Assessing Community Based Water Organization Performance in Central America

by

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Executive Summary

What are the effects of household, community, technical, and environmental variables on the performance and resilience of CWOs in dry regions?

Since 2014, drought has severely affected Central American economic and health outcomes, necessitating international intervention. 2.5 million people were at risk of food insecurity across the region in 2014, and 65% of homes had no stock of food during the 2015 harvest season. Low-income families living in Central America's "dry corridor" are affected the most by droughts; the UN's long-term plan is to build climate resilience in these communities as climate change increases the magnitude and frequency of droughts.

Local community-based drinking water organizations (CWOs) are key actors in Central American water provision. In rural and urban peripheral areas, CWOs provide the populace with up to 60% of its drinkable water. As climate change strains water accessibility, these local institutions will require effective management strategies so they have the capacity to handle the resource declines they will experience.

I assessed how different independent variables are associated with the adaptive capacity of CWOs and identified attributes that lead to success by conducting regression analyses on a data set from three Central American countries: Costa Rica, Guatemala, and Nicaragua. I also compared the statistically significant outcomes across the three countries. The regressions are based on survey data that has been gathered at the household and CWO level, technical data that was collected by engineers, as well as environmental and census data on the subnational regions in question.

First, I examined household reports of water access – defined as number of hours per day. I analyzed how this definition of water access related to household, engineering, community-level, and environmental variables. I found that volumetric pricing and elevation are the key variables to consider when designing an effective governance structure for a Central American CWO. I also determined that it is possible that national norms in CWO procedures may overstate the effect of volumetric pricing.

Second, I used three different engineering variables as dependent and analyzed how they were affected by household, community-level and environmental variables. Unlike the hours of service variable, the engineering variables were collected at the community level by engineers, rather than self-reported at the household level.

I conclude that elevation and volumetric pricing are the most relevant variables to consider in effective rural water provision. Elevation increases the start-up and maintenance costs of obtaining water. Volumetric pricing should be promoted as well, as it encourages the regulation of scarce water resources in the simplest way. I also conclude that higher elevation communities require more maintenance from community members, and require more expensive and powerful pumping technology.

Background

Droughts

Since 2014, drought has severely affected Central American economic and health outcomes. They have decreased food security, local nutrition, hydroelectric output, and crop yields (Boulanger, 2014). Regional UN offices, NGOs and the international community have been supporting the region with funding and emergency support throughout the crisis (OCHA 2014).

When the drought began in 2014, the loss in corn and bean crops was 75% in Guatemala and 54-75% in Honduras, and 2.5 million people were at risk of food insecurity across the region (OCHA, 2014). By the start of the 2015 harvest season, 65% of homes had no stock of food. 2014 was the hottest year on record until 2015; 2015's heat, compounded by El Niño weather patterns, intensified the drought and ultimately left 3.5 million people food insecure and in need of international assistance (WFP, 2016).

Laborers, low-income families and subsistence farmers are affected the most by droughts in this "dry corridor" of Central America (El Salvador, and parts of Nicaragua, Guatemala, Costa Rica and Honduras). These groups are generally concentrated more in rural and urban peripheral areas. According to OCHA, the short-term priority for addressing those affected is to feed those that are in immediate need of food, the medium-term priority is to recover livelihoods to prevent a humanitarian crisis, and the long-term priority is to build sustainability and resilience in local communities (OCHA 2014). The latter two priorities require the development of an effective water provision system.

This last and farsighted priority is echoed the UN's Sustainable Development Goals, agreed on internationally in 2015. The Sustainable Development Goals place special emphasis on climate change adaptation and community resilience. Goal 13 is to "take urgent action to combat climate change and its impacts," and Goal 13's first target, 13.1, is dedicated to resiliency: "Strengthen resilience and adaptive capacity to climate related hazards and natural disasters in all countries." (UN, 2016)

Droughts and water shortages in Central America are predicted to get worse in coming years, (Boulanger, 2014) despite one of the worst El Niño on record having now passed. By 2050, the lack of water availability will likely lead to more water stress, water scarcity and absolute water scarcity in the dry corridor (Chiabai, 2015). Researching regions where humans are suffering from drought conditions is particularly vital now, so that effective longterm resiliency planning, policy and coordination can take place to prepare for future water shortages. As the Sustainable Development Goals suggest, many of climate change's effects require effective adaptive capacity to manage.

Community Water Organizations (CWOs)

A key actor in Central American water provision is local community-based drinking water organizations, or CWOs. In rural and urban peripheral areas in Central America, CWOs provide the populace with up to 60% of its drinkable water (Madrigal, 2010). 24,000 CWOs in the region provide this water, and are vital to the health and economic development of the region.

National governments delegate some water provision responsibilities to CWOs. In Costa Rica this has been done for decades, starting when the country began upgrading its water systems. As climate change further strains water accessibility, these local institutions will require better management strategies, knowledge, and capacity to handle the changes they are likely to experience. Surveys have shown that many of these organizations do not have information about how climate change will affect their operations. They also indicate that many cannot provide a reliable supply of water, face financial strain and state dependency, and are not always able to repair, replace and maintain infrastructure. A lack of organizational and administrative skills is cited most often by CWO officials as the reason behind service issues (Morton 2013).

My goal is to better understand CWOs in Central America. It is imperative that we increase our understanding of water provision in drought conditions so that we may develop effective best practices for CWOs, and donor guidance for how and where aid money can be best spent.

Literature Review

Social-Ecological Systems

The most common research framework used to explain human interactions with ecosystems is the social-ecological systems framework (SES), developed by Elinor Ostrom who argued that “all human resources are embedded in complex, social ecological systems.” Like an organism with cells and organs, these systems are comprised of multiple levels of subsystems, with variables embedded within. In this way, Ostrom’s framework is a way to facilitate research about how humans and ecosystems interact, how different disciplines can communicate with each other across sectors to more efficiently utilize resources in the community, and how laws and policies can affect the environment (Ostrom 2009) (Appendix 1).

Researchers have used the framework to investigate how SESs cope with various challenges. Fleischman et al. examined how self-organized communities react to disturbances. They defined a disturbance as "any relatively discrete event in time that disrupts an ecosystem, community, or population structure and changes resources, substrate availability, or the physical environment." This could include anything from a dispute over water to the theft of a piece of property.

Their conclusion was that collective choice, community leadership, entrepreneurship, project monitoring, and social norms are key to maintaining an SES’s desired performance when it is subjected to disturbances (Fleischman, 2010). Natural disasters like droughts are also considered disturbances, which implies makes this study relevant to this project.

Adaptation

In the context of climate change and how communities address it, there have been studies about how communities are acting collectively and adapting to the effects of climate change. Adger et al. gathered a range of studies from various countries about groups that are already adapting to climate change, particularly droughts.

In Sudan, traditional rainwater harvesting and water conservation techniques have become more widespread, and wind-breaks have been constructed to improve the resilience of rangelands. In Botswana, the national government has developed programs to create employment opportunities after the drought, and has started providing assistance to subsistence farmer households to increase crop production.

Nearer to the Dry Corridor in Mexico and Argentina, planting schedules are being adjusted and drought resistant crops such as agave and aloe are being grown more frequently. Communities have also started accumulating commodity stocks as an economic reserve setting up crop insurance programs. At a local level, individuals are developing local financial pools as an alternative to commercial crop insurance.

Adger et al. also observed that community adaptations to climate change were seldom taken because of climate change alone. They were often embedded into larger programs that were more immediately practical, like disaster management planning. He also found that the costs of making these adaptive changes in response to climate change, while often not large or prohibitive, were more feasible for some groups than they were for others. Women in subsistence farming, for instance, had less of a capacity to adapt to climate change because they were proportionately burdened with their community's costs as they recovered from its negative effects (Adger 2007).

Engle and Lemos explored the relationship between Brazil's decentralized water systems and their adaptive capacity to handle climactic change. The decentralized nature of the policy allowed Engle and Lemos to qualitatively compare different governing styles in different river basins around Brazil. According to their research, governance methods that allowed greater representation and participation within local water management institutions led to greater adaptive capacity. In their interviews of individuals in the basins, they determined that adaptations to climate change with more representation were better on average than in those with less, when judged against the study's determinants of adaptive capacity (Engle and Lemos, 2010).

Social Capital in Adaptation

Another study by Adger focused on the capacity of communities to self-organize and collectively act, and focused on social capital theory to explain why some groups are better able to adapt than others. He argues that the society's ability to adapt is dependent on their capacity to commit to collective action, and that “insights from these areas inform the nature of adaptive capacity and normative prescriptions of policies of adaptation.”

Social capital theory, in this context, is used as an explanation for why actors use relationships within societies in order to achieve good outcomes for themselves, or the collective. Because the collective good has material elements, wider spiritual elements, and social dimensions, he argues, it captures the nature of social relations. Regarding adaptive capacity, Adger concludes that community bonding and networking strengthens horizontal linkages and emphasizes the role of nongovernment actors.

If the state is supportive of social capital and works synergistically with the community, institutions can take advantage of networks of reciprocity (such as civil society,) to inspire action and help communities cope with risk. If, however, the state somehow limits social capital, then civil society can only operate to the extent that state institutions allow. This would shift the focus away from agency, and toward institutional action. Alger recommends a blend of both (Adger 2003).

CWO Studies

There are a few studies on community-based drinking water organizations, although they are not as thoroughly researched as other aspects of water provision. Many explore the governance of CWOs, but few touch on climatic and environmental factors.

Murtinho (2013)produced a study in the Colombian Andes about the relationship between external (government) funding and adaptation, and used CWOs as the subject. In his research he found that even in situations where communities tried to use their own funding and resources to complete a CWO adaptation project, they still needed resources from the government in order to complete it. However, external funding alone did not always have a positive impact on the CWO’s ability to set up adaptation programs. If the money was requested by the community, the government assistance is more likely to improve community-driven adaptation. However, if the funding is not solicited, it is more likely that the effort will crowd out community efforts to set up adaptation programs and hurt the projects long-term.

Isham and Kähkönen (2002) conducted a study in India and Sri Lanka on the “community driven approach” to adaptation. It is also referred to as the demand-driven approach; the idea that the community wants the project, solicits the donor, and is engaged with the project. The committee may commit to financially supporting the project in part.

Under this model, community members will participate in the design and monitoring of the program, and will have the final say on what the project will be. Isham and Kähkönen advise focusing on both the demand and the social capital of a community when establishing a project there. If there is demand without social capital, it is less likely that the project will be sustained long-term, so the authors recommend strengthening local groups if needed (Isham and Kähkönen, 2002).

Pattanayak et al. (2010) follow the approach in Isham and Kähkönen, except with a much larger data set (250 communities from 4 districts in the state of Maharashtra, India and a total of 10,000 households) to examine the performance of community managed water and sanitation systems. They find that compared to matched controls (using propensity scores, Pattanayak et al., 2009), the community managed systems improved environmental health outcomes, especially by reducing the costs borne by households to cope with unreliable and inadequate sanitation and water. In a follow-up study, Tan Soo and Pattanayak (2014) show examine the mechanisms that generate these outcomes.

Conclusions from Literature

Based on the existing literature, it is reasonable to conclude that community-based, demand-driven projects that utilize the effectiveness of social capital are the most effective. Ownership is key, as it can lead to community leadership, initiative, monitoring, and sustainability in the longer term.

One thing that is not answered in the existing studies is the effect of the environment on CWOs, or how CWOs can maintain water provision during drought conditions. In my research, I hope to contribute to this body of work by analyzing these issues. As climate change creates more water uncertainty in the Central American region, it is vital to understand the elements of successful water provision programs.

Methods Analysis

I conducted statistical analyses for this project; OLS regressions to assess a) how different independent variables of various kinds are associated with the adaptive capacity of Central American Community Based Drinking Water Organizations (CWOs) and b) emergence of the successful governance attributes of CWO isolated in a). I will also compare the statistically significant outcomes across the three countries I intend to focus on. The regressions are based on survey data that has been gathered at the household and CWO level, technical data that was collected by independent engineers, as well as environmental and census data on the subnational regions in question.

As discussed in my literature review, there have been multiple studies about the relationship between the adaptive capacity of CWOs and a variety of factors. Past factors that have been included are community-level and social capital factors; state financing versus local financing; and different types of institutional, managerial and legal variables. There have been few studies on how environmental and climatic factors have influenced the adaptive capacity of CWOs in a given region, so my exploration of them here will be a contribution to a growing body of knowledge.

There are two key attributes that must be measured when determining adaptive capacity; sensitivity, or, how affected the community is after a disturbance, and exposure, or, to what extent the system was exposed to a disruptive event (the drought.) My analyses will focus on sensitivity, and assume that the level of exposure to the drought in the randomly selected regions is roughly commensurate (see data section for details.) The lower the negative impacts to CWO performance there are as a result of the drought, the lower the sensitivity is, and the higher the adaptive capacity is. For the purposes of analysis in this study, "sensitivity" will be functionally considered the same as "performance."

The OLS regression analyses will be of household and community-level variables, and they will assess which factors affect the adaptive capacity of Central America's CWOs. The results comparison between countries that follows will help identify common factors that affect drought response.

Data

My project focuses on communities served by 178 CWOs selected at random from some of the driest subnational regions in Guatemala, Nicaragua and Costa Rica. These are the areas that are likely going to suffer the most stress to their agricultural and drinking water systems as climate change intensifies in the coming years. It is assumed in this case that because the areas suffer comparable levels of dryness, their levels of exposure to the drought are comparable as well.

These regions have had some of the lowest historical precipitations and highest temperatures for the past ~ 50 years (Appendix 2). Precipitation and temperature depend on the season, and on the presence of El Nino at the given period (El Nino has affected the Central American region 15 times between 1961 and the time of this study, and each iteration lasts between six and ten months.)

Survey data has already been collected, and it accounts for many the dependent variables. It contains CWO and household level data, and was gathered in 2014 and 2015 for a previous project in Guatemala, Nicaragua and Costa Rica, using standardized protocols. The data was initially collected to report general data for use in capacity building workshops but most of the data has not been explored or used for another scientific publication.

The CWO data contains all the variables in the Governance column for the 178 CWOs surveyed. Some examples include; a binary variable for volumetric pricing, cash savings per connection (the annual average of the last two years in USD,) a binary variable for the existence of written accountability reports to the community about activities and outcomes, a binary variable for monthly water committee meetings, the characteristics of water board members, the size of infrastructure by number of connections, and more.

Engineering data was also collected for the 178 CWO regions, and it includes technical data collected by professionals. Across the three countries, the engineering variables include well depth, water pressure, pipe diameter, and a range of binary questions about the state of the pipes, the tank, and the premises. Unfortunately, very few of these variables overlap across all three countries; the three variables that do have been included.

The household level data is composed of 7409 surveys from households served by the CWOs studied. It collects various indicators related to the performance perceptions of the CWO serving the given household, as well as very specific information about household demographics and behaviors. The dependent variable for analysis 1, hours of water accessibility, was drawn from this information; household total scores were averaged by each of the 178 CWOs.

GIS and national census data of climatic and environmental level featured are included. Variables available include precipitation, temperature, agricultural land percentage and forest land percentage will be obtained for each area in question, and aggregated census data will be added for demographic information.

Analysis 1: The Effects of Household, Technical, CWO and Environmental Factors on Daily Service Hours

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Data

The dependent variable is a self-reported proxy for performance; households reported in their survey how many hours per day they could access water. Thus, this analysis is conducted at the household level.

The independent variables fall into four categories; *community engagement, engineering, CWO policy* and *environmental factors*. Some of the variables used are all binary, with a 0 indicating No and a 1 indicating Yes, while others are continuous.

Community Engagement

Under community engagement, I took several binary variables from the household dataset. The **Meeting Attendance** variable represents whether respondents indicated that someone in their household attended a meeting at their community's CWO in the past year. The **Water Maintenance** variable represents whether respondents indicated that someone in their household worked to fix the community water system in the past year. The **General Community Maintenance** variable represents whether respondents indicated that, in the past year, someone in their household engaged in community maintenance generally, i.e., on public goods that are not related to water systems (schools or roads).

The **Any Org. Involvement** variable represents whether respondents indicated that someone in their household is a member of a community organization. The **Home Electrified** variable represents whether respondents indicated that their home is electrified, and the **Savings** variable represents whether respondents indicated in the past year, someone in the household has saved money somehow; in a bank, cooperative, microcredit company, in the house, or some other way. For these variables, a 1 represents "yes," while a 0 represents "no." These community engagement variables are proxies for social capital and community engagement. They include engagement both within their local CWO, and generally.

Engineering

The engineering data was collected by independent engineers at a community level. **Well Depth** (in meters,) **Flow** (in liters per second,) and **Pump Capacity** (in horsepower,) were all available across the technical reports from the three countries.

There were more missing communities in the engineering datasets than there were in the household and community level datasets, due to different methodologies across the three surveyed countries. Missing communities had a large effect on the number of observations when they merged with the household dataset, because one community represents many households; this explains the comparatively smaller number of observations.

CWO Policy

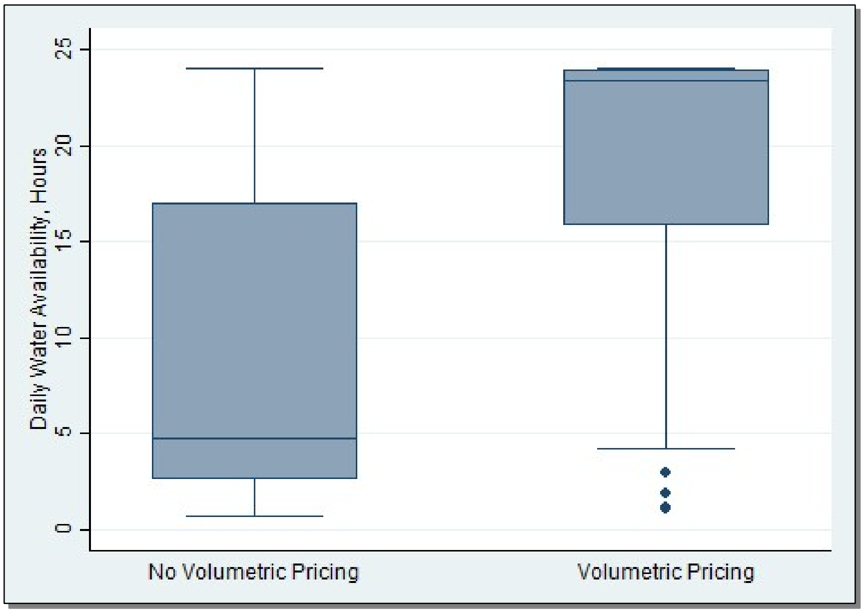
I used survey data taken from the CWOs themselves. CWOs were asked if they hold community meetings (**Meeting**) and whether they use a volumetric pricing scheme of some kind (**Volumetric Pricing**). Volumetric is contrasted by other forms of payment such as a flat fee, or a mixed program that combines multiple payment approaches.

Environmental

For environmental data, I used **Elevation** in meters, **Rainfall** in millimeters, and **Meters from City,** which indicates the distance from the nearest city center in meters.

Results: Table 1

Graph 1



Nine variables have a statistically significant impact on CWO performance in the column 5: **Meeting Attendance, Water Maintenance, General Maintenance, Home Electrified, Savings, Flow, Volumetric Pricing, Rainfall** and **Meters from City.** Five of these are from the Community Engagement category, one from the Engineering category, one from the CWO Policy category, and two from the Environmental category.

Community Engagement variables appear to show small, reliable and intuitive effects. If a household has engaged in water system or general maintenance in the past year, they can be expected to report one to two fewer hours of service per day, on average. This is a reverse causality issue; the only time a community would need to engage in maintenance is if there is a problem to fix, and it is likely that those problems lead to reduced hours of household water service. In addition, households that attend community meetings can be expected to report nearly an hour more of service during the day, households that have electricity can be expected to report nearly two more hours per day, and households that have savings can be expected to report nearly an hour more of service per day.

Table 1: Household, Technical, CWO and Environmental Factors on Daily Service Hours

Variables	1 Daily Service Hours	2 Daily Service Hours	3 Daily Service Hours	4 Daily Service Hours	5 Daily Service Hours
Meeting Attendance	0.671*				0.941**
	(0.405)				(0.372)
Water Maintenance	-3.170***				-1.589***
	(0.548)				(0.503)
General Maintenance	-3.126***				-1.120*
	(0.719)				(0.634)
Any Org. Involvement	1.859***				0.0764
	(0.505)				(0.388)
Home Electrified	4.230***				1.733**
	(1.011)				(0.742)
Savings	3.044***				0.941*
	(0.550)				(0.545)
Well Depth (M)		-0.0294			-0.00434
		(0.0231)			(0.0151)
Flow (LPS)		0.721***			0.426**
		(0.208)			(0.166)
Pump Capacity (HP)		-0.196**			-0.0598
		(0.0934)			(0.103)
Meetings			3.092**		1.321
			(1.454)		(1.598)
Volumetric Pricing			8.307***		6.478***
			(1.468)		(1.614)
Elevation				-0.00629***	-0.00207
				(0.00196)	(0.00296)
Rainfall				0.00667***	0.00875***
				(0.00167)	(0.00283)
Meters from City				3.22e-05	0.000278*
				(0.000154)	(0.000165)
Constant	12.41***	15.73***	8.204***	7.587**	-7.003
	(1.209)	(1.807)	(1.492)	(3.202)	(4.950)
Observations	7,283	4,798	7,158	7,255	4,598
R-squared	0.065	0.140	0.200	0.221	0.419

Robust standard errors in parentheses

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

One of the more practically significant findings that we see is that volumetric pricing has a particularly strong effect. The regression indicates that households served by CWOs that use volumetric pricing schemes report 6.5 more hours of service per day.

As we can see in Graph 1, communities that utilize volumetric pricing have a distinct advantage over those that do not. On average, communities with volumetric pricing schemes have water service available all day, and communities that do not average around 5 hours of service per day. Communities with volumetric pricing schemes in the 5 hour range are outliers and the minimum extreme.

Volumetric pricing schemes empower individuals to regulate their water usage to save money. This simple policy greatly improves a community's collective ability to conserve water based on need.

On a country level, the evidence shows that countries that are more likely to engage in volumetric pricing do better on average that those that do not. In Table 2 below, we see that 79.75% of Costa Rican CWOs sampled utilized volumetric pricing.

Table 2: Tabulation of Countries and Volumetric Pricing Schemes

COUNTRY PRICING	NO VOLUMETRIC PRICING	VOLUMETRIC	TOTAL
COSTA RICA	16 20.25%	63 79.75%	79 100%
NICARAGUA	16 41.03%	23 58.97%	39 100%
GUATEMALA	27 54%	23 46%	50 100%
TOTAL	59 35.12%	109 64.88%	168 100%

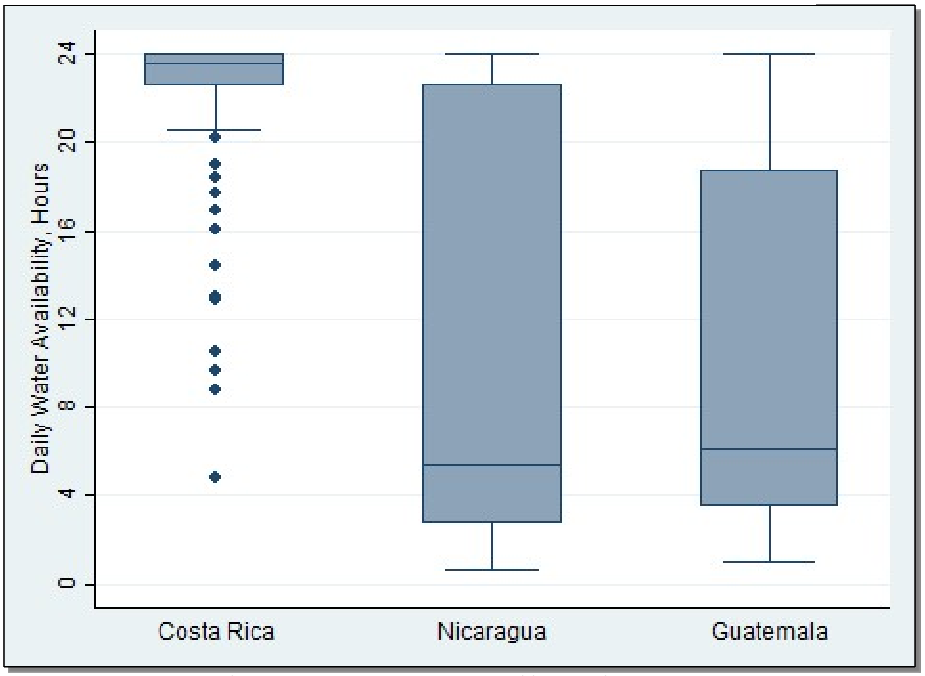
Graph 2 shows that communities in Costa Rica do far better on average than other communities in terms of average hours per day that they can access water. Before including variables related to the environment, the climate, or the engineering factors of these CWOs, we see that volumetric pricing is clearly a simple and effective way to ensure that users have consistent service. Communities in Nicaragua and Guatemala are less likely to use volumetric pricing, and have a larger range of outcomes. Their access averages between 4 and 8 hours per day on average.

However, Costa Rica may have other attributes, besides their apparent CWO norm of using volumetric pricing, that help it achieve such high levels of success.

Pumping equipment appears to influence service per day on a household level. Households report .426 more hours of pumping time per day for every extra liter per second that the community's equipment can pump. Factors related to flow in liters per second will be explored more in Analysis 2.

The final statistically significant effect in column 5 is rainfall. For every extra millimeter of rain, communities can expect .009 more hours of service per day. That's around 5.4 more service minutes per centimeter of rain. This is intuitive; wetter regions have greater access to water. As stated before, these communities were selected based on their low levels of rainfall. We see that even small amounts of rainfall in the Dry Corridor can have a measurable and notable effect on how reliable water access is.

Graph 2



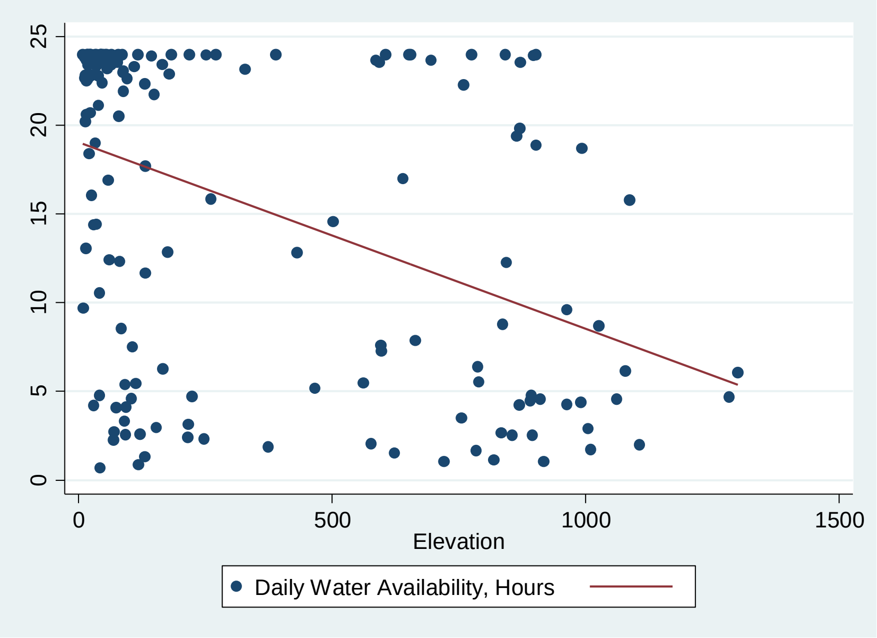
In column 4, which explores environmental factors alone, see the effect of elevation is significant. Considering only environmental factors, every 100 meters of elevation provides an average of 36 minutes of extra water service on a household level.

Whether a reporting household is in a more mountainous region is relevant for several reasons. Firstly, the up-front drilling costs of digging and outfitting a deeper well can cause significant financial strain on a local community. Even if a well is deep enough to reach the water table during times of drought water tables can drop, requiring more financial resources to respond.

Well maintenance can also be costlier, and a CWO may not have the resources to immediately replace a well if it is completely broken. This could leave a community with extremely poor daily access to water for long periods of time, which would bring down average water access per day down significantly.

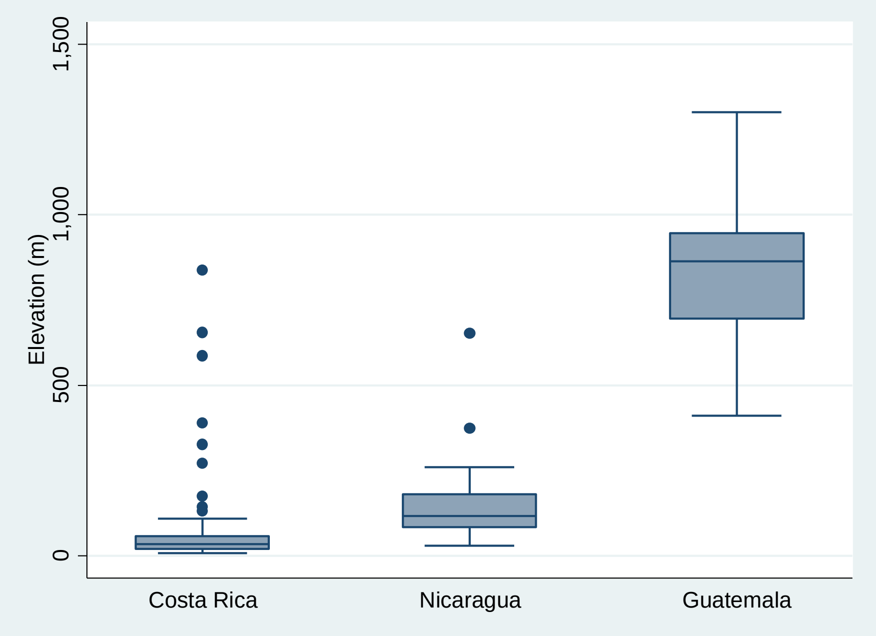
We see this displayed in Graph 3. CWOs that are at a lower elevation are more likely to receive between 20 and 25 hours or service per day. In Table 2 we saw that Costa Rica has great access to water, almost 24 hours a day, while Guatemala's average hourly rate was comparatively low. It should be noted, however, that Costa Rica is also the country with the lowest elevation, while Guatemala is far more mountainous. This is reflected in the small gulf between the large collection of lower altitude variables, and the more spread out higher altitude variables on the right.

Graph 3



Graph 4 shows the vast difference in elevation between the two countries, with Nicaragua in between the two, but closer to Costa Rica in elevation. Communities in Costa Rica and Nicaragua that are over 500 meters in elevation are outliers, while Guatemala's average elevation is well above that point.

Graph 4



As Analysis 2 will indicate, there is a clear correlation between the elevation of a community and the depth of drilling required for them to complete their well project. Elevation's correlation with the well depth further proves that higher altitudes necessitate deeper digging. The connection between well depth and elevation will be discussed further in the exploration of well depth in Analysis 2

Analysis 2: The Effects of Household, CWO and Environmental Factors on Well Depth, Flow and Pump Capacity

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Table 3: Household, CWO and Environmental Factors on Well Depth

Variables	1 Well Depth (M)	2 Well Depth (M)	3 Well Depth (M)	4 Well Depth (M)
Meeting Attendance	-0.277			13.52
	(27.36)			(26.01)
Water Maintenance	-47.73			-47.54
	(50.12)			(47.98)
General Maintenance	87.55**			90.58***
	(33.62)			(31.01)
Any Org. Involvement	-112.4*			-26.02
	(60.76)			(60.73)
Home Electrified	-194.3*			-67.49
	(103.9)			(102.8)
Savings Y/N	-99.23**			-50.83
	(48.50)			(47.85)
Meetings		-7.659		17.76**
		(9.314)		(8.343)
Volumetric Pricing		-9.489		7.120
		(9.366)		(7.979)
Elevation			0.0512***	0.0605***
			(0.0128)	(0.0139)
Rainfall			-0.0301***	-0.0209*
			(0.0110)	(0.0120)
Distance from City (M)			-0.00103	-0.00119
			(0.00103)	(0.000975)
Constant	257.2**	70.97***	99.52***	122.2
	(100.5)	(8.705)	(20.40)	(105.8)
Observations	141	138	142	137
R-squared	0.268	0.017	0.253	0.423

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Data

While using the self-reported household indicator of hours of service per day as a proxy was useful, it is important to analyze information that has been collected by professionals as well, as it is less likely to be biased. It is possible, for instance, that individuals that are more engaged in their local water organizations have a skewed perception of how many hours per day they have service; they may deflate the numbers because they are more sensitive to water provision issues and have higher expectations, or they might inflate the numbers because they think the system is more effective than it actually is. The same could be said of the questions answered by CWO officials at the community level.

For this reason, additional analysis using more objective measures is important to include. In the collection of this engineering data, specialists were tapped in Guatemala, Nicaragua and Costa Rica to collect a standard list of relevant data. They answered technical questions related to the functioning of CWOs and their systems. However, though technically standardized, not all questions were answered for all countries. The three variables that were consistent were **well depth, flow,** and **pumping capacity.**

The regressions use the same household, community level and environmental variables as were used in Analysis #1. The household variables, however, were averaged by community so that a condensed, community-level dataset could be used. This analysis is community level.

Results: Table 3

In Table 3, we see that there are four statistically significant effects that relate to Well Depth: general maintenance, meetings, elevation and rainfall.

Communities that spend more time on general maintenance are more likely to have deeper wells. This could be a function of altitude; a community that is in a mountainous region may need to more frequently call upon its citizens to engage in general community upkeep because it is more difficult for professionals to reach it. Strangely, we see that there is not statistical significance regarding water systems maintenance specifically. It is possible that when a well is deeper, it requires more specialized and equipped contractors or engineers maintain, not general community members.

There also appears to be a correlation between well depth and the CWO policy of holding CWO meetings with members of the community. This may be a function of, again, the challenge of living in a more mountainous region. It could be more difficult for professionals to reach. It may also be more expensive to maintain, necessitating more direct engagement from the community.

As stated before, elevation is related to well depth. The higher the elevation, the further a community is from the water table, and the deeper they must drill. According to the regression analysis, a unit of well depth is equal to only .06 meters of elevation. Higher elevation communities demonstrably need to be more concerned about the fragility of their water system, as deeper wells make otherwise routine maintenance issues more serious.

Lastly, rainfall affects well depth. The less rain there is, the deeper a well must be. Conversely, the more rain there is, the shallower (and less expensive) a well can be.

Table 4: Household, CWO and Environmental Factors on Flow in Liters Per Second

Variables	1 Flow (LPS)	2 Flow (LPS)	3 Flow (LPS)	4 Flow (LPS)
Meeting Attendance	-3.298			-1.422
	(2.231)			(2.414)
Water System Maintenance	-3.703			-2.733
	(3.876)			(4.160)
General Maintenance	-4.063			-4.251
	(2.639)			(2.735)
Any Org. Involvement	4.134			10.10
	(5.501)			(6.114)
Home Electrified	-7.252			-4.178
	(7.745)			(8.199)
Savings Y/N	2.691			6.158
	(4.114)			(4.509)
Meetings		-0.0599		-0.556
		(0.743)		(0.762)
Volumetric Pricing		1.002		0.669
		(0.716)		(0.676)
Elevation			0.00428***	0.00327**
			(0.00120)	(0.00138)
Rainfall			0.00350***	0.000734
			(0.00129)	(0.00140)
Distance from City (M)			-7.06e-05	-8.13e-05
			(8.75e-05)	(8.74e-05)
Constant	14.05*	3.735***	-1.926	7.546
	(7.364)	(0.702)	(2.305)	(8.711)
Observations	137	133	137	132
R-squared	0.245	0.015	0.088	0.291

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Results: Table 4

There are few connections between flow speed and the available variables. We found in table one that flow speed is correlated with hours of service per day. When analyzing flow in liters per second, the only statistically significant factor in column 4 is elevation. The data indicates that higher elevation could lead to slightly more liters per second in water flow. This is counterintuitive, as one would expect wells in more mountainous regions would have more trouble with maintaining flow. It is possible that in mountainous regions, water is pumped up to a higher altitude than the community and distributed using gravity-based methods that increase flow speed.

Another possibility, backed up by Table 5 analysis, is that deeper wells require more powerful pumps that communities with shallower wells can get away with not purchasing.

Yet another possibility, as outlined in Analysis 1 in the country-level discussion, is that there are geographic unobservables within the surveyed countries available that affect the flow. There could be an overall better flow rate in Guatemala, for instance, and because Guatemala has a higher altitude, it would affect the elevation variable in the aggregate regression.

Table 5: Household, CWO and Environmental Factors on Pump Capacity (HP)

Variables	1 Pump Capacity (HP)	2 Pump Capacity (HP)	3 Pump Capacity (HP)	4 Pump Capacity (HP)
Meeting Attendance	-16.50***			-10.97*
	(5.736)			(5.595)
Water Maintenance	-14.59			-11.34
	(10.15)			(9.903)
General Maintenance	7.371			7.806
	(6.788)			(6.306)
Any Org. Involvement	-17.19			-2.791
	(12.80)			(12.93)
Home Electrified	-20.94			-0.480
	(20.40)			(20.13)
Savings Y/N	-21.04**			-3.122
	(10.55)			(10.51)
Meetings		-3.276*		-0.334
		(1.791)		(1.720)
Volumetric Pricing		1.015		2.660
		(1.764)		(1.642)
Elevation			0.0139***	0.0130***
			(0.00240)	(0.00277)
Rainfall			-0.000699	-0.000777
			(0.00213)	(0.00247)
Distance from City (M)			-0.000306	-0.000283
			(0.000201)	(0.000209)
Constant	40.55**	10.20***	7.143*	11.74
	(19.57)	(1.713)	(3.916)	(20.59)
Observations	153	149	153	148
R-squared	0.173	0.023	0.255	0.312

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Results: Table 5

The results from regressing pumping capacity are in keeping with the hypothesis that more mountainous regions need more powerful pumps, and thus a faster flow rate. Elevation is a factor when engineering data is considered separately, and when it is considered with all other variables.

In addition, meeting attendance at local CWOs correlates with less horsepower in columns 1 and 4, and meeting policies at CWOs also correlate with less horsepower in column 2. As suggested in Table 3 when considering the effects of living in a mountainous region, it is possible that more meetings and more coordination are required because systems are not easily repaired. It is also possible that, when CWOs are widely attended by the community, they are more likely to select a lower horsepower pumps due to lower costs.

This second hypothesis is supported by the last statistically significant variable, Savings. Higher horsepower pumping systems on the community level correlate with a lack of savings among households in that community, implying that it may be optimal for communities with little savings to opt for lower horsepower pumps.

Conclusions

Volumetric Pricing and Elevation are the key variables to consider when designing an effective governance structure for a Central American CWO. It is possible that national norms in CWO procedures may overstate the effect of Volumetric Pricing, as in the case of this dataset where the nation with the lowest elevation also happens to have CWOs that utilize volumetric pricing the most.

Volumetric Pricing encourages people to regulate their usage of water, be it for drinking, agriculture, industry or washing. In times of strain, volumetric pricing allows market forces to act as a natural regulator of scarce resources. Flat fee schemes cannot do this, and do not incentivize users to consider the volume of water used.

Elevation is relevant for several reasons. Firstly, the up-front drilling cost of digging a deeper well can cause significant financial strain on a local community. Even if a well is dug deep enough to reach the water table, during times of drought water tables can drop, requiring more financial resources to respond. Well maintenance can also be more costly, and a CWO may not have the resources to immediately replace a well if it is completely broken; this could leave a community with extremely poor daily access to water for long periods of time, which would bring down averages significantly. Elevation’s correlation with the well depth variable further proves that higher altitudes necessitate deeper digging.

The apparently powerful effect of Volumetric Pricing may be overstated. It appears to be a norm in Costa Rica, the country with the highest number of variables and the country with the lowest elevation.

Further research could provide more insight on this issue; studies within Guatemala that can compare water provision proxies in the mountains and compare them with communities in the flatlands below. Ultimately, however, it is clear the volumetric pricing (a CWO policy factor) and elevation (a physiographic factor) are the two factors that stand out the most. Central governments, the United Nations, and water activists should consider elevation as a factor when determining where to assign funding within a nation. Elevation increases the start-up and maintenance costs of obtaining water. Volumetric pricing should be encouraged as well, as it encourages the regulation of scares resource in the simplest way.

Assessments of the engineering data show a mixed picture, but in general they indicate challenges for communities situated at higher altitudes. We determined that communities that dig deeper wells live in higher altitude areas, spend more time maintaining public goods, are less likely to have savings or an electrified home, and are more likely to have regular meeting policies at their CWOs.

Assessing the flow in liters per second, we see that a high elevation correlates with a faster flow. That finding is in keeping with assessments of horsepower and pumping capacity; there is also a positive correlation between high elevation and pumping capacity horsepower. Communities with higher pumping capacity often meet less than those with lower pumping capacity, which could imply that in more prudent or poorer communities, frequent meetings and coordination lead them to making lower cost purchases.

Donors who wish to engage in water provision ought to favor higher altitude regions for funding. Their financial need is greater up front, and over time. Bearing past research in mind from the literature review, a collaborative approach that emphasizes social capital and community involvement should also be included in any such project. As droughts in the dry corridor and other developing areas begin to intensify, it will take an informed, integrated approach to succeed.

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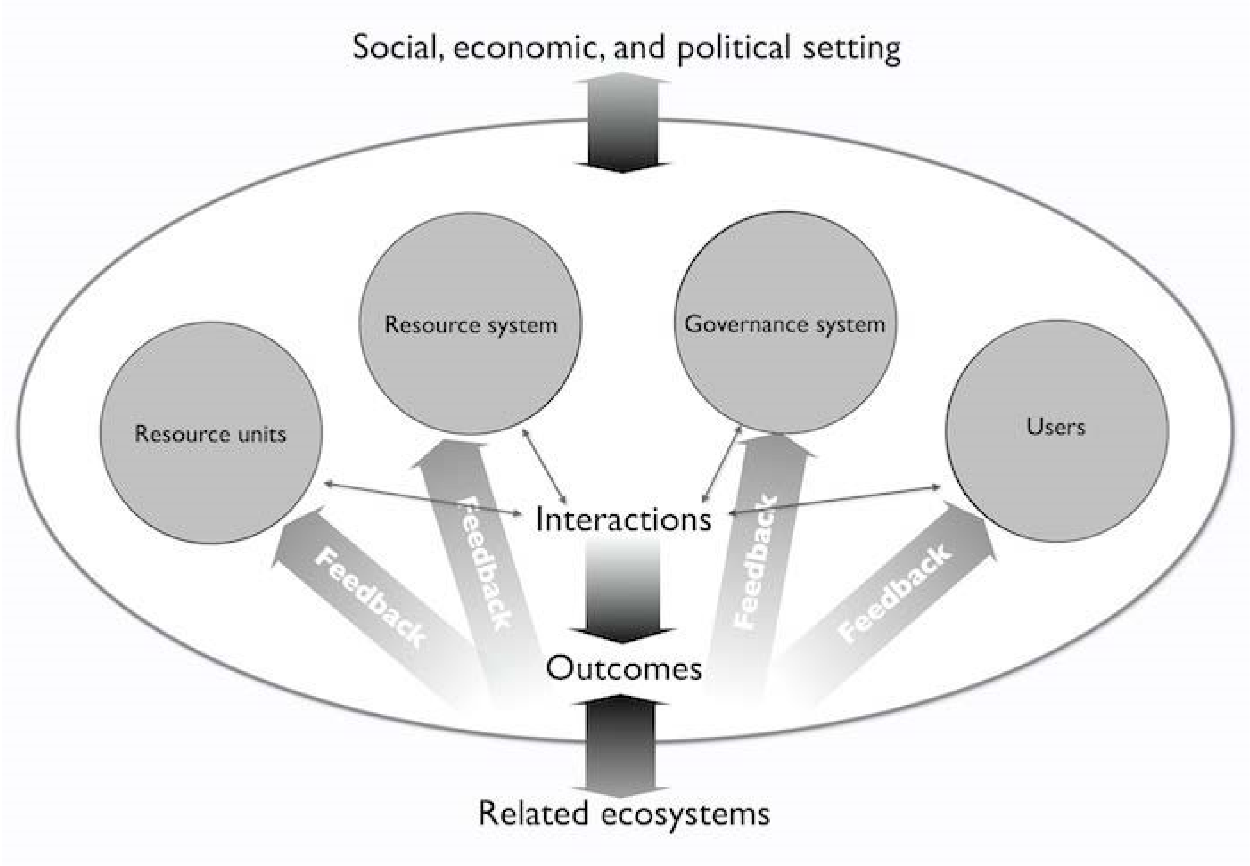
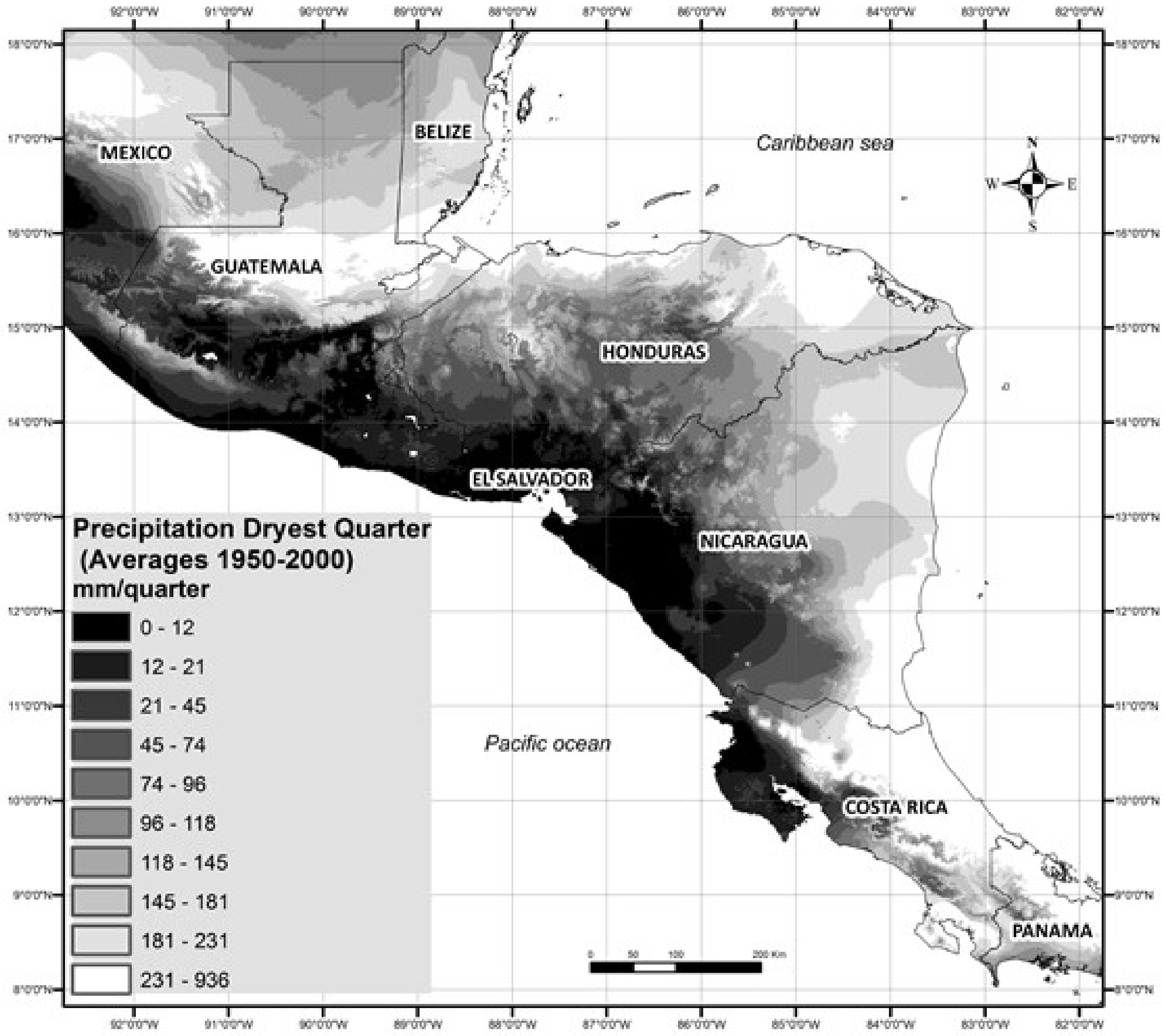
Appendix 1:


Social, economic, and political setting
Resource system
Governance system
Resource units
Users
Interactions
Feedback
Feedback
Feedback
Feedback
Outcomes
Related ecosystems

Appendix 2: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MEXICO
BELIZE
GUATEMALA
HONDURAS
EL SALVADOR
NICARAGUA
COSTA RICA
PANAMA
Caribbean sea
Pacific ocean
N
S
E
W
Precipitation Dryest Quarter
(Averages 1950-2000)
mm/quarter
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12 - 21
21 - 45
45 - 74
74 - 96
96 - 118
118 - 145
145 - 181
181 - 231
231 - 936
0
50
100
200 Km

Appendix 3-6 STATA Key

Variable Name	**STATA Code**
Pumping Hours Per Day	ii4a
Meeting Attendance	iv22
Water Maintenance	vi34a
General Maintenance	vi34b
Any Org. Involvement	vi35
Home Electrified	viii53electricidad
Savings	viii57
Well Depth	well_depth_mtrs
Flow	flow_lps
Pump Capacity	pump_capacity_HP
Meetings	meetings
Volumetric Pricing	tarifa_volum
Elevation	elev
Rainfall	ppt
Meters from City	City_Dist_mtrt

Appendix 3: Table 1

```
. regress ii4a iv22 vi34a vi34b vi35 viii53electricidad viii57, cluster(codcom)

Linear regression                               Number of obs     =        170
                                                F(6, 169)         =      22.81
                                                Prob > F          =     0.0000
                                                R-squared         =     0.3487
                                                Root MSE          =     7.3457

                                     (Std. Err. adjusted for 170 clusters in codcom)
------------------------------------------------------------------------------------
                   |               Robust
              ii4a |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------------+----------------------------------------------------------------
              iv22 |   11.62429   3.991874     2.91   0.004     3.743927    19.50465
             vi34a |  -26.77975   7.082238    -3.78   0.000    -40.76079    -12.7987
             vi34b |  -1.161976   5.039475    -0.23   0.818    -11.11041    8.786453
              vi35 |   1.859932      9.433     0.20   0.844    -16.76176    20.48162
viii53electricidad |   31.33463   16.13915     1.94   0.054    -.5256786    63.19493
            viii57 |   21.13501   7.044181     3.00   0.003     7.229094    35.04094
             _cons |  -16.66247   15.55008    -1.07   0.285    -47.35989    14.03495
------------------------------------------------------------------------------------

. regress ii4a well_depth_mtrs flow_lps pump_capacity_HP, cluster (codcom)

Linear regression                               Number of obs     =        111
                                                F(3, 110)         =       8.62
                                                Prob > F          =     0.0000
                                                R-squared         =     0.1621
                                                Root MSE          =     8.4529

                                   (Std. Err. adjusted for 111 clusters in codcom)
----------------------------------------------------------------------------------
                 |               Robust
            ii4a |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-----------------+----------------------------------------------------------------
 well_depth_mtrs |  -.0382024   .0226871    -1.68   0.095     -.083163    .0067581
        flow_lps |    .719399    .215464     3.34   0.001     .2923999    1.146398
pump_capacity_HP |  -.1857801   .0947189    -1.96   0.052    -.3734907    .0019305
           _cons |   15.94794   1.769839     9.01   0.000     12.44054    19.45535
----------------------------------------------------------------------------------

. regress ii4a meetings tarifa_volum , cluster (codcom)

Linear regression                               Number of obs     =        165
                                                F(2, 164)         =      32.23
                                                Prob > F          =     0.0000
                                                R-squared         =     0.2943
                                                Root MSE          =     7.5453

                               (Std. Err. adjusted for 165 clusters in codcom)
------------------------------------------------------------------------------
             |               Robust
        ii4a |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    meetings |   3.230295   1.347429     2.40   0.018     .5697506    5.890839
```

```
tarifa_volum |   9.057183   1.368212     6.62   0.000     6.355601    11.75876
       _cons |   7.725739   1.314219     5.88   0.000     5.130768    10.32071
------------------------------------------------------------------------------

. regress ii4a elev ppt City_Dist_mtrt, cluster (codcom)

Linear regression                               Number of obs     =        168
                                                F(3, 167)         =      19.88
                                                Prob > F          =     0.0000
                                                R-squared         =     0.2551
                                                Root MSE          =     7.7936

                                 (Std. Err. adjusted for 168 clusters in codcom)
--------------------------------------------------------------------------------
               |               Robust
          ii4a |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
---------------+----------------------------------------------------------------
          elev |  -.0061563   .0021113    -2.92   0.004    -.0103247    -.001988
           ppt |   .0069244   .0018591     3.72   0.000      .003254    .0105948
City_Dist_mtrt |  -.0000297   .0001638    -0.18   0.856    -.0003531    .0002937
         _cons |   7.098094   3.506962     2.02   0.045     .1744007    14.02179
--------------------------------------------------------------------------------

. regress ii4a iv22 vi34a vi34b vi35 viii53electricidad viii57 well_depth_mtrs flow_lps
pump_cap
> acity_HP meetings tarifa_volum elev ppt City_Dist_mtrt, cluster(codcom)

Linear regression                               Number of obs     =        107
                                                F(14, 106)        =      20.23
                                                Prob > F          =     0.0000
                                                R-squared         =     0.6047
                                                Root MSE          =     6.1202

                                     (Std. Err. adjusted for 107 clusters in codcom)
------------------------------------------------------------------------------------
                   |               Robust
              ii4a |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------------+----------------------------------------------------------------
              iv22 |   12.61176   4.593674     2.75   0.007     3.504351    21.71916
             vi34a |  -19.82911    8.12409    -2.44   0.016    -35.93591    -3.72231
             vi34b |  -1.769048   5.520133    -0.32   0.749    -12.71325    9.175153
              vi35 |  -10.81402   11.22705    -0.96   0.338    -33.07274     11.4447
viii53electricidad |   7.131984   17.42979     0.41   0.683    -27.42426    41.68823
            viii57 |   2.168004   7.634275     0.28   0.777    -12.96769     17.3037
   well_depth_mtrs |   .0043865   .0166946     0.26   0.793    -.0287122    .0374852
          flow_lps |   .2725723   .1561871     1.75   0.084    -.0370839    .5822285
  pump_capacity_HP |  -.0410576   .0993793    -0.41   0.680    -.2380867    .1559715
          meetings |   .6485375   1.700779     0.38   0.704    -2.723422    4.020497
      tarifa_volum |     6.7763   1.492506     4.54   0.000     3.817262    9.735338
              elev |  -.0050383   .0034652    -1.45   0.149    -.0119084    .0018318
               ppt |   .0057929   .0028171     2.06   0.042     .0002077    .0113781
    City_Dist_mtrt |   .0002639   .0001733     1.52   0.131    -.0000797    .0006075
             _cons |  -7.112743   18.48325    -0.38   0.701    -43.75758     29.5321
------------------------------------------------------------------------------------

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```

Appendix 4: Table 3

```
. regress well_depth_mtrs iv22 vi34a vi34b vi35 viii53electricidad viii57

      Source |       SS           df       MS      Number of obs   =       141
-------------+----------------------------------   F(6, 134)       =      8.19
       Model |  94148.3451         6  15691.3908   Prob > F        =    0.0000
    Residual |  256656.389       134  1915.34619   R-squared       =    0.2684
-------------+----------------------------------   Adj R-squared   =    0.2356
       Total |  350804.734       140   2505.7481   Root MSE        =    43.765

------------------------------------------------------------------------------------
   well_depth_mtrs |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------------+----------------------------------------------------------------
              iv22 |  -.2771281   27.36417    -0.01   0.992    -54.39869    53.84444
             vi34a |  -47.73029     50.123    -0.95   0.343    -146.8649    51.40428
             vi34b |    87.5548   33.62307     2.60   0.010     21.05422    154.0554
              vi35 |  -112.3839   60.76182    -1.85   0.067    -232.5602    7.792367
viii53electricidad |   -194.268   103.9129    -1.87   0.064    -399.7896    11.25368
            viii57 |  -99.23476   48.50315    -2.05   0.043    -195.1655   -3.303981
             _cons |   257.1819   100.5363     2.56   0.012     58.33857    456.0253
------------------------------------------------------------------------------------

. regress well_depth_mtrs meetings tarifa_volum

      Source |       SS           df       MS      Number of obs   =       138
-------------+----------------------------------   F(2, 135)       =      1.15
       Model |  5692.62506         2  2846.31253   Prob > F        =    0.3200
    Residual |  334427.752       135  2477.24261   R-squared       =    0.0167
-------------+----------------------------------   Adj R-squared   =    0.0022
       Total |  340120.377       137  2482.63049   Root MSE        =    49.772

------------------------------------------------------------------------------
well_depth~s |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    meetings |  -7.659225   9.313942    -0.82   0.412    -26.07934    10.76089
tarifa_volum |  -9.489222   9.366096    -1.01   0.313    -28.01248    9.034034
       _cons |   70.96918   8.705403     8.15   0.000     53.75257    88.18578
------------------------------------------------------------------------------

. regress well_depth_mtrs elev ppt City_Dist_mtrt

      Source |       SS           df       MS      Number of obs   =       142
-------------+----------------------------------   F(3, 138)       =     15.59
       Model |  91716.7646         3  30572.2549   Prob > F        =    0.0000
    Residual |  270706.722       138  1961.64291   R-squared       =    0.2531
-------------+----------------------------------   Adj R-squared   =    0.2368
       Total |  362423.487       141  2570.37934   Root MSE        =     44.29

--------------------------------------------------------------------------------
well_depth_m~s |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
---------------+----------------------------------------------------------------
          elev |   .0512299   .0127691     4.01   0.000     .0259816    .0764783
           ppt |  -.0301319   .0109618    -2.75   0.007    -.0518068    -.008457
City_Dist_mtrt |  -.0010298   .0010295    -1.00   0.319    -.0030654    .0010059
         _cons |   99.51715   20.39781     4.88   0.000     59.18449    139.8498
--------------------------------------------------------------------------------

. regress well_depth_mtrs iv22 vi34a vi34b vi35 viii53electricidad viii57 meetings
tarifa_volum
```

```
> elev ppt City_Dist_mtrt

      Source |       SS           df       MS      Number of obs   =       137
-------------+----------------------------------   F(11, 125)      =      8.33
       Model |  143498.271        11  13045.2974   Prob > F        =    0.0000
    Residual |  195747.398       125  1565.97918   R-squared       =    0.4230
-------------+----------------------------------   Adj R-squared   =    0.3722
       Total |  339245.669       136  2494.45345   Root MSE        =    39.572

------------------------------------------------------------------------------------
   well_depth_mtrs |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------------+----------------------------------------------------------------
              iv22 |   13.52127   26.01447     0.52   0.604     -37.9646    65.00714
             vi34a |  -47.53511   47.98355    -0.99   0.324    -142.5005     47.4303
             vi34b |   90.58415    31.0129     2.92   0.004     29.20578    151.9625
              vi35 |  -26.01859   60.72884    -0.43   0.669    -146.2085    94.17132
viii53electricidad |  -67.48539    102.843    -0.66   0.513    -271.0245    136.0537
            viii57 |  -50.83005   47.85292    -1.06   0.290    -145.5369    43.87682
          meetings |   17.76498   8.343007     2.13   0.035     1.253134    34.27683
      tarifa_volum |   7.120225   7.979394     0.89   0.374    -8.671986    22.91244
              elev |   .0604834   .0138621     4.36   0.000     .0330487    .0879182
               ppt |   -.020877   .0119852    -1.74   0.084    -.0445971    .0028432
    City_Dist_mtrt |  -.0011872   .0009754    -1.22   0.226    -.0031176    .0007433
             _cons |   122.2309    105.783     1.16   0.250    -87.12681    331.5887
------------------------------------------------------------------------------------

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.
```

Appendix 5: Table 4

```
. regress flow_lps iv22 vi34a vi34b vi35 viii53electricidad viii57

      Source |       SS           df       MS      Number of obs   =       137
-------------+----------------------------------   F(6, 130)       =      7.02
       Model |  503.119126         6  83.8531876   Prob > F        =    0.0000
    Residual |  1553.63372       130  11.9510286   R-squared       =    0.2446
-------------+----------------------------------   Adj R-squared   =    0.2098
       Total |  2056.75284       136  15.1231827   Root MSE        =     3.457

------------------------------------------------------------------------------------
          flow_lps |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------------+----------------------------------------------------------------
              iv22 |  -3.297701   2.231135    -1.48   0.142    -7.711734    1.116332
             vi34a |  -3.703156   3.875517    -0.96   0.341     -11.3704    3.964091
             vi34b |  -4.063351   2.639009    -1.54   0.126    -9.284314    1.157613
              vi35 |   4.133776   5.500755     0.75   0.454    -6.748811    15.01636
viii53electricidad |  -7.251832   7.744685    -0.94   0.351    -22.57377      8.0701
            viii57 |   2.691306   4.114441     0.65   0.514    -5.448623    10.83124
             _cons |   14.05351   7.364212     1.91   0.059    -.5156997    28.62273
------------------------------------------------------------------------------------

. regress flow_lps meetings tarifa_volum

      Source |       SS           df       MS      Number of obs   =       133
-------------+----------------------------------   F(2, 130)       =      1.00
       Model |  30.5226647         2  15.2613324   Prob > F        =    0.3719
    Residual |   1990.6937       130  15.3130284   R-squared       =    0.0151
-------------+----------------------------------   Adj R-squared   =   -0.0001
       Total |  2021.21636       132  15.3122452   Root MSE        =    3.9132

------------------------------------------------------------------------------
    flow_lps |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    meetings |  -.0599048   .7428464    -0.08   0.936    -1.529538    1.409728
tarifa_volum |    1.00219   .7158247     1.40   0.164    -.4139832    2.418364
       _cons |   3.735238   .7019239     5.32   0.000     2.346566    5.123911
------------------------------------------------------------------------------

. regress flow_lps elev ppt City_Dist_mtrt

      Source |       SS           df       MS      Number of obs   =       137
-------------+----------------------------------   F(3, 133)       =      4.29
       Model |    181.3925         3  60.4641666   Prob > F        =    0.0063
    Residual |  1875.34212       133  14.1003167   R-squared       =    0.0882
-------------+----------------------------------   Adj R-squared   =    0.0676
       Total |  2056.73462       136  15.1230487   Root MSE        =     3.755

--------------------------------------------------------------------------------
      flow_lps |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
---------------+----------------------------------------------------------------
          elev |    .004279   .0012018     3.56   0.001      .001902    .0066561
           ppt |   .0035009   .0012949     2.70   0.008     .0009397    .0060622
City_Dist_mtrt |  -.0000706   .0000875    -0.81   0.421    -.0002436    .0001024
         _cons |  -1.925816   2.304585    -0.84   0.405    -6.484196    2.632564
--------------------------------------------------------------------------------
```

```
.  regress  flow_lps  iv22  vi34a  vi34b  vi35  viii53electricidad  viii57  meetings
tarifa_volum elev pp
> t City_Dist_mtrt

      Source |       SS           df       MS      Number of obs   =       132
-------------+----------------------------------   F(11, 120)      =      4.49
       Model |  588.865931        11  53.5332665   Prob > F        =    0.0000
    Residual |  1432.21041       120  11.9350867   R-squared       =    0.2914
-------------+----------------------------------   Adj R-squared   =    0.2264
       Total |  2021.07634       131  15.4280636   Root MSE        =    3.4547

------------------------------------------------------------------------------------
          flow_lps |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------------+----------------------------------------------------------------
              iv22 |  -1.421556   2.413978    -0.59   0.557    -6.201064    3.357952
             vi34a |  -2.732536   4.159613    -0.66   0.512    -10.96828    5.503209
             vi34b |  -4.251118   2.735481    -1.55   0.123     -9.66718    1.164944
              vi35 |   10.10213   6.113682     1.65   0.101    -2.002529     22.2068
viii53electricidad |  -4.178073   8.199327    -0.51   0.611    -20.41217    12.05602
            viii57 |   6.158265   4.508847     1.37   0.175    -2.768939    15.08547
          meetings |  -.5557555   .7621923    -0.73   0.467    -2.064843    .9533322
      tarifa_volum |   .6686767   .6755987     0.99   0.324    -.6689617    2.006315
              elev |    .003271   .0013812     2.37   0.019     .0005363    .0060056
               ppt |   .0007343   .0013989     0.52   0.601    -.0020354     .003504
     City_Dist_mtrt |  -.0000813   .0000874    -0.93   0.354    -.0002544    .0000917
             _cons |   7.546271   8.711127     0.87   0.388    -9.701155     24.7937
------------------------------------------------------------------------------------

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```

Appendix 6: Table 5

```
. regress pump_capacity_HP iv22 vi34a vi34b vi35 viii53electricidad viii57

      Source |       SS           df       MS      Number of obs   =       153
-------------+----------------------------------   F(6, 146)       =      5.10
       Model |  2776.21687         6  462.702811   Prob > F        =    0.0001
    Residual |  13234.7962       146  90.6492891   R-squared       =    0.1734
-------------+----------------------------------   Adj R-squared   =    0.1394
       Total |  16011.0131       152  105.335612   Root MSE        =     9.521

------------------------------------------------------------------------------------
  pump_capacity_HP |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------------+----------------------------------------------------------------
              iv22 |  -16.50106   5.735864    -2.88   0.005    -27.83711   -5.165009
             vi34a |  -14.58786    10.1546    -1.44   0.153    -34.65685    5.481136
             vi34b |   7.371166   6.788003     1.09   0.279    -6.044274    20.78661
              vi35 |  -17.18565   12.80004    -1.34   0.181    -42.48295    8.111647
viii53electricidad |  -20.94298   20.39805    -1.03   0.306    -61.25657    19.37061
            viii57 |  -21.04283   10.55458    -1.99   0.048    -41.90233   -.1833373
             _cons |   40.55109   19.57237     2.07   0.040     1.869328    79.23285
------------------------------------------------------------------------------------

. regress pump_capacity_HP meetings tarifa_volum

      Source |       SS           df       MS      Number of obs   =       149
-------------+----------------------------------   F(2, 146)       =      1.70
       Model |  340.010771         2  170.005386   Prob > F        =    0.1871
    Residual |  14640.7409       146  100.279047   R-squared       =    0.0227
-------------+----------------------------------   Adj R-squared   =    0.0093
       Total |  14980.7517       148  101.221295   Root MSE        =    10.014

------------------------------------------------------------------------------
pump_capac~P |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    meetings |  -3.275759   1.791351    -1.83   0.069    -6.816089    .2645703
tarifa_volum |     1.0152   1.764266     0.58   0.566    -2.471599    4.501998
       _cons |   10.20042   1.712747     5.96   0.000     6.815437     13.5854
------------------------------------------------------------------------------

. regress pump_capacity_HP elev ppt City_Dist_mtrt

      Source |       SS           df       MS      Number of obs   =       153
-------------+----------------------------------   F(3, 149)       =     16.96
       Model |  4072.61385         3  1357.53795   Prob > F        =    0.0000
    Residual |  11925.2129       149  80.0349862   R-squared       =    0.2546
-------------+----------------------------------   Adj R-squared   =    0.2396
       Total |  15997.8268       152  105.248861   Root MSE        =    8.9462

--------------------------------------------------------------------------------
pump_capacit~P |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
---------------+----------------------------------------------------------------
          elev |    .013902   .0024006     5.79   0.000     .0091584    .0186456
           ppt |  -.0006991   .0021306    -0.33   0.743    -.0049093     .003511
City_Dist_mtrt |  -.0003058   .0002012    -1.52   0.131    -.0007033    .0000918
         _cons |   7.143317   3.916101     1.82   0.070    -.5949498    14.88158
--------------------------------------------------------------------------------
```

```
. regress pump_capacity_HP iv22 vi34a vi34b vi35 viii53electricidad viii57 meetings
tarifa_volum
>  elev ppt City_Dist_mtrt

      Source |       SS           df       MS      Number of obs   =       148
-------------+----------------------------------   F(11, 136)      =      5.61
       Model |  4670.59001        11  424.599092   Prob > F        =    0.0000
    Residual |  10296.7664       136  75.7115177   R-squared       =    0.3121
-------------+----------------------------------   Adj R-squared   =    0.2564
       Total |  14967.3564       147  101.818751   Root MSE        =    8.7012

------------------------------------------------------------------------------------
  pump_capacity_HP |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------------+----------------------------------------------------------------
              iv22 |   -10.9685   5.595114    -1.96   0.052    -22.03318     .096181
             vi34a |  -11.33649   9.902588    -1.14   0.254    -30.91946    8.246482
             vi34b |   7.805535   6.305572     1.24   0.218    -4.664118    20.27519
              vi35 |  -2.790599   12.93058    -0.22   0.829     -28.3616     22.7804
viii53electricidad |  -.4797556   20.13277    -0.02   0.981    -40.29354    39.33403
            viii57 |  -3.122275   10.50744    -0.30   0.767    -23.90138    17.65683
          meetings |  -.3339185   1.720009    -0.19   0.846    -3.735341    3.067504
      tarifa_volum |   2.659559   1.642199     1.62   0.108    -.5879891    5.907108
              elev |   .0129529   .0027727     4.67   0.000     .0074698    .0184361
               ppt |  -.0007771   .0024668    -0.32   0.753    -.0056553    .0041011
    City_Dist_mtrt |  -.0002828   .0002087    -1.35   0.178    -.0006956      .00013
             _cons |   11.73786    20.5851     0.57   0.569    -28.97044    52.44615
------------------------------------------------------------------------------------

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```