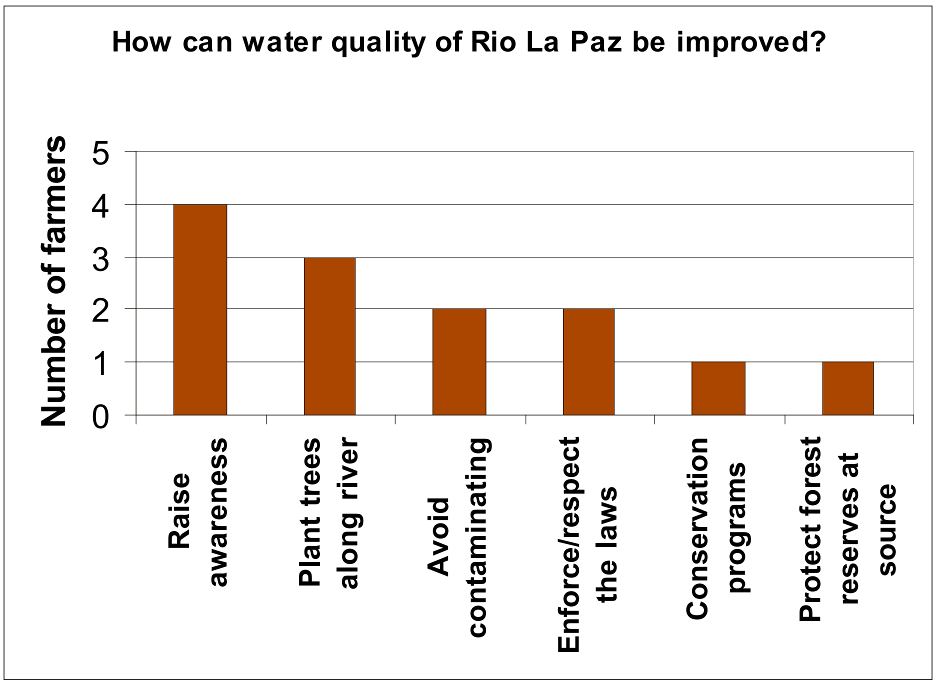


Ten farmers said that the water quality of the river could be improved in various ways (**Figure 31).** The phrase "raise awareness" was the most popular.

Laws and government

Opinions varied about the role of the government in improving water quality—one farmer said the government needs to enforce the law and the people need to be educated. Another farmer said people need to respect the limits and laws that exist. A third farmer said that governmental conservation programs would be the most effective, and that prohibition does not work.

Figure 31.



If yes or no:* Do [pesticides, fertilizers, manure, soil] contaminate the Río La Paz? (*If no, why not?)

Farmers more often said that the pollutants did contaminate the river (**Figure 32).** One man commented on contaminants in general, saying that they kill the insects in the water and darken the water.

Pesticides and fertilizers.

Farmers made no distinction between pesticides and fertilizers in their explanations. Two farmers talked about bottles of agrochemicals instead of chemicals applied to fields—one said that people take care of the river, and it is better to burn or bury agrochemicals than throw them in the river, and another said that jugs of pesticides thrown in the river are contaminants, and if too much pesticide is used, rain can wash it into the river. Similarly, another farmer said you don't have control; the same chemicals that you use to spray for pests can get washed into the river with rain if you are not careful. A couple of farmers said that a more "rational" application of chemicals would lessen contamination. Three farmers said that only farms close to the river contaminate it, two saying irrigation washes chemicals into the river and the other saying rain washes them away. In contrast, another farmer said that rain washes everything into the river, and in the river you can see how dirty the river is with all the wastes.

Manure.

One farmer said that an engineer told them that nitrogen in manure can be a contaminant if a lot is used, while another farmer said that manure doesn't contaminate because it's organic. Some farmers wanted to add stipulations—one said the "chemical part" of the manure contaminates and another said manure contaminates if it rains a lot and you work near the river. A third said manure doesn't contaminate the river because it rapidly filters through the soil.

Soil.

When asked if soil contaminates the river, most farmers asked for clarification. I repeated the question by asking if soil on its own can contaminate, for example when erosion happens. Three said yes—for example, one farmer said if there is lots of erosion, you can't use the water because it is dirty, but you can't avoid erosion. Seven farmers said soil contaminates only if it contains agrochemicals, and some farmers further specified only when it rains and the soils are washed into the river. One farmer mentioned that soils washed away by the rain carry nutrients to the rivers and to the ocean. Another farmer said the same thing, explaining that nutrients carried into the rivers wash into the ocean, cause algae blooms, and kill the aquatic life.

Figure 32. Do ______ contaminate the Río La Paz?

	Pesticides	**Fertilizers**	**Manure**	**Soil (erosion)**
Yes	11	10	9	3
No	3	4	4	2
Don't know	1	1		
If it contains agrochemicals				7

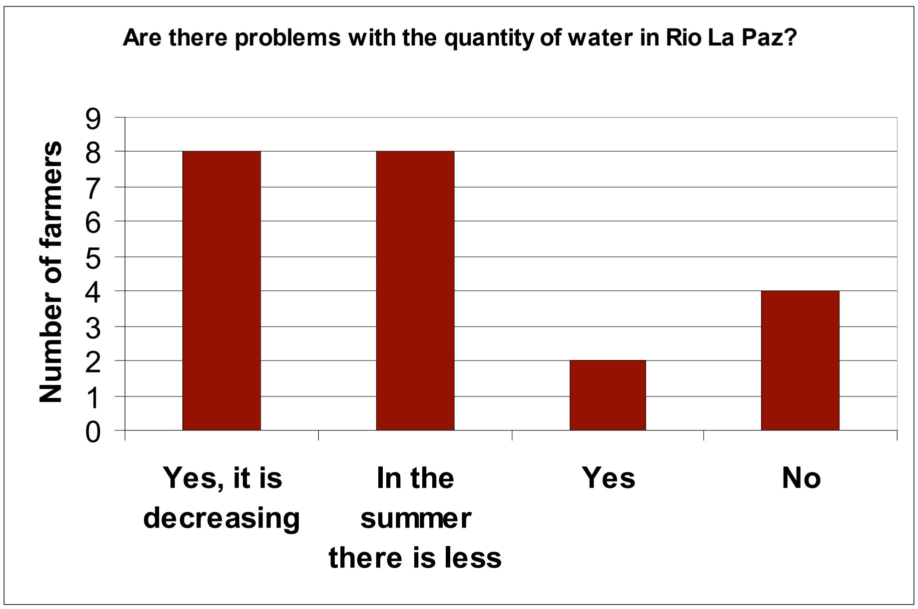
Question 22. Are there problems with the quantity of water in Río La Paz? Why or why not? *If yes:* Who or what wastes the most water (for example, houses, trapiches, lecherías, chancheras, agricultures)? Do you think anything can be done to increase the quantity of water in the Río La Paz? If yes, what?

Dropping water levels in the river—caused by an increase in users and higher evaporation rates from warmer temperatures and decreasing rainfall due to climate change—are an immediate concern in maintaining the health of the watershed. The ecological effects of a decreased water level in the river include an increase in temperature, increase in pollutant concentrations, easier evaporation, a weakened ability of the river to maintain its channel, a smaller floodplain, changes in the biotic community including vegetative structure and a shift towards more pollution-tolerant macroinvertebrates and aquatic organisms, and more sedimentation that gets into irrigation systems.[140]

Most farmers said there were problems with the quantity of water in the river (**Figure 33).** While one man said that there are no problems but water levels decrease a little in the summer, seven said that the water levels are decreasing and in the summer there is less. One farmer who said there are no problems said the water levels were stable.

Five farmers offered explanations for the waning levels of water—one farmer cited deforestation, two mentioned the diversion plan, two said lots of water is being used for irrigation, one said the sugarcane factories are using lots of water, one cited global warming, and one cited contamination.

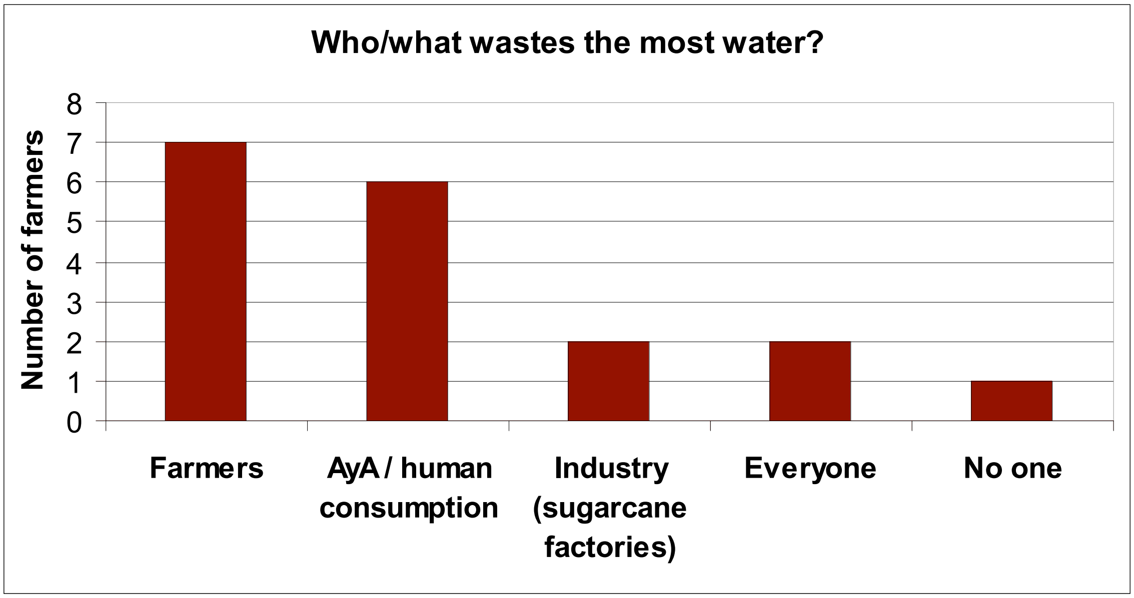
Figure 33.



Surprisingly, seven farmers said farmers waste the most water, followed closely by the aqueduct company that supplies domestic water (**Figure 34**).

[140] Dethier, D., professor of geology at Williams College. (6-23-2008). Personal comm. Hydrology. A. Gulley. Williamstown, MA.

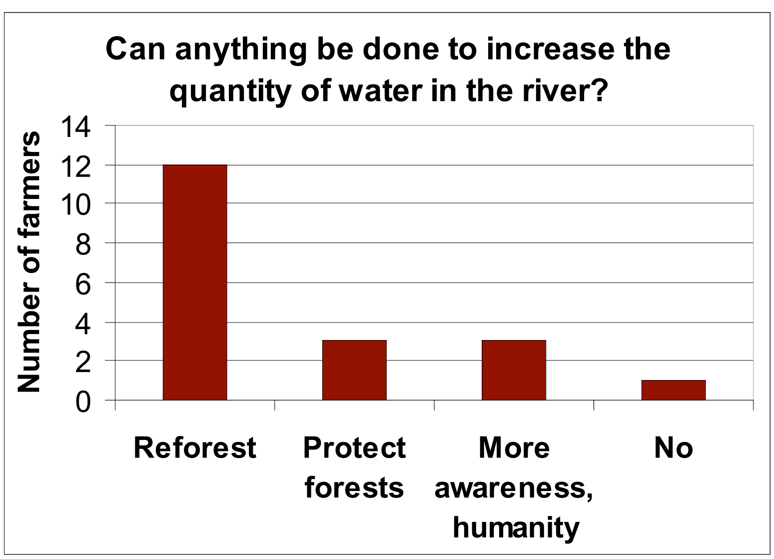
Figure 34.



When asked if anything can be done to increase water levels, the vast majority of farmers said reforestation (**Figure 35).** Furthermore, an additional farmer said that reforesting can help maintain water levels but not increase the amount of water. One farmer said it is difficult to reforest because everyone cuts trees from the mountains. Another farmer said he is reforesting himself: He found a group of schoolchildren in San Ramón who come to his land to plant trees they get from nurseries run by ICE, the Costa Rican Institute of Electricity.

Only two other methods were suggested, protecting forests—one farmer said at the source of the river—and raising awareness and showing more humanity—for example teaching people to not use so much water in the summer.

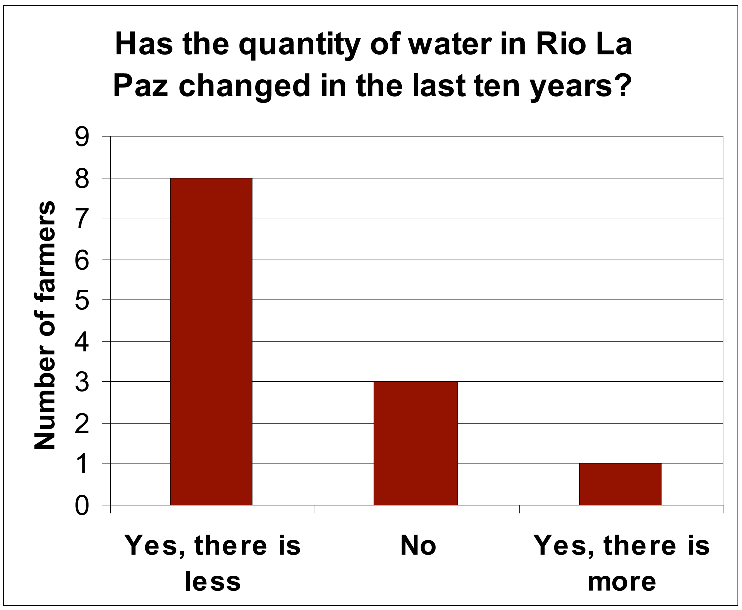
Figure 35.



***If yes or no:* Has the quantity of water in Río La Paz changed in the last 10 years? If yes, how?**

Most farmers said there is less water now than ten years ago (**Figure 36)**. One farmer who thought the quantity has remained the same said that the river is always dry during the summer. Another farmer estimated that there is 30% less water now than ten years ago. Another farmer said it is raining less now than in the past. The man who said there is more water now said the people are reforesting a lot.

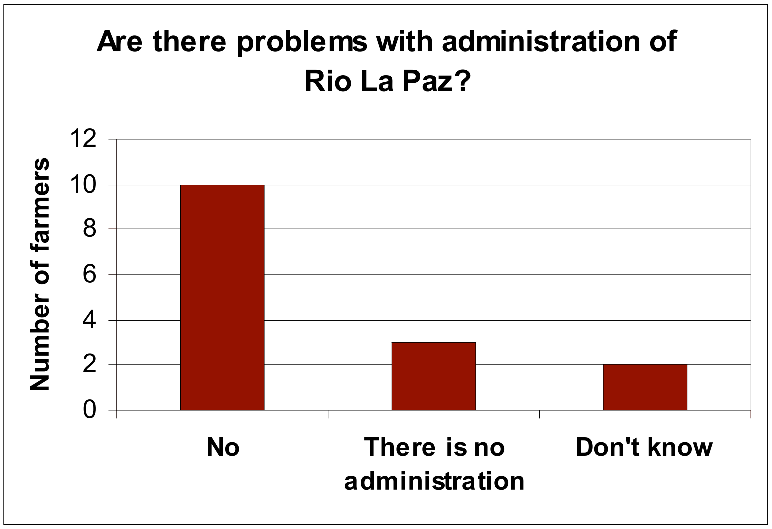
Figure 36.



Question 23. Are there problems with the administration of Río La Paz? Why or why not?

No one said there are problems with the administration (**Figure 37),** but one farmer said there would be problems if the diversion plan is put into place. One farmer expressed confidence in the government, saying that MINAE (the ministry of energy and the environment) takes care of the river, while another said that although there are no problems, MINAE is ineffective. He said MINAE's laws of prohibition—like prohibiting the cutting of trees near the river—do not work because there is no enforcement; he said he has never seen a MINAE agent walking by the river. Three farmers said that the people are taking care of the river—one said that the river passes by farms and each farm owner is free to responsibly use the water they want, and another said a committee in La Paz is working on administration of the river.

Figure 37.



Question 24. Do people in your community want to protect the river? If yes, who? *If yes or no:* [Why do/why don't] they want to protect the river?

The majority said that everyone in their community wants to protect the river (**Figure 38).** One man said this is because everyone uses the water. Another farmer said people are reforesting land, and a second said that people agree with receiving trees to plant. One man said that only the farmers who have farms bordering the river want to protect it. Another farmer who said that only some people want to protect the river said people don't get together to talk about the river. Farmers gave myriad interesting reasons why community members want to protect the river (**Figure 39).** For further discussion, see the Value Paradigms section in the Discussion section below.

Figure 38.

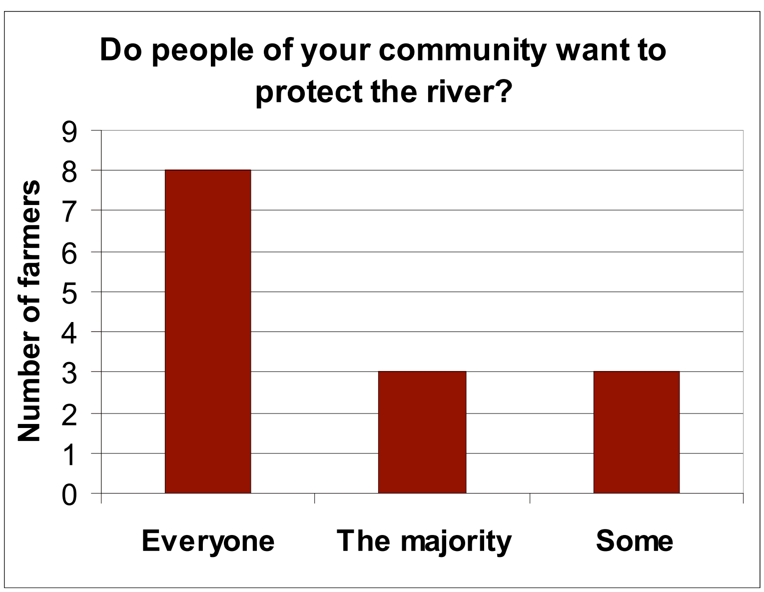


Figure 39. All farmers' responses for the question "**Why do people in your community want to protect the river?"**
It is life. Without water, we won't have anything.
The lack of water. The people have awareness.
A future for grandchildren and great-grandchildren.
The people use it. People can't plant if the river is gone in the future.
Water is life, you need it to survive.
It gives a better price to land. Water is a resource, and it is clean and pretty, and you can use it for many things. You have to take care of it because it's part of your farm.
It is a source of water, you have to protect it.
(WIFE:) There are few rivers like the one I have. It is teaching the children to protect the river.
Now [there is] not so much deforestation but in years past they didn't take care of it. They take care of it now because people have seen that the levels of water in the rivers have dropped. In the winter there was a huge amount of water but not any more.
We have love for life. For the human being that lives well.
It is that which provides us existence. Without her, the whole world would be affected.

Question 25. How should humans relate to their natural environment?

Farmers had extensive responses, most of them using the word *cuidar,* meaning to take care of, care for, or protect, and many using the word *conservar,* meaning to conserve, protect, or preserve (**Figure 40)**. For further discussion, see the Value Paradigms section in the Discussion section below.

Figure 40. All farmers responses to "how should humans relate to their natural environment?" (some lengthy responses shortened).

They should take care of the environment a lot. For example, water sources and reforestation. Reforest, preserve the environment, take care of the rivers and mountains.
Try to take care [of the environment] a little. Each day there is climate change. Before there was a huge amount of water, and in the past few years there have been droughts and much contamination. The ozone layer is open. Reforest--we keep cutting and cutting. Take care of what we have now, because if we don't we will die.
Do the least possible to contaminate.
Try to do things so they don't affect nature...Earlier, people threw trash and now it is changing a lot. The people have a consciousness that they have to take care. The courses have helped teach caring for the environment…The people are learning to manage all of this, for a sustainable development--I think that yes we can work in harmony.
It depends on the consciousness of each human being. On my land, I try to take care, so that a liter of fungicide or insecticide doesn't get into the stream. Try to prevent a little at least.
Protect the environment. We all have responsibility. The government is corrupt.
With much respect. If we respect it more, it will respect us. We need it to survive. The conservation of the environment: try to work to reduce the impact on vegetation and animals. Contamination hurts us too.
Using natural resources, but in a sustainable development...Use them in a sustainable development for the environment and for the human being. Work in equilibrium with nature. Don't exploit nature. Tell people to care [for the environment] for future generations. If we have a source of water, try to care for it as much as possible. Because in the future, there will not be water. And if we have some mountains or a little forest, try to protect it. Because they are natural, they are pretty, and they've lasted many years. In a day or an hour you can destroy everything.
What we have to do is take care of it, try to not contaminate it, to live well. To contaminate is to break

relationships with the environment.
We should have taken care of the ecology from the beginning. Because in reality what I feel is that things are there for us to take advantage of, but not to destroy. But we refused to respect nature because it was more convenient. What we did is destroy it. We have to protect the waters. The problem has grown to the global level. Thank god here in Costa Rica there is enough water. Costa Rica is trying to take care; in other countries there are much larger problems with water. Thank god, the people are becoming conscious of reforestation. If everyone plants five trees, we will be okay...
Take care of it. Not contaminate the environment, like the sugarcane factory we have. Nor contaminate the human being.
The best [action to take] is conservation programs on the television...And educate the kids in school, raise awareness, [make] required conservation material in Costa Rica and all the world. Make the kids environmentalists. Create a culture of conservation. Prohibition is the worst there is, it does nothing, nothing, nothing. We have to talk about freedom, not slavery. [Create] a motivation not for only Rio La Paz but also for all of the rivers in Costa Rica and the world, a motivation to protect because we all live on the same planet...If a nuclear plant at Chernobyl explodes, it affects everyone...We are all connected at the global level. Create a consciousness that money is not the most important thing. We think that each country has a border--no, the border is something symbolic. And unfortunately, the poorest countries suffer the most. Pray for a better world, pray and participate. And each day there are more worried people, for conservation and not for money...
If we don't protect the environment, the species will disappear. The ozone layer, climate change are problems.
Take care of the environment. Not pollute the waters or cut trees, to preserve. We have to protect it.

Results and Discussion, Part 2: Themes and Connections

Throughout my investigation, I examined the overarching question, "How do cultural variables affect those land-use decisions made by individuals that alter the water quality or quantity of the Río La Paz microwatershed?" When I interviewed people in the watershed, I only had a general and vague idea of the definition of culture. But after analyzing the interviews, certain obvious trends emerged that I categorized as aspects of culture. The three cultural trends I noticed were the importance of *traditions* in farmers' land-use decisions, the diverse *value paradigms* of residents that affect their valuation of the river and environment, and *dominant discourses* or narratives that get propagated throughout the communities and impact people's beliefs and assumptions about the river and environment. I also noticed certain correlations between people's knowledge of water-related issues and social variables such as age, gender, and residency, which also have cultural implications. I will examine each of these four cultural aspects below. After recognizing these trends, I followed Davis et. al. and Toupal to narrow culture to shared traditions, values, and beliefs or assumptions that affect people's relationship to the natural environment.[141] However, these categories are fluid and interconnected, impacting each other and changing shape over time and place.

Awareness of water issues and ecological systems

The majority of watershed residents seem informed of water-related problems. In the April interviews, four main questions acted to assess residents' awareness of water issues in the Río La Paz area:

1) *"Are there problems with water in the area?"*
2) *"Is there contamination in the river?"*
3) *"Do you know about the diversion plan?"*
4) *"Do you think there is less water in the river now than in the past?"*

Almost two-thirds of interviewees said that there are problems with water, two-thirds of interviewees reported knowing about the diversion plan, more than half of respondents said there is contamination in the river, and three-fourths of people said there is less water in the river than in the past.

The participatory workshops further revealed that many residents possess a multi-dimensional understanding of human impacts on the watershed. Residents identified both point sources of river contamination (trapiches, chancheras, lechería) and non-point sources or general causes of river contamination (agricultural run-off, erosion, trash disposal). They came up with a number of creative and practical solutions to contamination problems that demonstrate a working knowledge of how human actions impact the watershed. For example, in Bajo Zúñiga participants discussed how pure chicken manure should not be used as an organic fertilizer because of the negative impacts it causes when it runs into the river; in Bajo La Paz, participants discussed using terracing and barriers to reduce erosion. Participants also demonstrated knowledge of

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[141] Davis, S. A., Lawrence R. Shaffer, and Julie H. Edmister (2003). Sustainability of aquatic systems and the role of culture and values. Achieving sustainable freshwater systems. M. M. Holland, Elizabeth R. Blood, and Lawrence R. Shaffer.; Toupal, R. S. (2003). "Cultural landscapes as a methodology for understanding natural resource
management impacts in the western United States." Conservation Ecology **7**(1): 12.

multiple "water-affecting activities," including changes in land use and water flow.[142] In terms of land-use changes, many participants discussed the negative ecological effects of deforestation on the river. In terms of flow modifications, participants in Bajo La Paz acknowledged the negative impact that the diversion plan would have on aquatic life.

In addition, the interviews with farmers showed that many farmers not only aware of the negative impacts of chemical pesticides and fertilizers on human health and ecological health, but they are also considering these factors in their decision-making process. They are also extremely knowledgeable about the multifaceted ecological benefits of certain common practices such as terracing.

However, our data does show a lack of awareness of water issues for a significant portion of watershed residents, as 38% of interviewees said there were no water problems in the area in the April interviews, less than half said there is no contamination in the river, and one-fourth said there is not less water in the river than in the past. Surprisingly, similar percentages were obtained from the December farmer interviews: Only 7 out of 15 farmers said there were problems with the river other than the diversion plan. When directly asked, 9 farmers said there was contamination in the river (5 saying "yes" and 4 saying "a little"). When directly asked, 10 out of 15 farmers said there was a problem with water quantity in the river.

Correlations Between Social Variables and Water-related Knowledge

To investigate the reasons why some watershed residents possess more extensive knowledge of water issues than other residents, my April Directed Research group ran statistical analyses on the correlations between various independent variables and answers to the four questions about water issues. Most of these independent variables are social variables (gender, occupation, education, income, age, and residency) that consider people's identity or status within the social system. The final independent variable we tested is source of drinking or irrigation water.

We found no statistically significant correlation between education level, occupation, or annual income and knowledge of the watershed and water issues (answers to the four main questions). The lack of correlation between education level and knowledge of water issues is intriguing—I had expected that more educated people would have a deeper understanding of water problems. This result might be explained by the fact that the four questions were not specific enough to test ecological knowledge, but more likely tested a general awareness of water issues. The first question, "Are there problems with water in the area?" is vague enough that education level is probably irrelevant; the second question, "Is there contamination in the river?" could be correlated with education level if only the higher-level curriculum includes material on contamination, but could also be answered using observation rather than classroom knowledge; the third question, "do you know about the diversion plan?" more closely tests people's awareness of political issues; and the fourth question, "do you think there is less water in the river now than in the past?" can be answered through observation rather than classroom information.

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[142] Falkenmark, M. (2003). "Freshwater as Shared between Society and Ecosystems: From Divided Approaches to Integrated Challenges." Philosophical Transactions: Biological Sciences **358**(1440): 2037-2049.

The result that occupation is not correlated to water-related knowledge is also surprising. Furthermore, the December farmer interviews with the April resident interviews supports the lack of correlation—farmers are no more likely to possess knowledge about the river than other residents. Farmers come into daily contact with the river, use it for multiple purposes, and must make crucial everyday decisions that directly impact the quantity and quality of the river water, so it is unclear why many farmers still do not think that the river is contaminated or there are any problems with the water. The lack of correlation may suggest that some farmers do not connect their agricultural decisions with the overall health or status of the river.

The lack of correlation between income and knowledge of water issues makes sense because there is a small income range within the watershed—most people have annual incomes close to the national average ($4590/year)[143], making them not wealthy but not struggling to survive either.

We also found no correlation between water source and knowledge of the watershed, despite our initial hypothesis that people who get drinking and/or irrigation water directly from the river, rather than supplied by the aqueduct or from a well, would be more aware of water problems. The vast majority of people we interviewed get their drinking water directly from Río La Paz, either from the aqueduct (which gets its water from the springs), a spring, or downstream, and the vast majority of farmers get their irrigation water directly from Río La Paz, either from a spring or downstream. The rest get their water from wells, which tap the water table that is also integral to the Río La Paz watershed. Therefore, everyone living in these communities is in some way directly dependent upon the healthy functioning of the river and the watershed. Since most people seem to know that the aqueduct water comes from the springs of the river, they may be just as concerned about problems affecting the river than those who obtain their water directly from the river.

Nonetheless, our data does illuminate certain trends among various other aspects of the social system—we found correlations with gender, age, and residency. Our April interview data show that men are more likely to respond affirmatively to the four questions than women. This could be in part due to occupation; women are most likely to be *amas de casa* (keepers of the house) while men are more likely to have other jobs that could relate to contamination of the river, such as farming or working in livestock operations or at the *trapiches*. Our data also shows that older people are more likely to respond affirmatively to the four questions than younger people; this could be due to knowledge and awareness of issues gained over time. Older people are more likely to remember the previous state of the river and make mental comparisons with its current state—they describe the river in the past as having more water and less contamination, with more forested and less populated borders. The knowledge that older people have about the history of their watershed should be valued and sought after when designing watershed management strategies.[144]

Our data also show that residents of La Esperanza are less likely, and residents of Bajo La Paz are more likely, to respond affirmatively to the four questions than people from other communities. The drastic difference in lifestyle between La Esperanza and

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[143] See note 135 above (UNICEF 2007).

[144] Steedman, R. J. (1994). "Ecosystem Health as a Management Goal." Journal of the North American Benthological Society **13**(4): 605-610.

Bajo La Paz residents could explain differences in awareness about water issues: Many residents of La Esperanza told us that although they live there, they work in San Ramón and often feel disconnected from the rest of the communities as a result. On the other hand, people in Bajo La Paz are more likely to have livelihoods connected to the watershed—many raise fish or farm using Río La Paz water, or manage trails running through the forest. Watershed management efforts should be aware of the effect of occupation and lifestyle on knowledge of water issues, and pursue strategies that integrate communities and raise awareness among people less directly connected to the watershed.

To summarize, we found a correlation between knowledge of water-related issues and age, gender, and community of residence; we found no correlation with education level, income, occupation, or source of water. Considering all of these results, I argue that more testing is needed to fully understand the nuanced correlations, including testing beyond the four limited questions I used. Nonetheless, it seems clear that in the future, community leaders and watershed planners should focus on educating those people with less extensive water-related knowledge—women, young people, and people living in downstream communities—about ecological issues such as contamination sources and the importance of keeping forested river borders. An emphasis should be placed on participatory education such as water quality monitoring that encourages hands-on involvement and future self-organization and governance.[145]

In addition, an effort should be undertaken to understand the underlying cultural reasons why these groups of people are less knowledgeable to begin with. For example, if women know less about the river because they are taught that their responsibilities are mostly domestic, efforts should be undertaken to empower women and increase their understanding of the crucial role they play in maintaining a healthy watershed, for example through participatory water quality monitoring.

Traditions

The 15 farmer interviews highlighted the importance of traditions in their decision-making process. While many more farmers cited economic reasons for their agricultural practices, some farmers directly cited traditions, so they should be investigated more fully. The traditions seem to mostly get passed down from generation to generation within families, but it seems that neighbors' practices also help shape traditions over time: about half of the farmers said that their agricultural practices were the same as their family's, and in response to a different question, about half of the farmers said that their neighbors' agricultural practices were the same as theirs. This result also indicates that many farmers do rely on traditions, even if they did not specifically cite them in other interview questions.

Specifically, farmers cited traditions as important in determining their crop selection, use of chemicals, and water source. For example, one sugarcane and coffee farmer said he has always lived by cane and coffee and it is his family's sustenance. In addition, it seems likely that the popular use of sprinkler irrigation is due in large part to traditions. While the single farmer using drip irrigation ensured us that the system is

[145] The Pennsylvania Department of Conservation and Natural Resources. "Watershed Education (WE)." Retrieved 5/11/09, from http://www.watersheded.dcnr.state.pa.us/.; Middleton, J. V. (2001). "The Stream Doctor Project: Community-Driven Stream Restoration." BioScience **51**(4): 293-296.

cheaper, easier, uses less water, and is healthier, the farmers using sprinkler irrigation thought that the system was more expensive, harder, and required more labor. Therefore, actual economic factors seem to be less important than the farmers' perceptions of economic factors, and these perceptions could be based on their traditions. In the future, communities should be educated about the exact benefits and drawbacks of the water-efficient drip irrigation system. To do this, many farmers mentioned that they learned some of their agricultural practices through courses taught by the agricultural extension service (INA); I would recommend a course on drip irrigation technology.

Watershed planners and government organizations working with the communities like AyA should recognize that traditions influence everyday practices and land-use decisions that impact the natural environment. Therefore, when introducing a new practice such as drip irrigation or a natural fertilizer, they should be aware that people's initial response will be to keep their old practices. It seems that people are more likely to make incremental changes that do not drastically alter their traditions, so these types of changes should be persistently encouraged in striving towards a more sustainable watershed.[146]

Value Paradigms

The varying reasons farmers gave for why the river was important to them, why people in their community wanted to protect the river, and how humans should relate to the natural environment help reveal the farmers' differing value paradigms. The value paradigms help structure their perceptions of themselves in relation to the river and the natural environment, like the dominant discourses below. However, while the discourses below can represent or misrepresent real facts about ecological systems, value paradigms cannot be right or wrong but rather concern how the farmers value nature.

The majority of the farmers' statements represent an anthropocentric value paradigm based on use of resources: they portray the river as a source of goods and services for humans. These goods and services include water for human consumption, the consumption of livestock that humans raise, irrigation water, water for industry as in the sugarcane factory, the ability to fish for recreation, and the opportunity for jobs. Many other responses are anthropocentric even if they do not explicitly contain a resource-based approach, explaining the river's importance in terms of its effect on humans. A common example of this approach is the appeal to future generations: many farmers expressed that they want to protect the river for the sake of their children and grandchildren. In my experience, women were more likely to make claims based on future generations while men were more likely to make claims based on the resources the river provides. This could be linked to occupation and more subtle cultural expectations of gender roles—women more often care for the children while men must use the river for various farming tasks.

Many less responses indicate a more ecocentric value paradigm that perceives nature as a holistic system with intrinsic value; in other words, the environment is not just important because it provides resources to humans but important because it sustains the life of plants, animals, and humans, and encompasses complex socio-ecological systems.

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[146] Davis, S. A., Lawrence R. Shaffer, and Julie H. Edmister (2003). Sustainability of aquatic systems and the role of culture and values. Achieving sustainable freshwater systems. M. M. Holland, Elizabeth R. Blood, and Lawrence R. Shaffer.

For example, one farmer describes our duty to protect the river because it has always existed, suggesting he values the river not for its explicit benefit to humans but because it existence, an example of intrinsic value. When asked why people want to protect the river, some farmers state, “We have love for life,” “It is that which provides us existence,” and “It is life. Without water we won’t have anything.” These responses acknowledge an importance of water beyond its use as a resource for humans. The more ecocentric value paradigm was revealed the most in response to the rather abstract question, “How should humans relate to the natural environment?” Here some farmers indicated that they were thinking about the interrelationships between the natural environment and humans—for example, one farmer said “If we respect [the natural environment] more, it will respect us...Contamination hurts us too.” Another farmer said “Using natural resources, but in a sustainable development...Use them in a sustainable development for the environment and for the human being. Work in equilibrium with nature.” Another farmer used a duty-based approach in explaining why we should protect nature while acknowledging our dependence on natural systems by saying, “What we have to do is take care of it, try to not contaminate it, to live well. To contaminate is to break relationships with the environment.”

These results suggest that value paradigms are complex and heterogeneous even within small communities, affecting people’s environment-impacting decisions in subtle ways. Therefore, more research should be undertaken to understand patterns of value paradigms, how they are distributed and propagated within and between communities, and how exactly they inform people’s decision-making behavior. It is important for watershed managers, community leaders, and government organizations to recognize that value paradigms most likely play a significant role in the way people relate to their natural environment. For example, a farmer who values the river mostly because it provides him with water for his livestock and crops may not be as likely to use natural pest control methods than a farmer who values the river for its service to future generations and its ability to sustain plants, animals, and people.

Dominant Discourses

Our data show that watershed residents hold certain misconceptions and over-simplifications about water issues that get propagated through discourses or narratives. Throughout the interview process, it became evident that watershed residents repeat certain discourses in response to certain questions. These discourses are like stories that are told to explain how humans ought to act in relation to the natural environment or how the natural environment operates. Discourses are used in every culture to help explain and structure the world. For example, in the U.S. a popular current discourse is that hybrid cars will save the world from global warming and allow us to continue our current habits of over-consumption.

The first striking discourses concerned the contamination sources in the river. First, many people said that household trash is a large contamination source. Trash was the most commonly cited contamination source in the April interviews of watershed residents (Table 3) and the December interviews of farmers. Many respondents elaborated, saying that “outsiders throw trash in the river” (*gente de afuera tira basura en el río).* People also blamed water contamination on the dirty practices of pig farms. After household trash and agrochemicals, pig farms were the most often cited contamination source in the April interviews of watershed residents. Surprisingly, pig farms ranked second, behind household trash, in the contamination sources cited by farmers in December interviews, while pesticides and agrochemicals ranked fourth.

The second set of discourses concerns the actions that people thought should be taken to improve water quality and quantity. Surprisingly, 12 out of 15 farmers said that reforestation could actually increase the levels of water in the river, another farmer said that it couldn't increase levels but it could help maintain the current levels, and the remaining two farmers said that protection of forests could increase water levels. When asked how water quality in the river could be improved, three farmers cited reforestation and one cited protection of forests. Many people also thought that raising awareness or improving consciousness (*mejorando conciencia)* could improve water quality or quantity. The farmers interviewed in December most commonly cited improving consciousness as a way to improve the water quality of the river, and three farmers also suggested improving consciousness to increase water quantity. Throughout the April and December interviews, watershed residents mentioned improving consciousness at various points in the interviews. However, their explanations would usually end there—while two people mentioned education and conservation programs on TV, the majority did not suggest any particular method.

I would argue that these discourses are essential components of the cultural fabric of watershed residents, often informing their ethical frameworks: people use these discourses to help explain crucial questions about how they *ought to* act in relation to their natural environment. As with the pig farms and household trash discourses, this often involves displacing the blame for environmental problems onto others outside of one's own social sphere. Rather than relying directly on scientific information, government policies, or economic cost-benefit analyses, it seems that people often rely on these discourses.

However, discourses have the potential to simplify or reinterpret reality. For example, although pig farms were blamed as a large contributing factor to contamination in the river, many more farmers own cows than pigs, and a larger number of cows than pigs. There are no large-scale pig farms in the watershed but rather many farmers with a small number of pigs each. Therefore, the insistence on pig farms (not just pig manure) as large contamination sources does not represent reality, and could be a way to scapegoat the problem, blaming these mysterious pig farms rather than themselves for contamination. In this way, their current behavior is rationalized so the necessity to change their practices is eliminated. Similarly, the repeated motif of "outsiders throwing trash in the river" is equally mysterious and misrepresentative of reality. Outsiders do not generally visit these communities, and if they do occasionally throw a soda bottle into the river, they are not dumping entire bags of garbage like people said households in the watershed were doing. Again, it seems easier to blame the "outsiders" than oneself for contamination problems. Furthermore, although household trash does pose a threat to water quality if the practice still continues, it is not the most damaging to the ecological integrity of the watershed—pesticides and other agrochemicals contaminate much more thoroughly and pose more significant problems to the aquatic life and functioning of ecosystem processes. Finally, it is still an open question among hydrologists whether reforestation increases or decreases streamflow. It is probable that planting trees along river borders and at the sources of rivers actually decreases streamflow because the trees will evaporate more water than other land-uses such as a pasture or cropland. However, in cloud forests the situation is more complicated because the trees also increase deposition of water vapor in clouds—in other words, the trees remove water from clouds passing through the forest and bring the water to the ground where it can easily enter streams and rivers, increasing the streamflow.[147] In any case, the process is complicated and uncertain. There is a definite benefit to keeping a forested border along the river in terms of water quality—the shade from the trees keeps water temperatures low which supports a diversity of aquatic life, reduces erosion, and filters pollutants, among other benefits.

There also seems to be a disconnect between how the residents think they should act and how they actually act. While all 15 farmers said that reforestation or protection of forests is important in improving water quantity, only one mentioned that he actually does plant trees himself. Many people said improving consciousness was crucial, but few spoke about how this could be accomplished or how they contribute themselves.

In addition, overlapping discourses present an interesting dynamic. For example, many people said that trash thrown in the river is the greatest source of contamination, but only two people cited not throwing trash in the river when asked how water quality could be improved; instead, they said reforestation and improving consciousness. Therefore, it seems that the discourses have a rigid structure, associated with a limited number of concepts. Since narratives are real and functioning, we need more research into how narratives can be changed to better reflect the true state of the watershed, to more effectively support the interrelated functions of the watershed's social-ecological system.

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[147] Calder, I. R. (2002). Forest valuation and water--the need to reconcile public and science perceptions. Understanding and capturing the multiple values of tropical forest: International Seminar on Valuation and Innovative Financing Mechanisms in support of conservation and sustainable management of tropical forest. P. A. Verweij**:** 49-62.

Conclusion: Towards Socio-Ecological Sustainability

Considering all of my results, I first conclude by asserting that culture affects land-use decisions made by individuals that alter the water quality or quantity of the Río La Paz microwatershed. More broadly, I argue that culture must be considered in any sustainable watershed management plan. The specific aspects of culture that emerged as the most important in my study include traditions, value paradigms, and discourses or narratives. First, people relied on traditions of their family or neighbors to help inform their agricultural practices. Second, people tended to value the river and the natural environment for the resources they provide to humans, which may more subtly impact their perceptions and land-use decisions. Third, discourses about contamination and water conservation activities oversimplify and misrepresent the complexities of the socio-ecological system, leading to inaction or ineffective actions in protecting the environment.

However, these categories are fluid and interchanging, and more aspects of culture that I did not address likely also play a role in individuals' decision-making behavior. For example, I did not address whether people perceive consequences or duties as more important in their moral framework. We should also consider the heterogeneity within "communities"—such as the varying degrees of knowledge held by people of different ages, genders, and places of residency—and value the unique knowledge possessed by different groups while explicitly working towards more equitable information flow. In this study, I recommend that organizations work with women, younger people, and downstream communities to help them understand more scientific information about the ecology of the watershed.

I recommend that an emphasis should be placed on participatory education such as water quality monitoring that encourages hands-on involvement and future self-organization and governance.[148] [149] For example, participatory water quality monitoring involves encouraging community members to perform simple physical, chemical, and biological sampling on the river. This will help people recognize more concrete connections between the ecological life of the river and human modifications of the watershed, while helping the community develop a greater sense of ownership of the river.[150] In addition, water quality monitoring could make cultural expectations fit more with reality by allowing for incorporation of local knowledge and use of differing value paradigms, and by slowly reforming misleading discourses or narratives about the ecological functioning of the watershed.[151] Finally, it will begin to create a database of crucial information that could help communities, organizations, and institutions evaluate

[148] Veelen, M. v. a. F. C. v. Z. (1995). "Integrated Water Quality management: getting people involved in the Jukskei River." Wat. Sci. Tech. **32**(5-6): 153-159, Richter, B. D. (In Press). "Ecologically Sustainable Water Management: Managing River Flows for Ecological Integrity." Ecological Applications.

[149] See note 145 above (Pennsylvania 2009 and Middleton 2001).Middleton, J. V. (2001). "The Stream Doctor Project: Community-Driven Stream Restoration." BioScience **51**(4): 293-296.

[150] Ugalde, A. (4-19-2008). Personal comm. Water management in Costa Rica. A. Gulley. Angeles Norte, Costa Rica.

[151] Steedman, R. J. (1994). "Ecosystem Health as a Management Goal." Journal of the North American Benthological Society **13**(4): 605-610.

the current state of the river in making management decisions, which could eventually be compared with past data.

Finally, I also argue that these cultural aspects cannot be adequately addressed using only socioeconomic or scientific perspectives. The existing water management literature focuses almost exclusively on science and economics, ignoring cultural aspects that also impact people's decisions that alter the natural environment. In the future, watershed planners, theorists, community leaders, and government organizations need to focus more on incorporating cultural approaches into their plans, in striving towards socially and ecologically sustainable watersheds.

Policy Recommendations

My investigation has allowed me to brainstorm ways in which the Costa Rican government could adopt more effective policies to deal with water problems. Here I outline some of them:

1. Establish Basic Water Requirements. Within the national Water Law, set a Basic Water Requirement for ecosystem use and human domestic use. This requirement should not be viewed as a one-size-fits-all threshold but rather as a standard that can be adapted to watersheds throughout the country, depending on specific needs. For example, a watershed in a mountainous cloud forest will need differing percentages of river flow than a watershed in a flat dry forest. For example, South Africa's 1998 National Water Act sets aside specific quantities of water called "Reserves" for human health (25 L/day/person) and aquatic ecosystems (11-28% of median annual flow).[152]

2. Raise the national price of water. To alleviate the under-funding of AyA, ARESEP should raise the national price of water. The current price of 155 colones, or $0.27 US dollars per cubic meter of water could be raised substantially; for example, in the US water is sold at an average of $1.22 per cubic meter.[153] The increased income from raising the price could help at least maintain the aqueduct system in good condition—reducing water losses from leaks and other problems—and expand the system where needed. Raising the price would also encourage water-saving behavior in consumers, reducing many problems from water shortages.[154]

3. Hold large tourist businesses accountable for water. Services comprise 62% of Costa Rica's GDP, compared to 29% from industry and 8.5% from agriculture.[155] This means that Costa Rica's economy is highly dependent on revenues from tourism, and the government has been attracting foreign investors to construct new hotels, restaurants, golf courses, and other tourist attractions at an incredible rate. However, these tourist businesses often threaten freshwater supplies, taking water directly from communities' aqueducts and sparking protests that sometimes turn violent.[156] Therefore, large tourist businesses should be legally bound to pay to expand the municipality's aqueduct system to supply the necessary increase in water, or to locate their own water supplies that are not already in use, such as constructing wells.

4. Provide government incentives for drip irrigation and other water conservation activities. Since such a small percentage of Costa Rica's GDP is derived

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[152] See note 140 above (Falkenmark 2003); Republic of South Africa. (1998). "National Water Act, Act no. 36 of 1998, Chapter 3 Part 3." Retrieved 4/11/09, from ftp://ftp.hst.org.za/pubs/govdocs/acts/1998/act36.pdf.

[153] Pennsylvania State University. (2008). "Household Water Conservation." 4/11/09, from http://pubs.cas.psu.edu/FreePubs/pdfs/uh164.pdf.

[154] Rogers, P. (2008). "Facing the Freshwater Crisis." Scientific American **July 22**.

[155] Gapminder Foundation. "Agriculture, Industry, Services—value added (% of GDP)." Gapminder World Retrieved 1/26/09, from http://graphs.gapminder.org/world/.

[156] Cantero, M. (2008, May 20). "Turba vapuleó a policías en protesta por acueducto." La Nación, from http://www.nacion.com/ln_ee/2008/mayo/21/pais1544922.html.

from agriculture, there may be a tendency for the government to prioritize water use for service and industry. However, small-scale agriculture comprises the livelihood and cultural backbone of many communities and provides sustenance for many families. In an effort to conserve freshwater flows and protect farmers' livelihoods, the government should offer subsidies, grants, or other incentives for drip irrigation at least. They could also consider providing incentives for wells, rain storage tanks, efficient sprinkler heads, and other technologies.

5. Don't let CAFTA threaten freshwater already allocated to communities. Within the new framework of CAFTA, Costa Rica will have to battle with the potential for private corporations—including huge multinational corporations—to exploit freshwater flows already in use by communities for domestic purposes, agriculture, and industry.[157] If it is inevitable that corporations like Coca-Cola will infiltrate the country to bottle water and export it or use the water for other purposes, then the Costa Rican government will have to work hard to protect the water supplies of small-scale farmers. Luckily, Latin America has withdrawn less than two percent of its freshwater resources.[158] Therefore, the government should require corporations to use only previously untapped water resources in Costa Rica that do not interfere with the water sovereignty of communities.

[157] Florez-Estrada, M. (4-11-2007). "Costa Rica: CAFTA threatens to turn water into merchandise." Latinamerica Press Retrieved 1/27/09, from http://www.bilaterals.org/article.php3?id_article=10204.
[158] FAO. "Water at a Glance." Retrieved 4/11/09, from http://www.fao.org/nr/water/art/2007/glance/managing3.html.

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Appendix A.
Semi-structured interview instrument for interviews conducted April 17-24 in the Río La Paz microwatershed. English translation.

Interview about Uses of Water (April 2008)

General____

1. Name:
2. Name of residence or farm: 3. Location:
4. Age: 5. Sex: Male__ Female__
6. Education: 7. Annual salary:

8.What do you use water for? To drink______ Irrigate_______ Domestic uses______ Other______
9. The water you use comes from:
Río la Paz?___Another river or stream?___the spring?___a well?__ the aqueduct?

10. Do you pay for the water you use? Yes______ No_______
11. Do you have a water meter? How much do you pay today for a cubic meter of water? Yes______ No_______ How much_______
12. Would you be willing/ready to pay for your water use? Yes_______ No_______

Agriculture and Irrigation____

13. What do you grow?

14. What is your income per crop?

15. What irrigation systems do you use?
Sprinkler__________ Gravity________ Drip___________
16. How much does your irrigation cost per week or month in: The summer?______ The winter?_________

17. How much do you spend on energy for irrigation?

18. How many liters of water do you use per minute for irrigation? How much water do you use in a month for irrigation?
per minute________ per month_________

19. What crops do you irrigate and which needs the most water?

Lettuce________Tomato_______Onion_______Garlic_______ More?__________

20. When do you irrigate and for how much time?
In the day: When_____________ How much time______________

In the night: When___________ How much time______________

Institutions____

21. Are you familiar with the following institutions?
AyA ASADAS MINAE
22. What do the following institutions do in relation to Río La Paz?
AyA:
ASADAS:
MINAE:

23. Do you participate in any groups dealing with water issues? (como Desarrollo Comunal, Junta de Agua)
Yes______ No______
24. What are some problems in this area in relation to water?

25. How important are the following water problems for you?

	A lot	A little	Not important
Administration	______	_______	_______
Scarcity	______	_______	_______
Distribution	______	_______	_______
Contamination	______	_______	_______

26. Do you know the future plans for using the water from Rio La Paz?
Yes______ No______

Concessions____

27. Compared to previous years do you think there is a difference in the quantity of water available?
Yes______ No______

28. Do you have a concession for using water? Yes ______ No______

29. If not, do you know what a concession is? Yes ______ No______

30. Do you know how to apply for a concession? Yes ______ No______

Contamination____

31. Is there contamination in Río La Paz or another stream? Yes______
No______

32. Have you ever gotten sick from drinking water from the river? Yes ______
No______

33. Do you purify the water you drink? Yes ______
No______

34. Do you know any method for avoiding contamination of the water?Yes ______
No______

Conservation

---

35. What are the most important sectors in the misuse of water?
Agriculture_______Irrigation_______The home______
Livestock______Others_______

36. What are the sectors that waste the most water?
Agriculture_______Irrigation_______The home______
Livestock______Others_______

37. Do you know any method for conserving water? Yes ______ No______

38. Do you practice any method for conserving water? Yes ______ No______

Appendix B. Survey instrument for residents used May 10-29 in the Río La Paz microwatershed. English translation.
*Note: We crossed out the areas indicated before handing out the surveys since they were confusing or not useful.

Survey About the Use and Protection of Water in Rio La Paz

Location (Community you live in)

Age		Sex	M F	Education	Primary Secondary Univ PostGrad Other
Monthly family income				Members of family	

Uses of water

Do you use aqueduct water Y N How much do you pay monthly
What do you use it for? Drinking Irrigating Washing Other
Do you use well water Y N
What do you use it for? Drinking Irrigating Washing Other
What do you pay monthly for the well concession?
Do you use river/stream water Y N | Drinking Irrigating Washing Other
Do you pay anything for the use of the river water? Y N How much per month?
Would you be interested in forming part of a water organization? Y N Maybe Don't know
Do you irrigate your garden? Y N
Where do your black and gray waters go? River SepticTank Hole Seedlings
Do you have pigs Y N How many
Do you have livestock Y N How many

Use of the Soil	Total area of the farm				
Coffee	area	Irrigate Y N	Use fertilizers Y N	Pesticides Y N	
Sugar cane	area	Irrigate Y N	Use fertilizers Y N	Pesticides Y N	
Horticulture	area	Irrigate Y N	Use fertilizers Y N	Pesticides Y N	
Pastures	area	Irrigate Y N	Use fertilizers Y N	Pesticides Y N	
Forest	area	Irrigate Y N	Use fertilizers Y N	Pesticides Y N	
Other	area	Irrigate Y N	Use fertilizers Y N	Pesticides Y N	
Total					

~~**Factors that influence water use (0 is not important 5 is very important)**~~

~~Nature as a source of water 0 1 2 3 4 5~~
~~Rio La Paz as a source of water 0 1 2 3 4 5~~
~~"Clean" water for agricultural uses 0 1 2 3 4 5~~
~~Having a clean Rio La Paz 0 1 2 3 4 5~~

With respect to the following factors how have things changed in the last 10 years?
0 they haven't changed at all 5 they've changed a lot

The quantity of water in Rio La Paz	0	1	2	3	4	5
The quantity of rain	0	1	2	3	4	5
The availability of firewood for cooking	0	1	2	3	4	5
The dirtiness of the streams	0	1	2	3	4	5
The dirtiness of rio La Paz	0	1	2	3	4	5
The quantity of people using water from Rio La Paz	0	1	2	3	4	5
Willingness to do something and protect the water	0	1	2	3	4	5

Today San Ramon and Palmares have water shortages, and they plan to divert at least 100L/sec from Rio La Paz for their use. On a scale where 0 represents that you don't want to do anything and 5 where you would be very involved in figuring out how to resolve the problem.

In the future I would be ready to form part of groups dealing with themes of water	0	1	2	3	4	5
I would get a concession to continue using the water that I need	0	1	2	3	4	5
I would support those who protect water in the community	0	1	2	3	4	5

How much would you be willing to accept in colones/month, ~~so that Palmares and San Ramon divert the 100L/sec that they want to divert and to protect the springs from deforestation?~~

THANK YOU FOR YOUR TIME AND COLLABORATION.

Interview for Farmers (December 2009)

Communities of Bajo La Paz, La Paz, Bajo Zúñiga, Piedades Norte, and La Esperanza

My name is [_____] and I'm a student working on a project for my university in the United States and the university in Atenas (Center for Sustainable Development Studies). My project is about Río La Paz and the agricultural practices of farmers in Bajo La Paz, La Paz, Bajo Zúñiga, Piedades Norte, and La Esperanza. Could you help me with a 40-minute interview? Your answers will be confidential.

Date:
Description of address:

Part I

---

1. What do you grow? How many *manzanas* of each crop do you have?

   Sugar cane______ Coffee______ Vegetables (List all)________________________
   Other (describe) _______________ ________________________
   ____
   ____
   ____
   ____

2. Why did you decide to grow [____________]?
   1)

   2)

   3)

   Are there advantages to growing these crops? *If yes*, what?
   1)

   2)

   3)

   Are there disadvantages to growing these crops? *If yes*, what?
   1)

   2)

   3)

Have you considered growing other crops? Why or why not?

3. Do you fertilize your crops?___
   If yes: How (e.g. chemicals, manure, compost, charcoal, field rotation)?

   (If applicable): Where do you get them?
   What crops do you fertilize?

   Do you use them on pastures?___*If yes,* how many manzanas?___
   Why do you fertilize in this way?

   Are there any other advantages to fertilizing in this way?

   Are there any disadvantages to fertilizing in this way?

   If yes or no: Have you ever considered fertilizing by [using chemicals/using a natural
   method such as manure, compost, charcoal, or field rotation?]___
   Why or
   why not?

4. Do you use any pest control methods?___
   If yes: Could you describe them (e.g. pesticides, insecticides, fungicides, diversifying
   crops, mulching)?

   (If applicable): Where do you get them?
   What crops do you use them for?
   Do you use them on pastures?___*If yes,* how many manzanas?___
   Why do you use these pest control methods?

   Are there any other advantages to using these pest control methods?

   Are there any disadvantages to using these pest control methods?

If yes or no: Have you ever considered using [chemical pesticides/using natural pest control methods such as diversifying crops, mulching, cover cropping]?___
Why or why not?

5. Do you use terracing?____
If yes: Why do you use terracing?

Are there any other advantages to terracing?

Are there any disadvantages to terracing?

If no: Have you ever considered terracing? Why or why not?

6. Do you use any other methods to conserve soil?____(*If no, suggest: mulching, growing cover crop/agroforestry, reforestation)*

If yes: What method(s)?

Are there any other advantages to this method?

Are there any disadvantages to this method?

If no: Have you ever considered a soil conservation method? Why or why not?

7. Do you have pigs, cows, or other animals?____
If yes: How many?
What happens to the manure?
Do you keep them near the river?

8. What do you do with your house's trash?_________________
Do you compost your food waste?____

Why do you dispose of your trash in this way?

Are there any other advantages to disposing trash in this way?

Are there any disadvantages to disposing trash in this way?

Have you ever considered [*circle one: throwing it in the river/burning it/getting it picked up*]?___ Why or why not?

Have you ever considered [*circle one: throwing it in the river/burning it/getting it picked up*]?___ Why or why not?

Part II

9. Do you irrigate any of your crops?___ ***If no, skip to question #15***
If yes, continue with this section

Which ones?

10. What type of irrigation system do you use?
Sprinkler____ Gravity____ Drip____ Other (describe)____

Why do you use this type of irrigation system?

Are there any other advantages to this type of irrigation system?

Are there any disadvantages to this type of irrigation system?

Have you ever considered [*circle one: sprinkler/gravity/drip*] irrigation? Why or why not?

Have you ever considered [*circle one: sprinkler/gravity/drip*] irrigation? Why or why not?

11. Where do you get your irrigation water?
a) Aqueduct
How much is your *monthly* water bill in
the summer?________ the winter?________
b) River, Stream, Spring, Well
Do you have a concession for the water you use?
How much does energy for pumping the water cost *each month* in
the summer?________ the winter?________
How much water do you use *per day* to irrigate in
the summer?________ the winter?________

Why do you get your irrigation water there?

Are there any other advantages to getting your irrigation water there?

Are there any disadvantages to getting your irrigation water there?

Have you ever considered getting your irrigation water from the [aqueduct/river/well]? Why or
why not?

Have you ever considered getting your irrigation water from the [aqueduct/river/well]? Why or
why not?

12. What time of day do you irrigate and for how many hours?

In the day: When_______________ How many hours_______________

In the night: When_______________ How many hours_______________

Why do you irrigate at these times?

Are there any other advantages to irrigating at this time?

Are there any disadvantages to irrigating at this time?

Have you ever considered irrigating during the [day/night]? Why or why not?

13. Do you use the same quantity of water for all your crops?___

If no: Which crops require the most water? Which crops require the least water?

14. Do you use a water conservation method such as a rain barrel or storage tank for your irrigation water?

If yes: Which ones?

Why do you use these water conservation methods?

Are there any other advantages to using these methods?

Are there any disadvantages to using these methods?

If no: Have you ever considered using a water conservation method for your irrigation water?

Why or why not?

Part III

---

15. How many years have you been farming?

16. Where did you learn your farming techniques?

17. Are any of your agricultural practices different from those of your [father/organization/etc]?___
If yes: How?

18. Are your agricultural practices different than your neighbors'?___
If yes: How?

Part IV

19. Is Río La Paz important to you?___
Why or why not?

20. Are there any problems with Río La Paz?___
If yes: What?

What will happen if these problems continue?

21. Are there problems with contamination in the Río La Paz?___ Why or why not?

If yes: What types of contamination are in the river?

Where does the contamination come from?

Who or what contaminates the river the most (for example, houses, trapiches, lecherías, chancheras, agricultures)?

Do you think anything can be done to improve the water quality of Río La Paz?___ *If yes:* What?

If yes or no: Do__________ contaminate the Río La Paz? (*If no, why not?)*
Pesticides
Fertilizers
Manure
Soil

22. Are there problems with the quantity of water in Río La Paz?___ Why or why not?

If yes: Who or what wastes the most water (for example, houses, trapiches, lecherías, chancheras, agricultures)?

Do you think anything can be done to increase the quantity of water in the Río La Paz?___ *If yes:* What?

If yes or no: Has the quantity of water in Río La Paz changed in the last 10 years?___
If yes: How?

23. Are there problems with the administration of Río La Paz?___ Why or why not?

24. Do people in your community want to protect the river?___
If yes: Who?
If yes or no: [Why do/why don't] they want to protect the river?

25. How should humans relate to their natural environment?

26. Is there anything else you'd like to add?

General

30. Community (ask!): *Bajo La Paz* *La Paz* *Bajo Zúñiga* *Piedades Norte* *La Esperanza*
31. Age:
32. Sex:
33. Education (N, P, S, U, PG):
34. *Monthly* family income:
35. Members of family:

36. Do you participate in any of the following organizations?
    Community Development group
    Water board
    Church group
    School board
    Others:

Appendix D. Water Quality Monitoring: Methods, Results, Discussion.[159]

Methods

We performed basic water quality tests at five points along Río La Paz on April 23, and one point on Río Barranca, downstream of its confluence with Río La Paz on April 21. At each location, we used a hand-held SperScientific Water Quality Meter to measure the temperature, conductivity, and pH of the water. We measured the Dissolved Oxygen content at one point on the river before the meter broke, and the pH values could not be used due to a fluctuating baseline. In addition, we measured the river depth, width, and velocity in order to calculate stream flow. We measured the river depth and width using a meter tape and the water velocity directly upstream or downstream of the riffle sampling area by timing how long it took a stick to float twenty meters downstream.

Finally, we collected benthic macroinvertebrates at each location to use them as ecological indicators of the river health. Emma Kravet and I sampled every location on the same day (April 23), except for the Río Barranca site (April 21). We collected the macroinvertebrates from rock habitats of shallow riffles by holding colinders downstream of rocks we disturbed with our hands and then using tweezers to pick macroinvertebrates directly off of the rocks. We each sampled for twenty minutes and changed locations in the stream approximately every five minutes to control for the diversity of microhabitats. We used tweezers to place the macroinvertebrates into small jars of alcohol marked by location. Back in the lab, we used a dissecting light microscope and guides to macroinvertebrates (Pérez 1988, Lehmkuhl 1979) to identify the macroinvertebrates to Order. We compiled this information into an Excel database. We used Hilsenhoff's family level Pollution Tolerance Values (PTV) to calculate the average PTV for each Order; then we used these Order averages to calculate the mean PTV for each river location (Hilsenhoff 1988).

Results

The temperature at the *naciente* of Río La Paz was significantly colder (18.9°C) than the temperatures further downstream (**Figure 1**). After a spike in temperature around La Paz, where we observed algae on the rocks in the river, there is a general trend of decreasing temperature as distance downstream increases.

[159] Gulley, A. (2008). "Working Towards Adapative Co-management of Freshwater Systems: A Case Study from the Río La Paz Watershed, Costa Rica." School for Field Studies Directed Research paper.

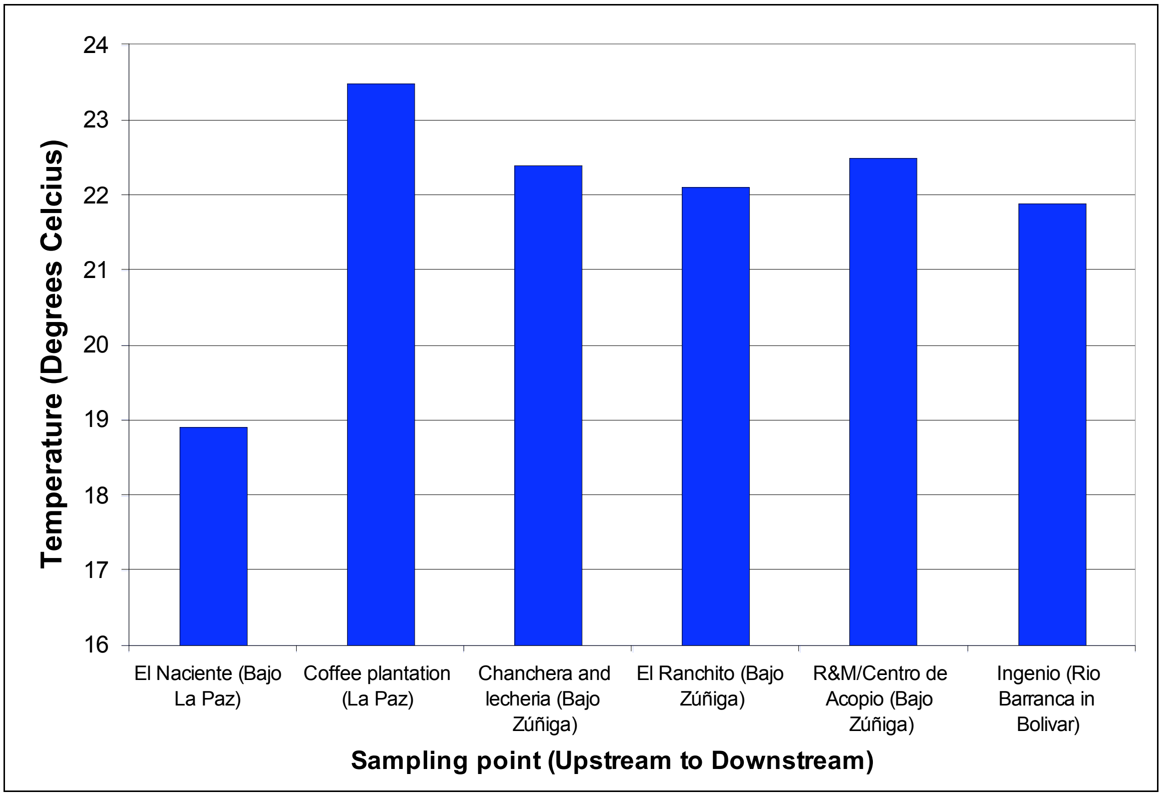

Figure 1. Water temperature of sampling points in Río La Paz

Conductivity in Río La Paz steadily increased with distance downstream (**Figure 2**). There was a large spike in conductivity downstream of the sugar cane processing plant (*ingenio*) on Río Barranca. Conductivity is a measure of the amount of electricity that the water can conduct, which increases with an increasing level of ions. Ions can be added to the water through agricultural run-off, urban run-off such as road salt, and sewage (Water on the Web 2004). Evaporation of river water also increases conductivity by concentrating the ions (Water on the Web 2004).

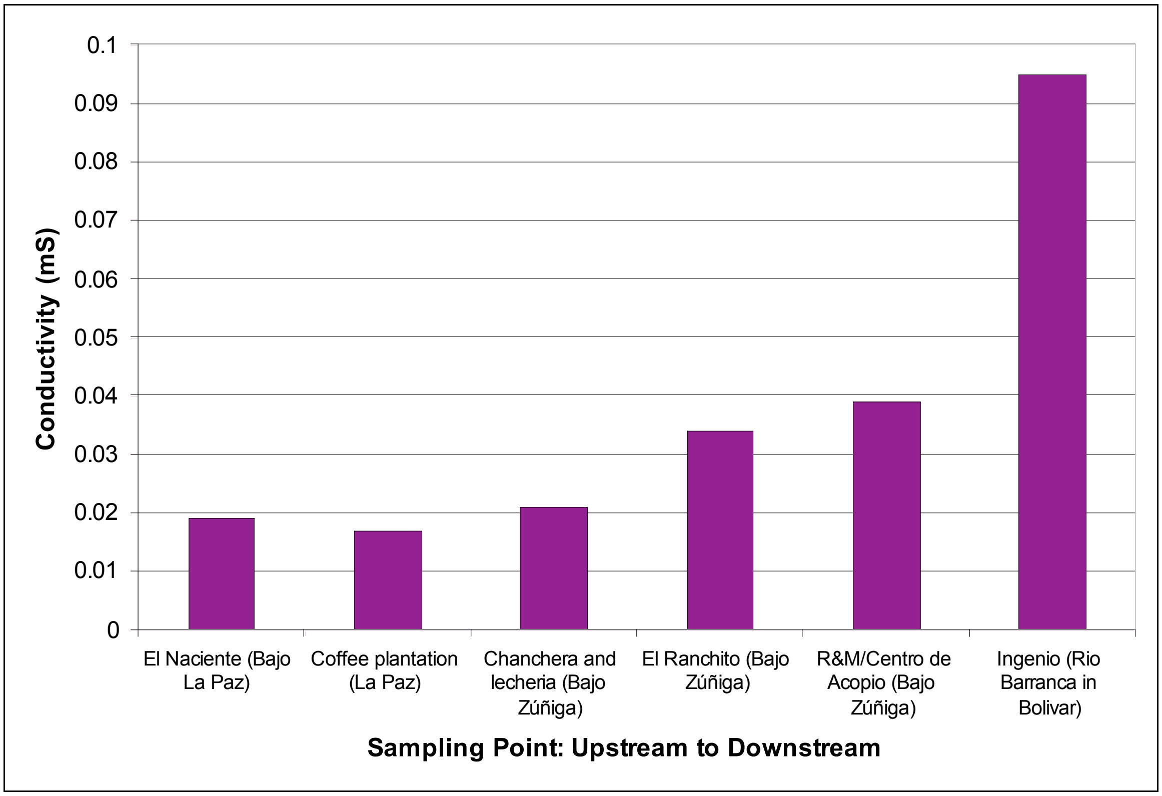

Figure 2. Water conductivity of sampling points in Río La Paz

The mean Pollution Tolerance Values of macroinvertebrates generally increase as distance downstream increases (**Figure 3**). Hilsenhoff, who developed the Family-Level Biotic Index, defined the water quality in relation to these pollution tolerance values as follows (1988):

TABLE 2. Evaluation of water quality using the family-level biotic index.

Family Biotic Index	Water Quality	Degree of Organic Pollution
0.00–3.75	Excellent	Organic pollution unlikely
3.76–4.25	Very good	Possible slight organic pollution
4.26–5.00	Good	Some organic pollution probable
5.01–5.75	Fair	Fairly substantial pollution likely
5.76–6.50	Fairly poor	Substantial pollution likely
6.51–7.25	Poor	Very substantial pollution likely
7.26–10.00	Very poor	Severe organic pollution likely

Under this evaluation scheme, all of the water sampled is considered “Excellent” or “Very Good,” with slight or no organic pollution likely. The sites of the *naciente,* coffee plantation, and *Centro de Acopio* on Río La Paz are considered “Excellent,” while the sites of the *chanchera and lecherí* and *El Ranchito* on Río La Paz and the *ingenio* on Río Barranca are considered “Very Good.”

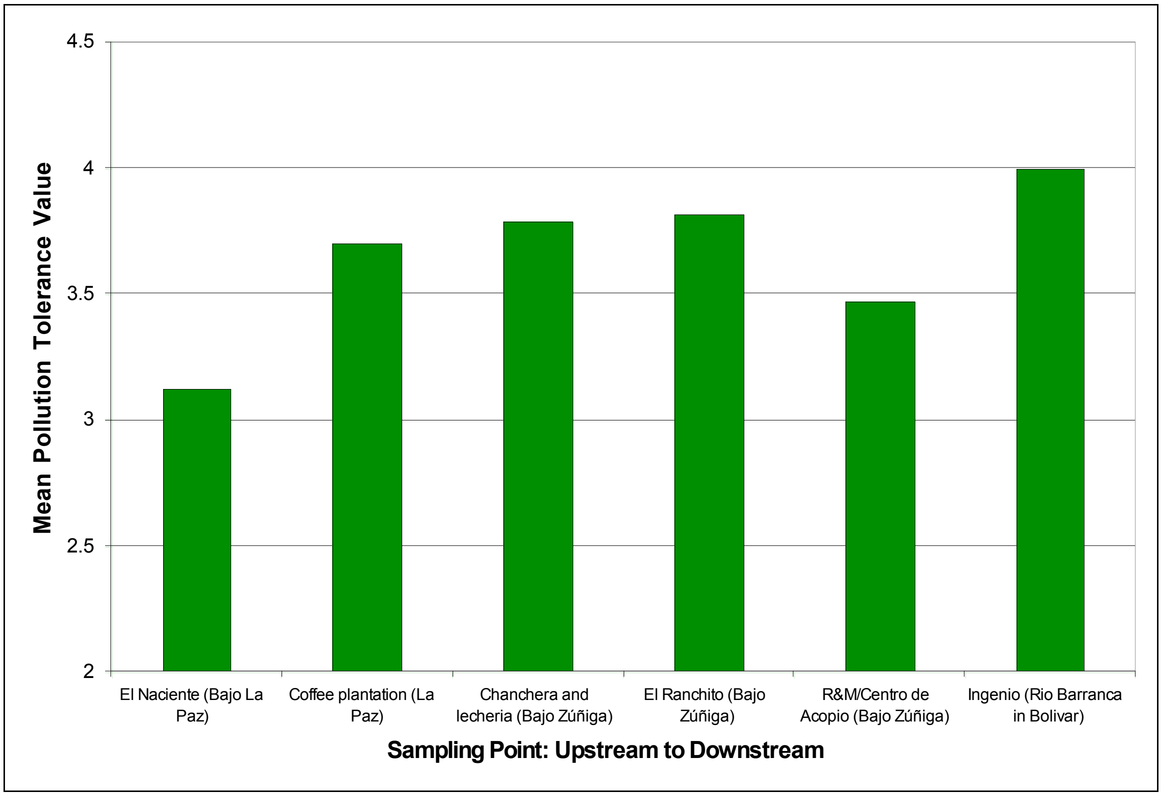

Figure 3. Mean Pollution Tolerance Values (PTV) of benthic macroinvertebrates sampled in Río La Paz, according to location.

We calculated the stream flow of Río La Paz to be between 200-600 liters/second, except for at the chancera and lechería point, directly downstream of where the large Quebrada Manco joins Río La Paz (Figure 4). After Río La Paz empties into Río Barranca, we calculated the stream flow to be about 2300 liters/second (**Figure 4**).

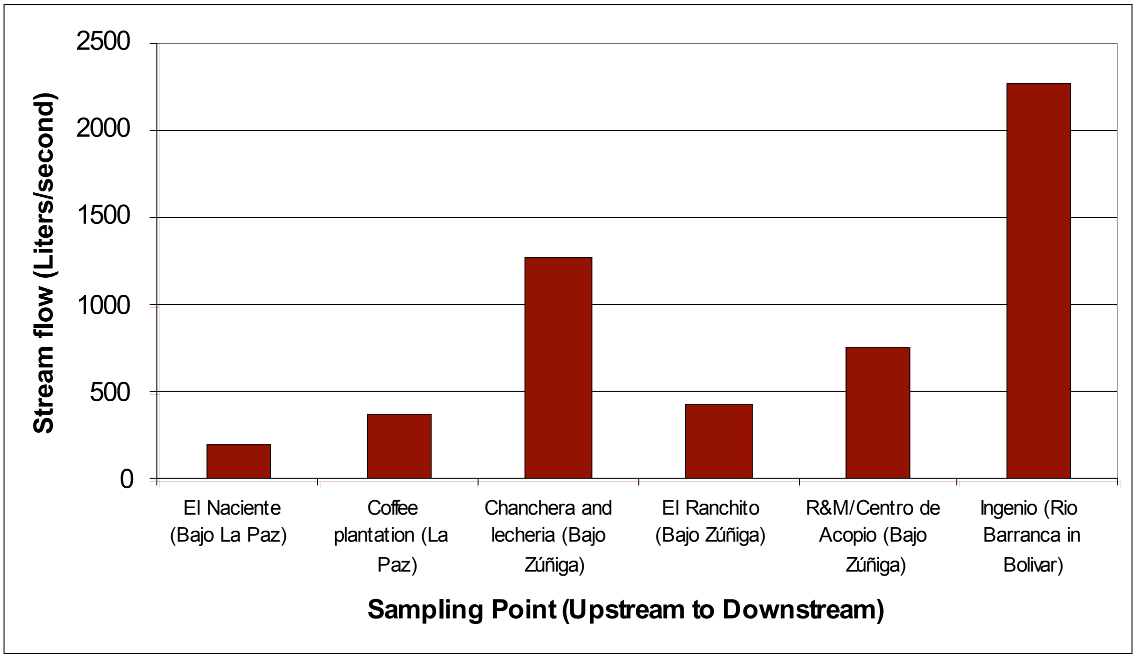

Figure 4. Calculated stream flow values at each sampling point in Río La Paz.

Discussion

The water quality tests we conducted provide evidence that humans are negatively impacting the ecological health of Río La Paz, currently to a limited extent. Our data indicate that the water from the *naciente* of Río La Paz is colder, has less conductivity, and is less polluted than the water in locations further downstream. In contrast, the water in Río Barranca downstream of its confluence with Río La Paz has the greatest conductivity and is the most polluted of our sampling locations.

Our data support the hypothesis that as the water moves from the *naciente* further downstream, various inputs enter the river and alter the physical, chemical, and biological composition of the river by increasing the temperature, conductivity, and ratio of pollution tolerant to non-pollution tolerant aquatic macroinvertebrates. From conversations with community members and workshops, likely inputs into Río La Paz include agrochemicals (fertilizer, pesticides, herbicides), livestock manure (mostly from chickens, pigs, and cows), organic wastes (from the *trapiches*, coffee plantations, and *lechería*), trash from households, and sediments from erosion.

Our data indicate a cumulative effect in electrical conductivity levels—the conductivity keeps increasing as distance downstream increases, most likely due to additional inputs that enter the water as it moves downstream. Temperature did not steadily increase, but rather fluctuated between locations, suggesting that local microclimates or chemical inputs have a large affect on water temperature. For example, at the coffee plantation sampling point, the temperature may have been the highest due to local agrochemical run-off. Average Pollution Tolerance Values for macroinvertebrates may or may not follow a cumulative trend downstream; future testing should investigate the relative impacts of point sources of contamination and cumulative contamination in the river. However, our data indicate that the biological composition of the river has indeed responded to human inputs, as the mean PTV is lower at the *naciente* than at other locations in the river.

Future Directions

The macroinvertebrate data also indicate that despite an increasing mean PTV downstream, the water quality can still be classified as “Excellent” to “Very Good.” Therefore, watershed management planners should focus their time and money on protecting and conserving the relatively clean river water rather than on remediation of existing contamination. However, efforts should still be focused on educating community members about ways to reduce contamination of the watershed, as the little water left in the river could easily become greatly contaminated.

Stream flow should continue to be monitored in the future in order to track changes in water quantity. In the future, macroinvertebrates should be identified to family in order to use more robust macroinvertebrate indices to more accurately determine water quality. Ideally, a multivariable, integrated water quality index should be used as a more robust measure of overall water quality in each location. Such an index could combine physical parameters such as pH, conductivity, DO, and temperature with chemical parameters such as nitrite/nitrate and phosphate composition as well as biological parameters such as family-level pollution tolerance values of macroinvertebrates. These parameters should be monitored regularly throughout the year, during both the rainy season and dry season. Future research should also investigate the effect of pollution point sources on water quality; for example, parameters could be measured directly upstream and downstream of a *chanchera* or *trapiche*.

This study has shown that data on stream flow and physical and biological water quality parameters can be easily obtained using cheap and simple equipment and limited calculations. Chemical kits for nitrate/nitrite and phosphate composition are easy to use and can be purchased cheaply (see PA Bureau of State Parks). Future studies should also work on connecting water quality data obtained with spatial information using GIS. This powerful mapping tool can help to relate contamination sources to specific farms or factories and can give a more integrated view of people’s place within the watershed and their relationship to other places around them.

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Appendix E.

Notes on the Diversion Plan

Many problems with the diversion plan study exist. The ecological requirements of the river were not considered in the calculations because there is no definition of ecological water needs in the national legislation.[160] The consulting company did not conduct an Environmental Impact Assessment before giving their recommendations. Therefore, the diversion plan fails to address the impact of removing a high quantity of water from the top of the watershed on the river system's ecological integrity, including the ability of aquatic and terrestrial organisms to adapt to a lower water flow and the river's ability to maintain its critical ecosystem functions such as pollution filtration and preservation of the hydrologic cycle. The diversion plan also fails to consider the impact on the farmers and industries of the watershed, who use a large amount of river and stream water for irrigation, livestock operations, sugar cane processing, and so on. The government has not consulted much with the Río La Paz communities, other than relaying them information about the plan in order to "raise awareness in the population," in the words of the head engineer.[161]

In trying to provide a short-term, quick fix for the cities' potable water problems, AyA would have endangered the long-term sustainability of multiple interconnected social and ecological systems: first, the ecological health of Río La Paz; second, the water security of community members who rely on water from Río La Paz for drinking and irrigation; and third, the food security of not only the Río La Paz communities but also the downstream cities, as farmers relying on water from Río La Paz sell their produce locally and to San Ramón and possibly Palmares.

Therefore, in future water provisioning plans I recommend including an ecological water requirement in calculations, conducting an Environmental Impact Assessment, and communicating with the residents who will be affected by the plans through well-advertised community meetings. These steps will contribute towards more socially and environmentally sustainable plans.

Current state of the diversion plan

Luckily, as of February 2009, AyA has decided to cancel its plans to divert Río La Paz water from the springs at the top of the watershed. If the current plans proceed, a water treatment plant will be constructed at the bottom of the watershed near the river's confluence with Río Barranca, and 70-100L/sec of Río La Paz water will be diverted to the downsteam cities of San Ramón and Palmares starting in 2015.

The farmers and residents of the watershed will not have to worry about losing a significant portion of their river water to the diversion plan. Nonetheless, climate change, contamination, future privatization, and overuse of water still threaten the river and the water it supplies.

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[160] Chavez, W. (2008). Personal comm. with head engineer of the Diversion Plan. A. Gulley. AyA office, San Ramon, Costa Rica.; CONSULTORES CENTROAMERICANOS EN INGENIERÍA S. A. (31 Enero de 2005). Estudio de la Situación y Propuestas de Mejoras para el Abastecimiento de Agua Potable en las Zonas de San Ramón y Palmares: Informe Principal. INSTITUTO COSTARRICENSE DE ACUEDUCTOS Y ALCANTARILLADOS. República de Costa Rica.

[161] Ibid (Chavez).

Our communications with Zayda Mora of AyA convinced us that developing institutional partnerships will be crucial for the communities in the management of their microwatershed. Although AyA has chosen to take the diversion water downstream of the farmers and residents, maintaining communication with institutions will be important for future negotiations between the residents and the government. Communities should also consider purchasing concessions for water, as AyA and the government must respect these individual property rights. Buying concessions should especially be considered by farmers who are using water from Río La Paz to irrigate. Legalizing their water needs may be the most important thing that farmers can do to ensure their water sovereignty does not become overridden by government or private corporations in the future.