Understanding Variability in Rural Water Use in the Colombian Andes

Antonia Kolic
Senior Undergraduate student
Applied Biology, Land and Food Systems, UBC
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Project supervisor: Sandra Brown
Faculty of Land and Food Systems
University of British Columbia

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1. Introduction

The access to safe drinking water is one of the most important indicators of socioeconomic development (Soares et al., 2002). Many regions of Latin America and the Caribbean, in particular, see large proportions of their populations without such access. In this region of the world, 15% of the population is not served by any drinking water service, and a further 11% must travel 1 km to reach the nearest source of drinking water (Soares et al., 2002). It has been suggested by the National Institute for Hydrology, Meterology and Natural Resources that 48% of the Colombian population has a high probability of experiencing water scarcity (Roa-Garcia et al., 2013). Precipitation is spatially and temporally variable, and a large proportion of rural communities obtain water from streams, creeks and small rivers (Roa et al. 2011)

The country of Colombia has one of the highest levels of water availability in the world, with an average of 57,000 m^3 of water per capita per year (Perez et al., 2004). However, the areas with the highest water availability are also the least populated. Approximately 30% of Colombia's population live in rural areas, and of the 1,972 municipalities in the country, 80% have a population of less than 12,500 (Perez et al., 2004). An important characteristic of the regional demography in Colombia, and Latin America in general, is the continuous migration of the rural population toward the cities. Since the end of the 1990s, populations in these regions have been characterized by the predominance of urban population over the rural (PAHO, 2001).

With a minority of the Colombian population living in rural areas, a large portion of government resources will typically go to the urban centers. This is in part due to the fact that these populations are better represented at the political and decision-making levels than the rural population (Soares et al., 2002). A result of this resource allocation is that access to safe drinking water in rural regions of the country has, in the past, not been prioritized. Water supply service in rural Colombia only reaches approximately 58% of the population, compared with 95% of the urban population (Roa-Garcia et al., 2013).

Further problems regarding water scarcity in rural regions of Colombia are associated with the way in which water services are managed. In fact, "water allocation decisions in rural regions of the global south can have profound implications for access to water, land use and livelihoods, and the environment" (Roa-Garcia et al., 2013, pg. 2). There are a large number of small water providers servicing Colombian rural regions. Municipalities are responsible for water supply, which may be provided either directly, through 'mixed' companies (public and private), private companies, or community-based organizations (Vargas, 2001). Approximately 11,500 community water organizations provide water to the rural regions, while only 1500 service the urban centers (Roa-Garcia et al., 2013).

There exists a lack of knowledge regarding variability in water use within the rural population of Colombia. An analysis of the water consumption habits within these populations will allow for a better understanding of how water is being used, and what anthropogenic or natural factors may be contributing to water scarcity in the region. This report aims to assess the differences in water use between five study sites in the Colombian Andes over time, between the different socio-economic levels of rural and peri-urban populations at these sites, and how water use varies between the seasons.

Furthermore, precipitation data for each of the study sites will be compared with water use in order to determine whether the amount of precipitation a region receives will affect how water is consumed. Finally, the major land uses of each of the study sites will be considered, in an attempt to account for any patterns observed in water use data.

2. Methods and Study sites

Water use data has been provided by community water providers from each study site to a project being funded by the International Development Research Centre. This project, *Climate Change Adaptation in Rural Colombia: the role of water governance* (Adaptación Cambio Climatico en Colombia Rural: el papel de la gobernanza del agua) is being conducted by Maria Cecilia Roa-Garcia, with the Instituto CINARA and Fundación Evaristo García. Further information on the project can be found at http://www.landfood.ubc.ca/swc/projects/ACCCR/socios.html.

Data from five of the seven study sites of the project have been provided for water use analysis. Two of the sites, Tribunas Corcega and Mundo Nuevo are located in the central branch of the Andes in Colombia. The township of Mundo Nuevo is in the department of Risaralda, and part of the municipality of Pereira. Land use in this region was originally dominated by agricultural activities (crops included coffee, bananas, corn, and cassava; livestock included pigs, chickens and cattle), but has recently shifted to rural residential. There is a significant presence of recreation and country houses in this region (Munoz, 2006). The township of Tribunas Corcega is mainly occupied by permanent crops. Coffee is the dominant crop, occupying 75% of the township area. Other crops include cassava, beans, tomatoes, and cold weather fruits. Approximately 20% of the area in this township is covered by both natural forest and timber plantation. That being said, the economic base of this region is logging and coffee cultivation, with other important economic activities including cattle rearing and eco-tourism (EATC, 2006).

The remaining three study sites, Golondrinas, Mondomo and La Sirena, are located in the Western branch of the Andes. The village of Golondrinas is located north of the city of Cali. Coal was commercially exploited in this region until 1997. At this time the principal mines were closed due to financial bankruptcy (Suarez, 2011), although artisanal mining continues. The current dominant land use in this region is forestry and conservation. Agriculture does occur, but is limited by climatic and soil conditions (PDG, 2003). Furthermore, the land and water resources available in Golondrinas have been degraded due to a recent population increase and a lack of clear land use policy (PDG, 2003). Mondomo is another study site that is located very close to the city of Cali. Land use in this region is dominated by forest and natural vegetation. However 20% of the land is used for agriculture, with major crops including coffee, cassava, and sugarcane. A further 20% of the land is used as pasture for cattle grazing (POT Santander de Quilichao, 2000). The final study site, La Sirena, is peri-urban, and is located in the southwest of the city of Cali. It is the result of a massive migration from the rural areas to the urban area that is Cali. This migration began in the 1960s. The dominant land use in this region is rural residential and small farms. A large portion of this region is designated as a forest reserve, but the latest community development plan is not compliant with these land use regulations (PDV, 2007).

3. Comparative Rural Water Use

3.1 Number of Connections

Small water providers (<2,500 connections) in Colombia often rely on volunteer or part-time administrators and less specialized technical staff than larger organizations (Brown, 2013). This may lead to an inconsistent record of data. Furthermore, it is less likely that these small providers will receive as much funding and support from the government as the larger providers might. This is due to the fact that many small water providers do not hold the legal right to withdraw water from streams (concessions), and do not have the appropriate accounting systems in place that are required in order to receive subsidies from the government (Brown, 2013). This is likely an issue faced by water providers at the five study sites being analyzed in this report, as they are all small community based organizations.

Figure 1 shows the average number of water connections in each study site for 2012. As can be observed, there is great variation between the sites, with Mundo Nuevo having the fewest connections (324), and Tribunas Corcega having the most (2074). The differences between these values can be attributed to population sizes at each site. Estimated population size at each study site has been determined with the use of the average family size of the department within which a study site occurs and number of connections at each site (Table 1). Tribunas Corcega has the highest estimated population size of 7673, and the most number of connections. Mundo Nuevo meanwhile, has the lowest estimated population size (1199), and therefore the fewest number of connections.

Figure 1 – Number of connections at each study site

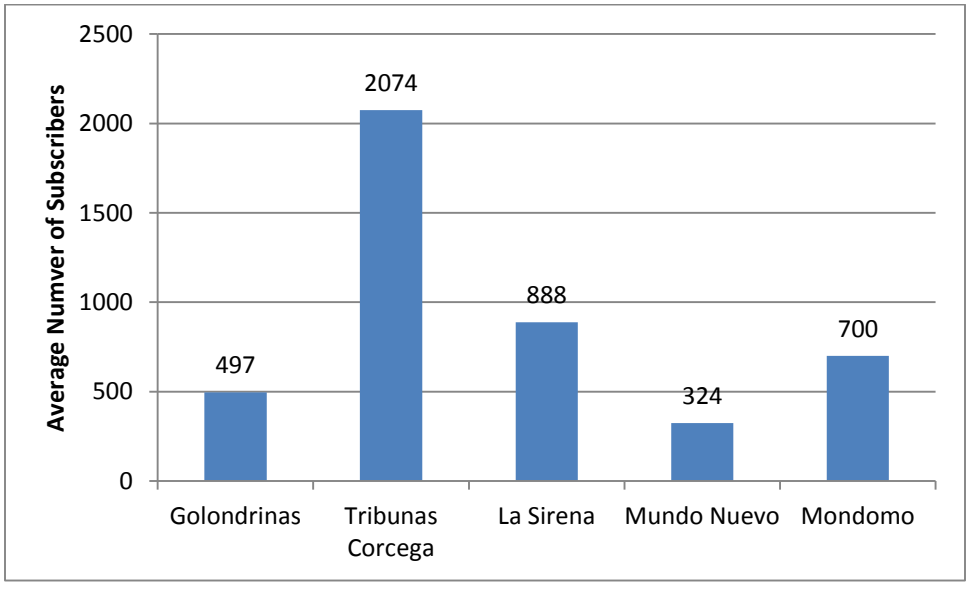


Table 1 - Estimated population size at each study site

Study Site	Average Family Size	# of Connections	Estimated Population Size
Tribunas Corcega	3.7 (DANE, 2005)	2074	7674
La Sirena	3.8 (DANE, 2005)	888	3374
Mondomo	4.0 (DANE, 2005)	700	2800
Golondrinas	3.8 (DANE, 2005)	497	1887
Mundo Nuevo	3.7 (DANE, 2005)	324	1199

Table 2 shows that the study sites with the most connections typically have the longest distribution networks. The water providers who are servicing distribution networks with a higher number of connections per km of the network will likely require fewer resources (both financial and labour) to maintain infrastructure. A higher concentration of connections per km of water distribution will likely also save providers time when repairs are needed, as they will have less distance to travel between connections. It is interesting to note that Tribunas Corcega, the site with a significantly higher number of connections than the others, is the site with the fewest number of connections per km of water distribution. This indicates that if repairs are necessary, it will take far more time for them to occur because of the distance between connections than it would in La Sirena, for example.

Table 2 – Number of connections per km of water distribution at each study site

Study Site	# Connections	Length of Distribution Network (km)	# Connections per km of Water Distribution
Golondrinas	497	7.5	66
La Sirena	888	9.753	91
Mondomo	700	17	41
Mundo Nuevo	324	10.5	31
Tribunas Corcega	2074	103	20

3.2 Socio-economic status of water users

Households in Colombia are classified by their socio-economic status by municipalities, with characteristics of the housing unit being considered when these classifications are made. Domestic water users are classified into six socio-economic estratos, with 1 being the poorest and 6 the wealthiest. This classification scheme also determines the rates paid for water distribution services. Households in the lowest estratos (1- 3) pay less than the cost of water distribution. Those in estrato 4 pay the cost of water distribution while households in estratos 5 and 6 (as well as non-domestic users) pay more than the cost of water distribution (Roa-Garcia et al., 2013). With that being said, the socio-economic composition of users at each study site will help to indicate how, and for what purposes, water is being used.

The distribution of connections among estratos varies greatly between the five study sites, as does the number of estratos represented. La Sirena, for example, is dominated by connections in estrato 1 (99%),

with only a relatively smaller number of Official and Commercial users (Figure 2). Tribunas Corcega, in contrast, has connections to subscribers in all estratos (Figure 3). While each socio-economic level is represented at this study site, the distribution of connections between them is not equal. Estrato 4 has the greatest proportion of connections (30%), while the industrial estrato has the lowest proportion (0.99%). Charts detailing the distribution of connections among estratos for Golondrinas, Mondomo, and Mundo Nuevo can be found in Appendix 1.

Figure 2 – Percentage of connections in each estrato at La Sirena

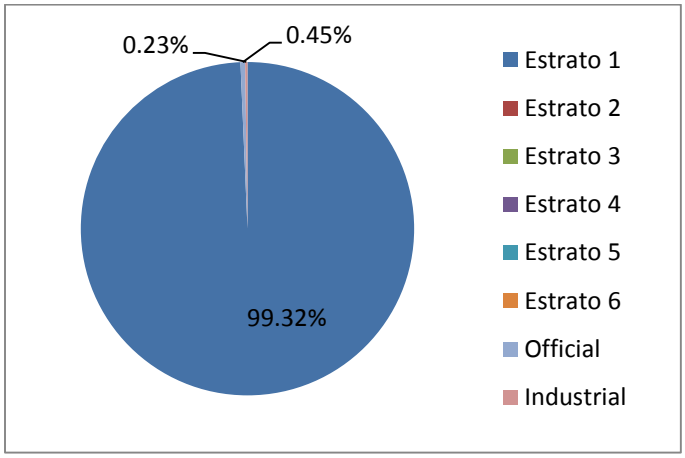
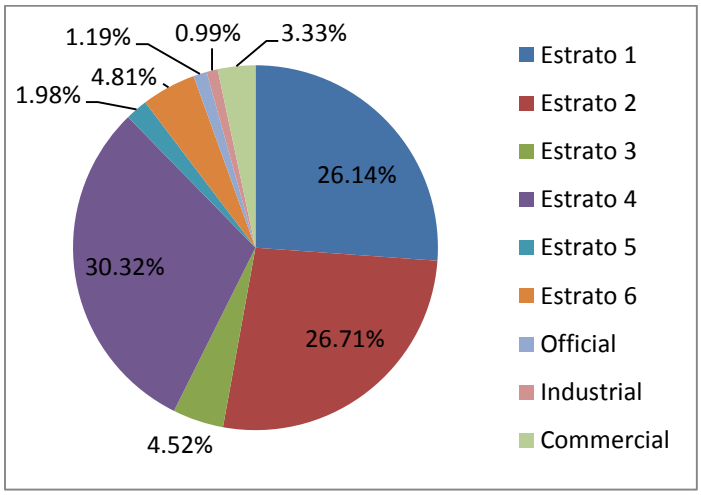


Figure 3 – Percentage of connections in each estrato at Tribunas Corcega



For community based water providers that see >95% of connections in estratos 1 to 3 (La Sirena, Golondrinas and Mondomo), the vast majority of income received from subscribers is below the cost of water provision. The proportion of connections at each estrato will signify how much money water providers have access to, to improve or expand infrastructure (Roa-Garcia et al., 2013). That being said, because the majority of subscribers in these three study sites are paying less than the cost of water distribution, the associated water providers will be unable to efficiently make repairs or improvements to the system due to a lack of money. Water providers in areas with a greater proportion of subscribers in wealthier estratos, such as Tribunas Corcega and Mundo Nuevo, will have more money at their

disposal for such repairs and expansions. Note that water providers are entitled to receive municipal subsidies based on their costs of water provision and the number of subscribers in low income categories (relative to high estratos), however many small organizations have difficulty meeting the accounting and other requirements to access these funds (Brown 2013).

3.3 Monthly Water Use Comparisons

Average total monthly water consumption is different at each study site. This is mainly due to the fact that each site has a different population size, and therefore a different number of water connections. Tribunas Corcega, the study site with the highest number of water connections, consumes the most water each month (Figure 4). Mundo Nuevo, meanwhile, is the study site with the fewest number of connections. It is also the site that consumes the least amount of water each month (Figure 5). The average monthly water consumption in this region is 5,946,750 L/month, while in Tribunas Corcega this value reaches 50,043,250 L/month. Charts describing total monthly water consumption at La Sirena, Mondomo, and Golondrinas can be found in Appendix 2.

Figure 4 - Monthly total water consumption at Tribunas Corcega

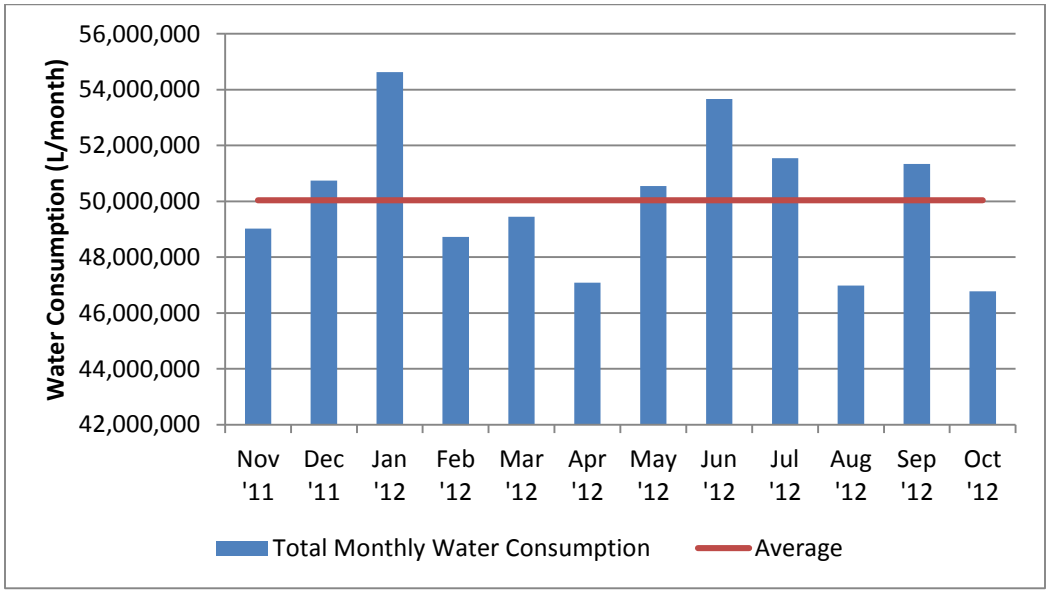
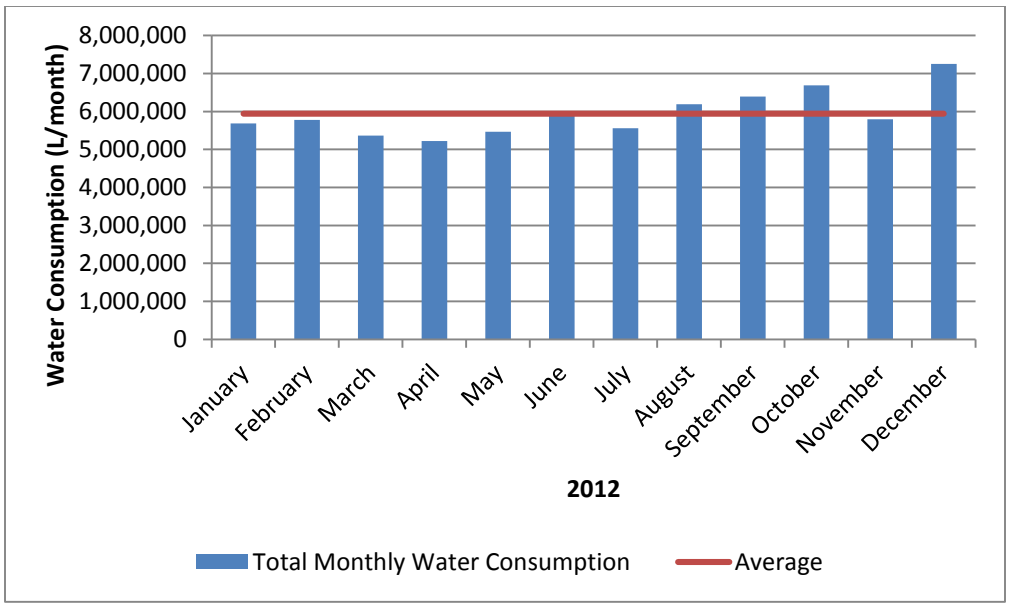


Figure 5 – Monthly total water consumption at Mundo Nuevo



While each study site has an allotted concession of water that they are entitled to use each month, four of the sites used less water than they were allowed. Table 3 shows that La Sirena, Mondomo, Mundo Nuevo and Tribunas Corcega each used at least 28% less water than they have been allocated in the month where total water use was the highest. The adjusted highest total monthly water use was calculated by taking into consideration the median leakage % throughout all months where data was available. This leakage % (18%-56.5%) was added to the total monthly water use value to account for water that was lost due to leakage in infrastructure or illegal connections. Only Golondrinas uses more water than it's allocated concession.

Concession allocations ideally account for stream flow in the catchments so that residents would only be allowed to use as much water as the stream could provide. Using more water than the allocated concession indicates water scarcity. Both Golondrinas and Tribunas Corcega report water scarcity, suggesting that concessions may not reflect actual dry season streamflow levels.

Table 3 – Water use vs. concession at each study site

Study Site	Concession (L/second)	Concession (L/month)	Adjusted[1] Highest Total Monthly Water Use (L/month)	% Difference
Golondrinas	3	7,776,000	14,620,375	88%
La Sirena	18	46,656,000	28,314,100	-40%
Mondomo	10	25,920,000	16,807,680	-35.2%
Mundo Nuevo	5.5	14,256,000	10,151,400	-28.8%
Tribunas Corcega	52.2	135,302,400	85,488,125	-36.8%

[1]Adjusted water use corresponds to metered water use + losses in the distribution network

While total water use (L/month) is of interest in relation to concessions and streamflow, water use by estrato provides an indication of the relative importance of domestic versus non-domestic water use (industrial, commercial, and official). Each estrato in every study site consumes a different amount of water. This is a reflection of the number of connections associated with each estrato. Estrato 1 at La Sirena consumes the most water (Figure 6) – a far greater amount than both official and industrial estratos. The reason for this great difference is due to the fact that 99% of the water connections in La Sirena are to estrato 1 subscribers (Figure 2). The other 1% is divided up between official and industrial subscribers. It is possible to draw this same conclusion for each of the other study sites (Figures 4, 5, and 6 in Appendix 2) – the amount of water consumed by each estrato is a reflection of how many connections are associated with each estrato. In all five study sites, domestic water use dominates total monthly water consumption values. However, in Tribunas Corcega, commercial water use is significant (Figure 7).

Figure 6 - Monthly water consumption in each estrato at La Sirena

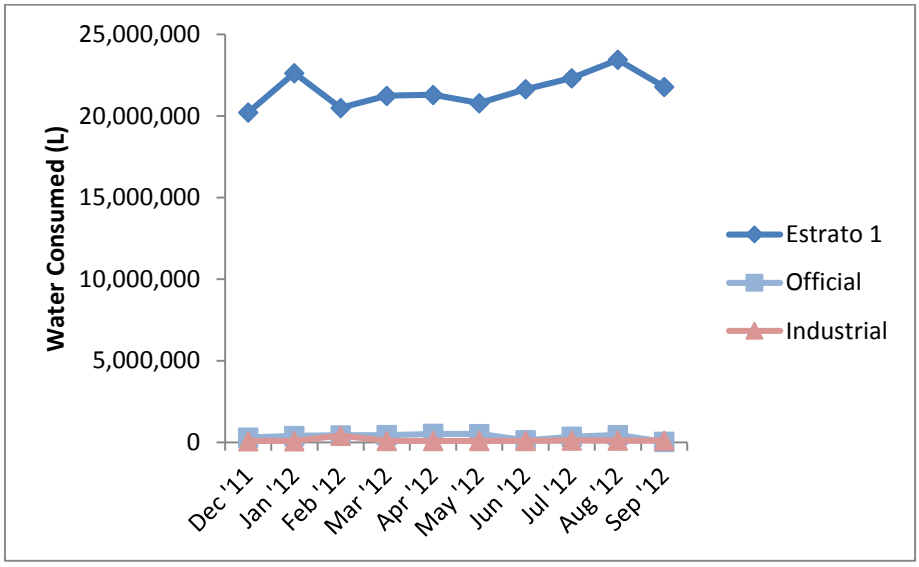
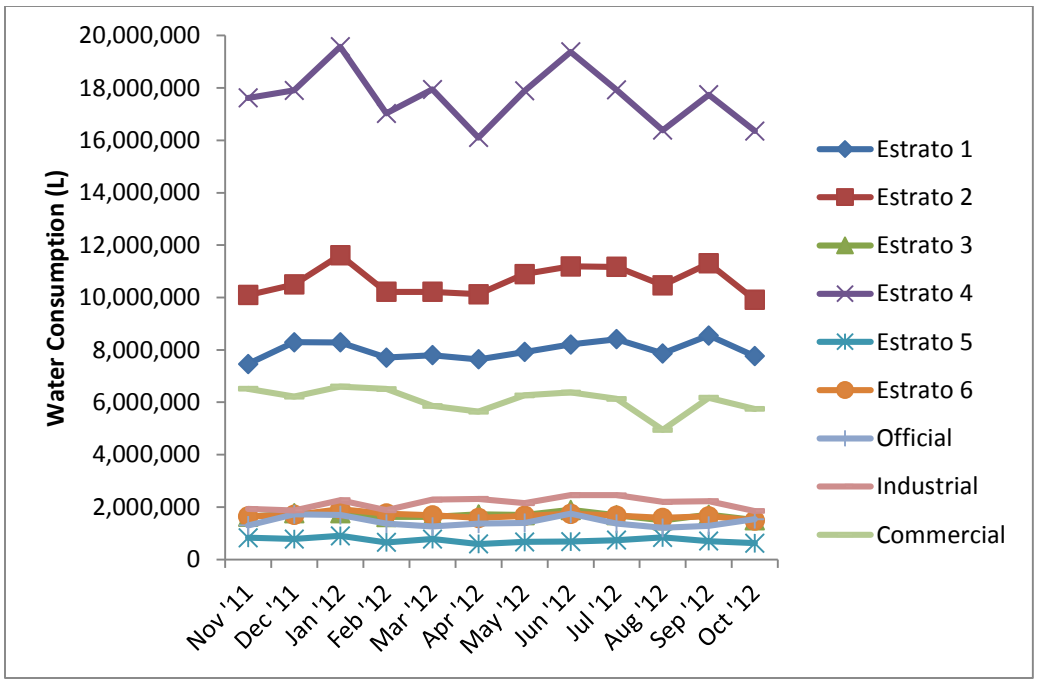
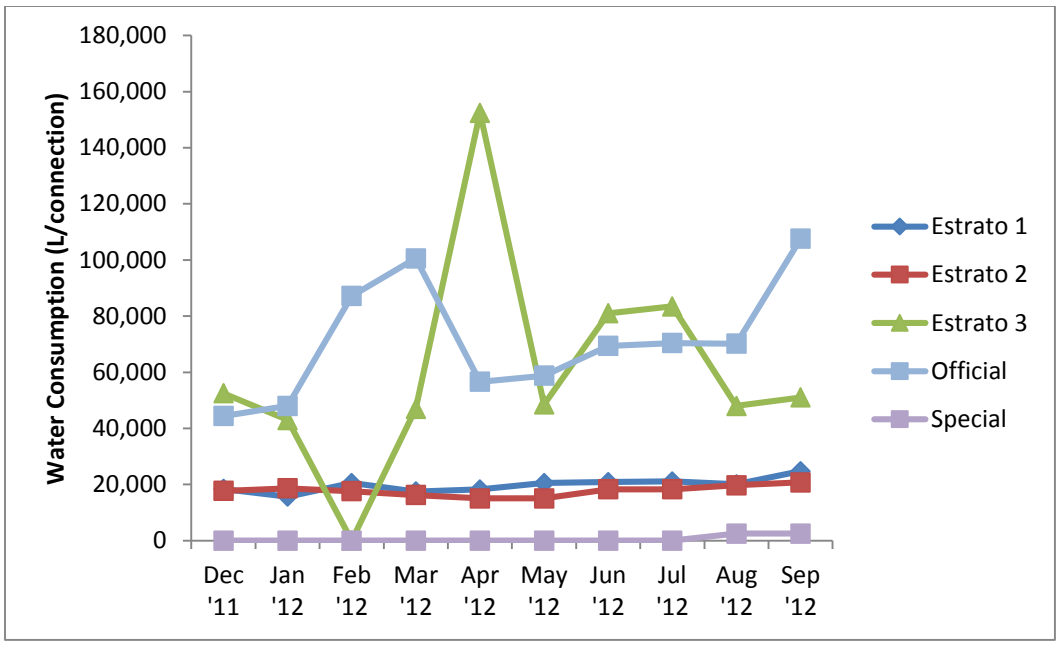


Figure 7 - Monthly water consumption in each estrato at Tribunas Corcega



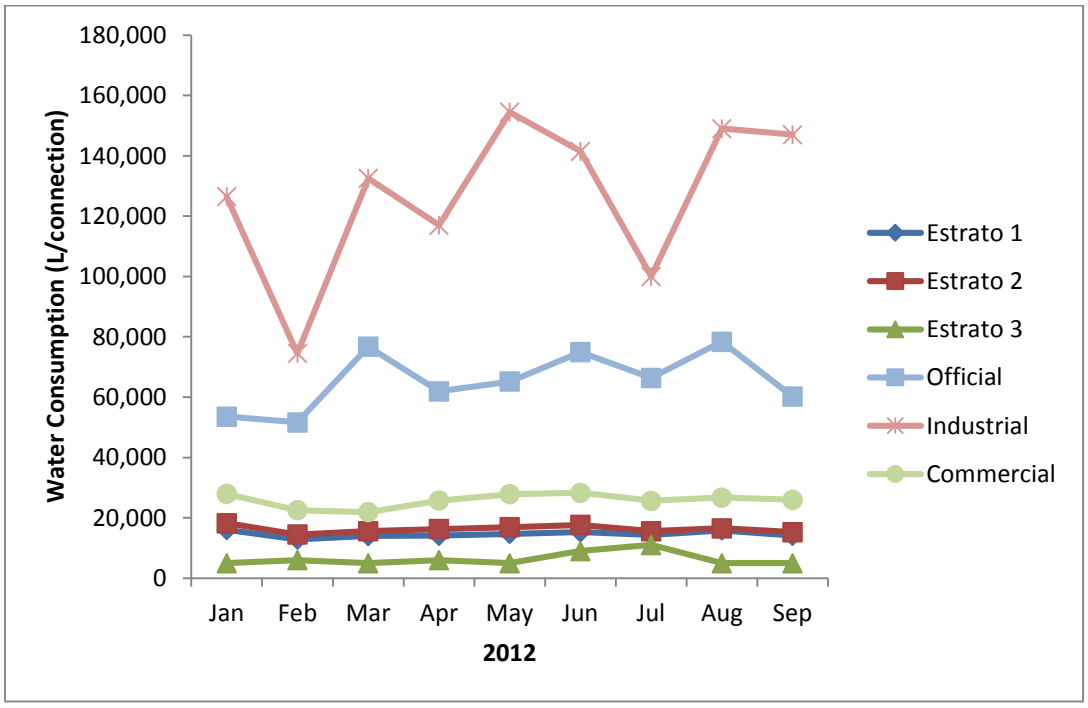
While the assessment of total water use per estrato gives an indication of the relative importance of domestic water use within rural areas, water consumption per subscriber gives a clearer picture of monthly variability and the differences that occur between regions. Figure 8 illustrates that water consumption per subscriber in estratos 1 and 2 at Golondrinas remains fairly constant throughout the year. Estrato 3, however, sees a significant decrease in water consumption in February, and a significant increase in water consumption in April. This significant increase in per subscriber water consumption in April could be related to the week long holiday of Semana Santa. The other water consumption peak in estrato 3, which occurs in June and July, may be attributed to a combination of hotter climate and the school holidays, and therefore children spending more time at home.

Figure 8 - Monthly water consumption/subscriber in each estrato at Golondrinas



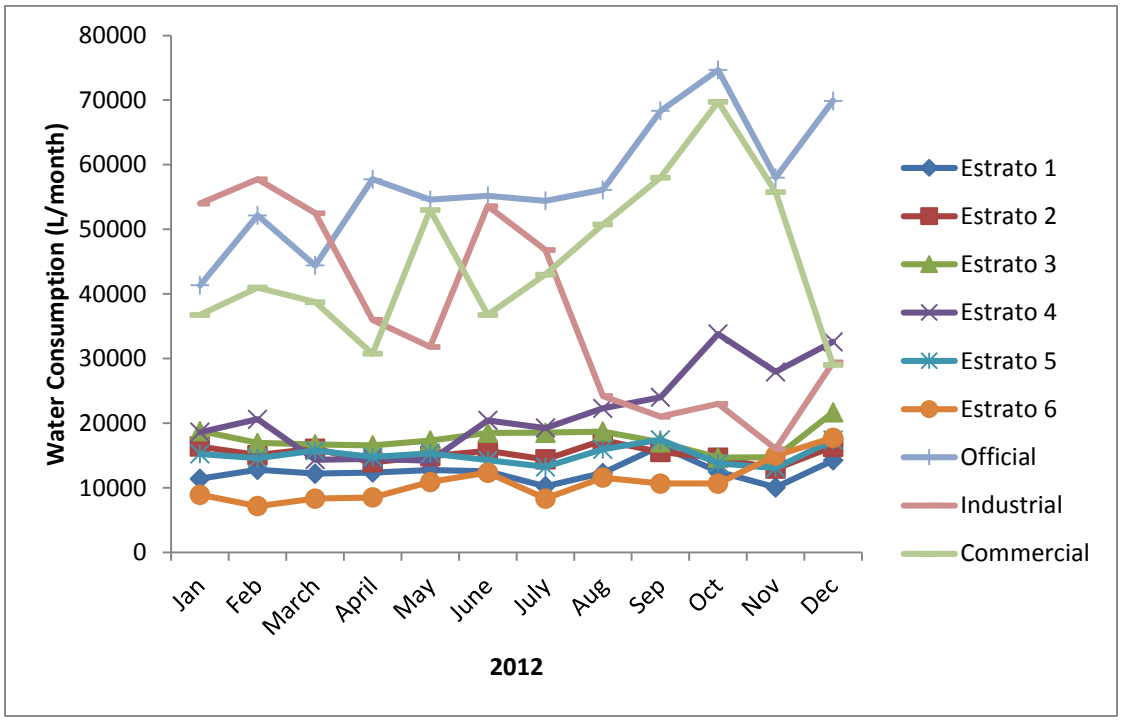
Monthly water use per subscriber in the domestic estratos at Mondomo remains relatively constant throughout the year (Figure 9). Interesting to note is the fact that 20% of the land in this study site is allocated to crops (POT Santander de Quilichao, 2000), and therefore it would be expected that metered water consumption would fluctuate throughout the year depending on harvest schedules for the different crops. However, this does not appear to be the case.

Figure 9 - Monthly water consumption/subscriber in each estrato at Mondomo



Water consumption per subscriber remains relatively constant in the residential estratos in Mundo Nuevo throughout the year (Figure 10). The non-domestic estratos, however, see a high degree of variation. Unfortunately there is no data available to assess what types of businesses are associated with the connections in these estratos, so the patterns cannot be easily explained. However, we again see peak commercial water use in the month of May, similar to what occurs in Mondomo. Furthermore, schools are associated with the Official estrato, and therefore the increase in water consumption starting in September is likely due to students returning to classes.

Figure 10 - Monthly water consumption/subscriber in each estrato at Mundo Nuevo



With the exception of Golondrinas, monthly water use per connection in domestic estratos falls approximately between 15,000 and 20,000 L/month. While some study sites see variability within this range, others do not. This is especially true for estratos 1 – 3. Analysis of another Colombian region by Roa-Garcia et al. (2013) shows that monthly water consumption per connection in a rural region very similar to those being examined here falls within a similar range (17,000 – 23,000 L/month). This similarity indicates that water consumption rates across rural regions of the country are similar. Charts describing water consumption per subscriber in La Sirena and Tribunas Corcega can be found in Appendix 2.

3.4 Variability in Water Use

There are two dry seasons that occur in these regions of Columbia. The driest occurs from July to September, while the 'smaller' dry season occurs through January and February. An average of water consumption during the larger dry season months was calculated and compared against the annual

water consumption average for each estrato at each study site. Results for Mondomo can be found in Appendix 3.

The decrease in water consumption during the dry season for official connections at La Sirena could be attributed to the fact that students are not attending classes as they are on summer holiday (Table 3). The increase in water consumption in Estrato 1 during this time could be associated with the large number of small farms in the region. These farms are likely to have animals which require more water as the temperature increases. The significant decrease in water consumption during the dry season in the official estrato is likely due to the fact that these subscribers (a government office, and health office, and a school) are taking holidays during this time.

Table 5 illustrates that estratos 1-5 in Mundo Nuevo use more water during the dry season. This could be attributed to the fact that there are many recreational and country homes in this study site (Munoz, 2006), and therefore families may come from the larger cities during these months on holiday.

The official estrato in Tribunas Corcega is dominated by schools (17 elementary schools, and 2 high schools). As Table 6 shows, dry season water consumption for the official estrato is 10.4% lower than the annual average. This is likely due to the fact that students are not attending classes during these months, but are at home instead. This may also result in the observed increase in water consumption in some of the domestic estratos. It is also interesting to note that commercial water use (the only significant non-domestic water use) decreased in the dry season.

Table 4 – Variability in seasonal water consumption at La Sirena

		Dry Season	
Estrato	**Annual Average**	**Jul/Aug/Sep**	**% Difference**
1	21,583,600	22,515,666	4.3%
Official	350,900	272,666	-22%
Industrial	123,400	108,333	-12%

Table 5 - Variability in seasonal water consumption at Mundo Nuevo

		Dry Season	
Estrato	**Annual Average**	**Jul/Aug/Sep**	**% Difference**
1	615,917	640,000	3.9%
2	1,584,667	1,639,333	3.4%
3	851,333	886,667	4.2%
4	1,429,250	1,435,667	0.4%
5	398,333	415,333	4.3%
6	130,167	122,333	-6%
Official	586,833	554,667	-5.5%
Industrial	169,167	153,333	-9.4%
Commercial	181,083	202,333	11.7%

Table 6 - Variability in seasonal water consumption at Tribunas Corcega

		Dry Season	
Estrato	Annual Average	Jul/Aug/Sep	% Difference
1	7,992,000	8,276,000	3.5%
2	10,641,500	10,978,667	3.1%
3	1,676,083	1,630,667	-2.7%
4	17,653,333	17,349,000	-1.7%
5	731,833	756,667	3.4%
6	1,673,750	1,633,000	-2.4%
Official	1,437,250	1,287,667	-10.4%
Industrial	2,155,750	2,293,333	6.4%
Commercial	6,081,750	5,751,667	-5.4%

3.5 Water Use versus Precipitation

Monthly precipitation data was available for Golondrinas, Tribunas Corcega, Mundo Nuevo (see Appendix 4) and La Sirena. This data was plotted with total monthly water consumption in order to compare whether water consumption increased or decreased with precipitation levels. Unfortunately, insufficient precipitation data was available for Mondomo, and so this comparison could not be made.

Figure 11 illustrates that at Golondrinas, water consumption (red line) decreases when precipitation is relatively high (April – May). It is interesting to note that during the dry season (June – August), water consumption increases, and reaches some of the highest annual levels. Similarly for Tribunas Corcega, it can be observed through Figure 12 that as precipitation decreases (blue bars), metered water consumption appears to increase (April - May). However, due to a lack of data regarding precipitation from June onwards, we are unable to determine if this pattern continues.

Figure 11 - Monthly water consumption in relation to precipitation at Golondrinas

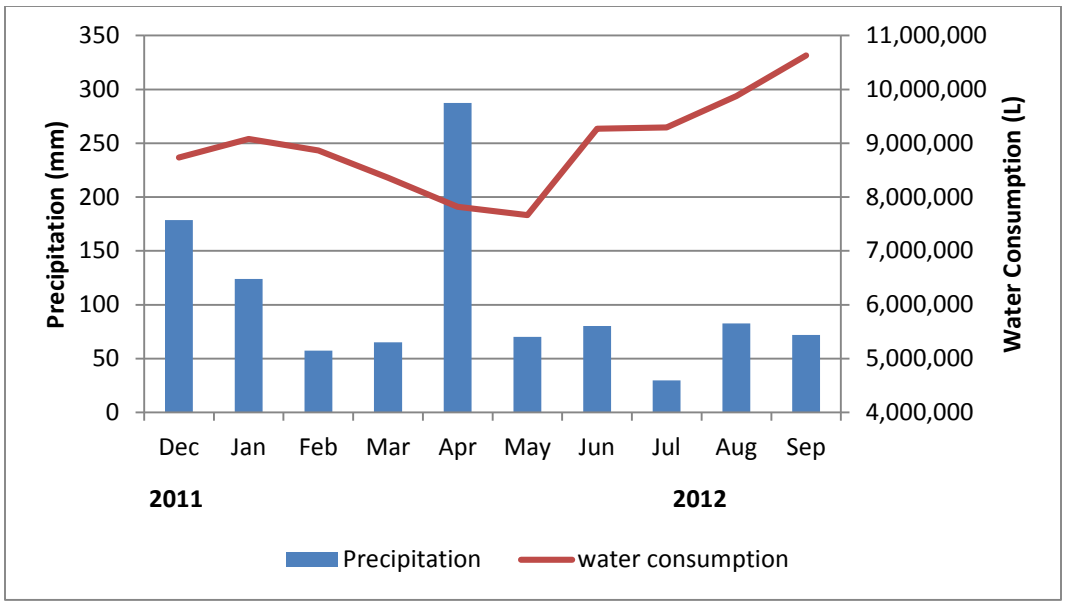
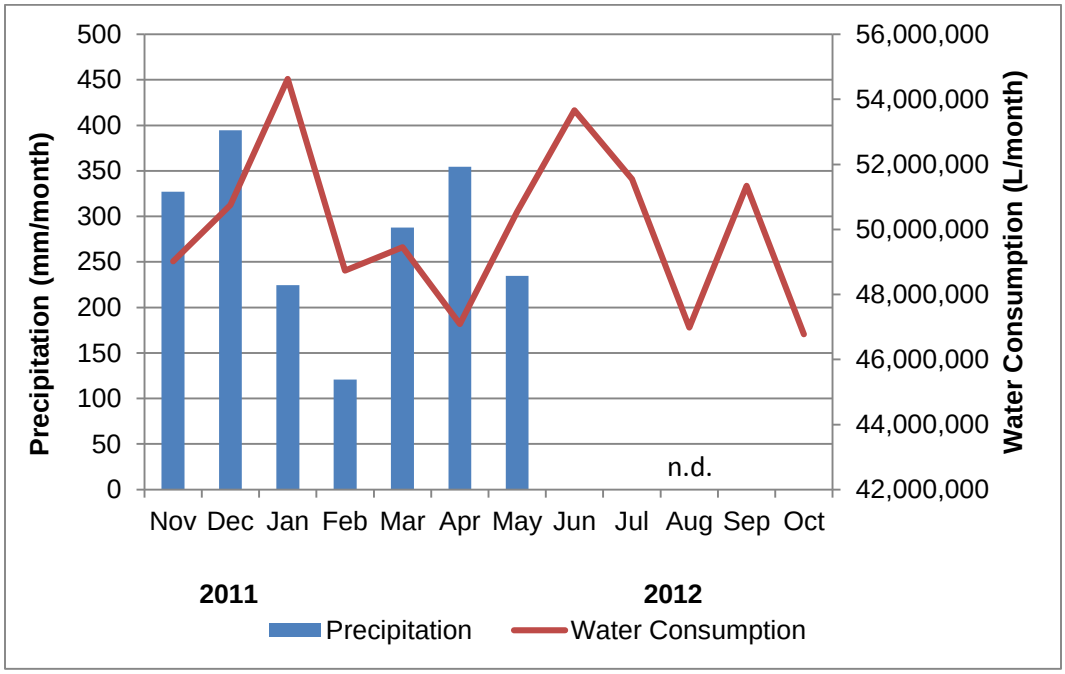
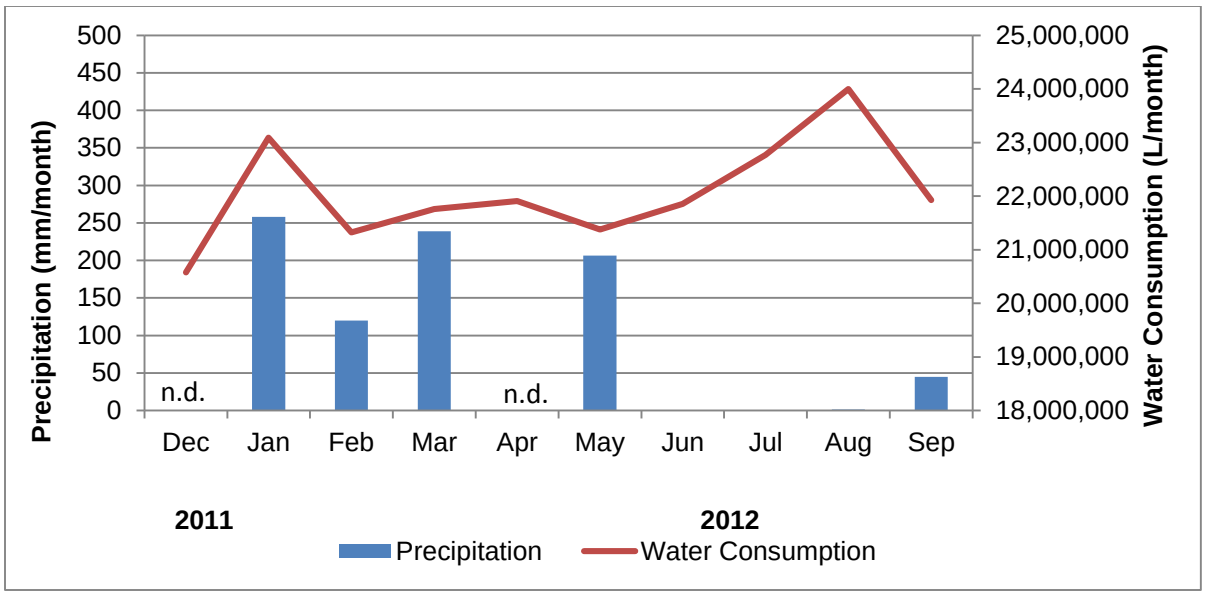


Figure 12 - Monthly water consumption in relation to precipitation at Tribunas Corcega



At La Sirena, water consumption appears to increase when precipitation increases (Figure 13). It is interesting to note, however, that during June, July and August there is virtually no precipitation occurring at this site, yet metered water consumption increases.

Figure 13 - Monthly water consumption in relation to precipitation at La Sirena



With the exception of the month of April, Golondrinas receives <200 mm/month of precipitation. Where data is available, we know that Tribunas Corcega, which is located in the central branch of the Andes, receives >200 mm/month of precipitation from November through May. Median monthly precipitation in Golondrinas is <80 mm/month, and water use per connection in the poorest estrato (estrato 1) averages to be 19,760 L/connection/month. Precipitation in Tribunas Corcega appears to be more than double that in Golondrinas (taking missing data into consideration), yet average water use per connection in the poorest estrato of Tribunas Corcega is less than that in Golondrinas (14,764 L/connection/month). La Sirena, located in the western branch of the Andes, has a precipitation regime similar to that of Golondrinas (also located in the western branch). Water use/connection/month in estrato 1 is higher here than in both Golondrinas and Tribunas Corcega (24,483 L/connection/month). Water availability, therefore, appears not to be constraining water use, as those communities receiving the most water in the form of precipitation are using less water than those that are receiving little precipitation.

However, if the same comparison is made with average monthly water use values for the wealthiest estrato (estrato 6), it is possible to observe the opposite trend. Water use per connection in estrato 6 at Tribunas Corcega averages to be 16,805 L/connection/month, while in Mundo Nuevo this value only reaches 10,847 L/connection/month. Mundo Nuevo receives <150 mm/month of precipitation (Appendix 4), which is significantly less than Tribunas Corcega. It appears, therefore, that in wealthier estratos, water availability constrains water use, as communities receiving more water in the form of precipitation are using more water than those that are receiving little precipitation. This may potentially be related to livestock or crop water requirements by lower estratos which cannot be significantly varied.

3.6 Potential Land Use Influences

In Tribunas Corcega, approximately 80% of the township is occupied by a variety of crops. The most prevalent ones are coffee and cassava, which occupy 75% of the township (EATC, 2006). It is expected that this would have an effect on water consumption rates at this study site. Areas with a large number of coffee plantations should see an increase in water consumption during the post harvesting processing of the coffee beans. This will typically occur during the months of April and May, with a second, smaller, harvest occurring in October and November (Roa-Garcia et al., 2013). That being said, the water consumption rates observed at this study site do not reflect this expected pattern. Figure 4 illustrates that monthly total water consumption decreases during these months, and is lower than the annual average. As previously discussed, Mundo Nuevo has a significant amount of land dedicated to specialty coffee crops. However, water consumption patterns in this region do not follow this expected pattern. A potential reason for this is likely that there are many other crops also growing in this region which have different harvest schedules than coffee, thereby keeping water consumption rates much more constant throughout the year. This lack of relationship is not surprising as the main coffee harvest corresponds to the wet season and much of the water used in coffee washing comes from stored rainwater.

Cattle are also an important part of the industry at Tribunas Corcega. Water demand in cattle rearing is typically highest from July to September. This is due to temperatures being higher and cattle needing to drink more water. Therefore, it is expected that regions that have a great deal of cattle farms will see an increase in water consumption at the start of the dry season. During the wet season, rainwater fills water tanks that cattle are able to drink out of, which would allow metered water consumption to be lower (Roa-Garcia et al., 2013). Figure 4 shows this expected pattern to be true in Tribunas Corcega. La Sirena is another study site where there is likely to be many small cattle farms. Figure 1 in Appendix 2 shows that this expected pattern holds true, and that water consumption peaks form July to September.

It is expected that in regions where there are a large number of recreational homes, or where ecotourism is abundant, water consumption will increase during holidays and during the summer months as people from the cities come to their country homes. This effectively increases the population at these sites, and results in a need for more water. Mundo Nuevo and Tribunas Corcega are examples of this.

4. Summary and Conclusions

As has been observed through the analyzed data, water consumption both between study sites and between estratos is highly variable. This variability can be attributed to a number of factors, both anthropogenic and natural. It appears as though land use has the largest impact on how water is consumed in each of the regions, especially at those sites with significant agriculture. Crops and livestock require more water at specific times of the year, as is supported by patterns of metered water use.

It has also been shown that domestic water use is less variable than non-domestic water use. A lack of data regarding the types of businesses associated with many of the non-domestic connections

prevented an analysis to be fully made, however it was surprising that these were the more variable estratos. Most businesses operate year-round, and therefore it could be assumed that their water consumption habits should remain relatively constant. Many of the study sites saw a great degree of annual variability within these estratos, in part associated with school and national holidays. There are likely further explanations as to what may be causing this variability, and it would be interesting to consult directly with managers of local water systems and business owners to garner further insight into these patterns.

It has been shown that precipitation levels do not have as great an effect on water consumption as was originally expected. Before analysis, it seemed logical that water consumption would decrease when precipitation was low. However this pattern was not observed. In fact, a number of the study sites showed patterns of increased water consumption when precipitation was relatively low.

In order to realize the full impact that land use, precipitation, and any other factors may have on water consumption habits in rural Colombia, further study is required. Since water scarcity is known to occur in these regions, this type of work is very important. Many of the small water providers that service these regions do not receive adequate funding from either rates paid by subscribers or from government, and therefore an increased incidence in water scarcity could result. An understanding of how water is used in these regions will greatly help water providers to determine where to place priority within the current infrastructure, and where improvements could be made to ensure that the occurrence of water scarcity is greatly diminished in the future.

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Appendix I

Figure 1 – Percentage of connections in each estrato at Golondrinas

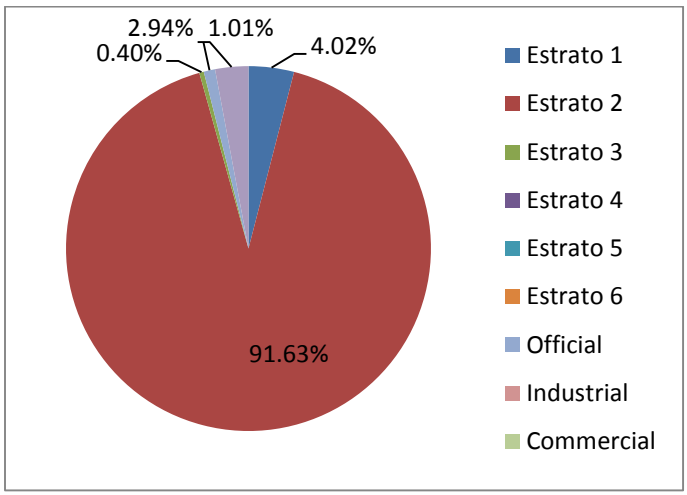


Figure 2 – Percentage of connections in each estrato at Mondomo

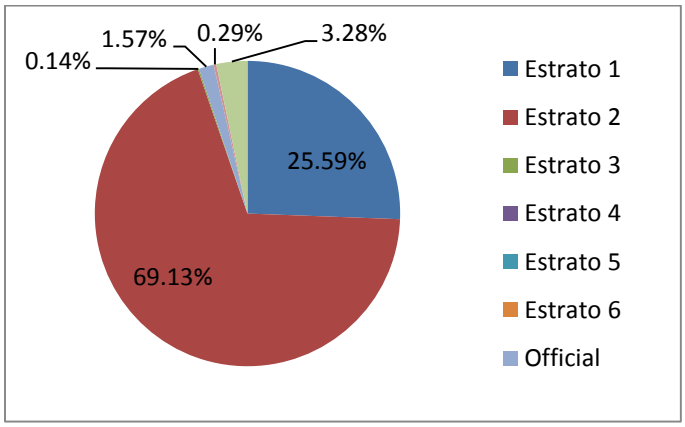
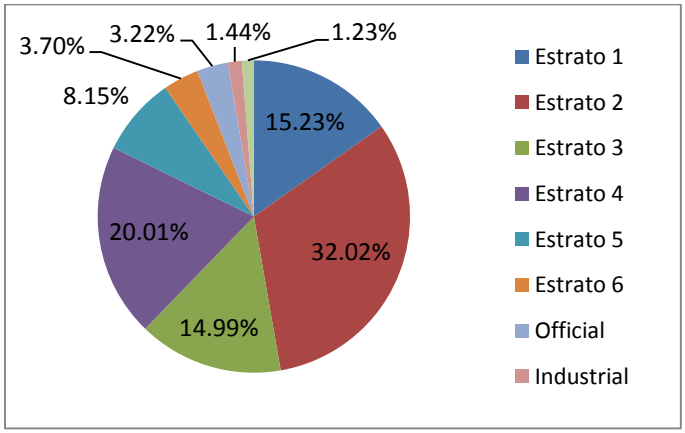


Figure 314 – Percentage of connections in each estrato at Mundo Nuevo



Appendix 2

Figure 1 - Monthly total water consumption at La Sirena

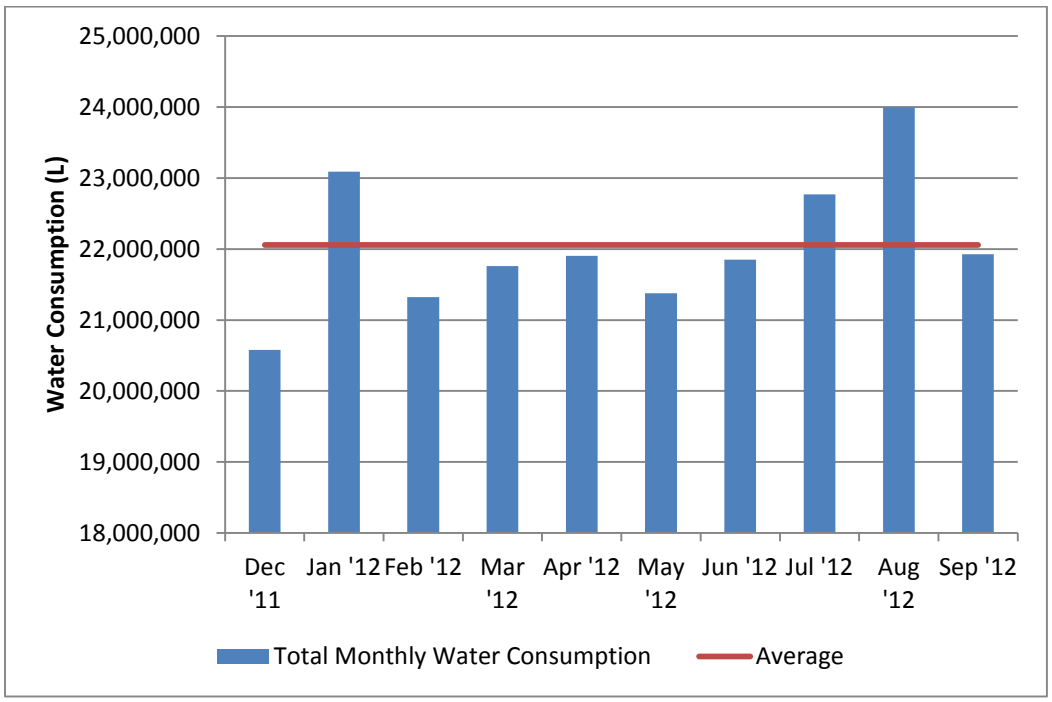


Figure 215 - Monthly total water consumption at Mondomo

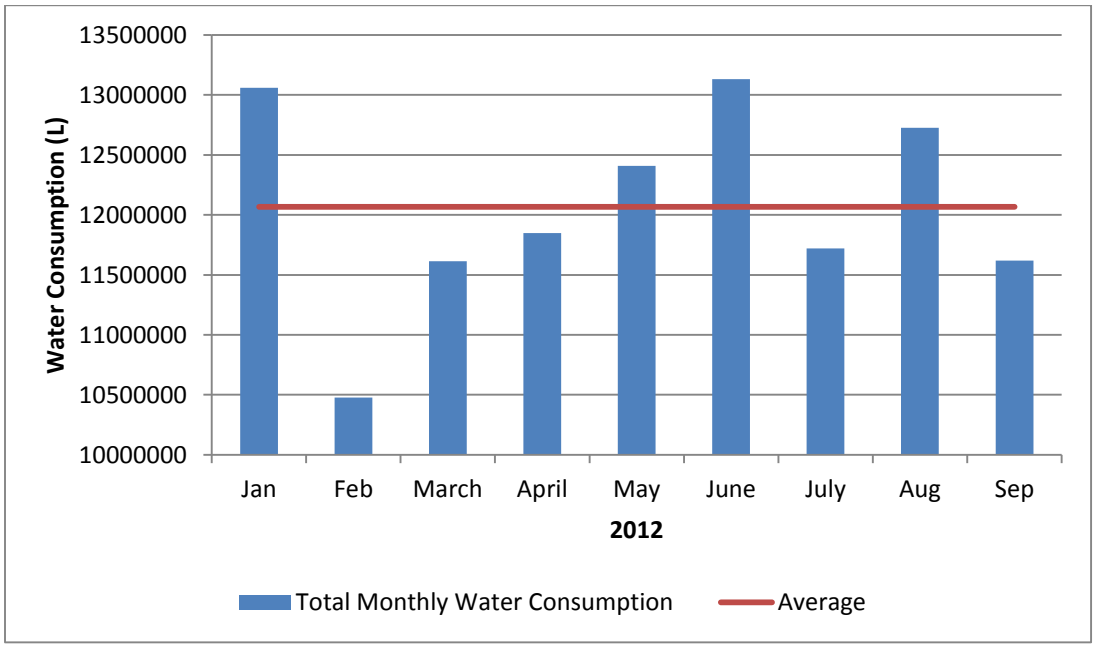


Figure 3- Monthly total water consumption at Golondrinas

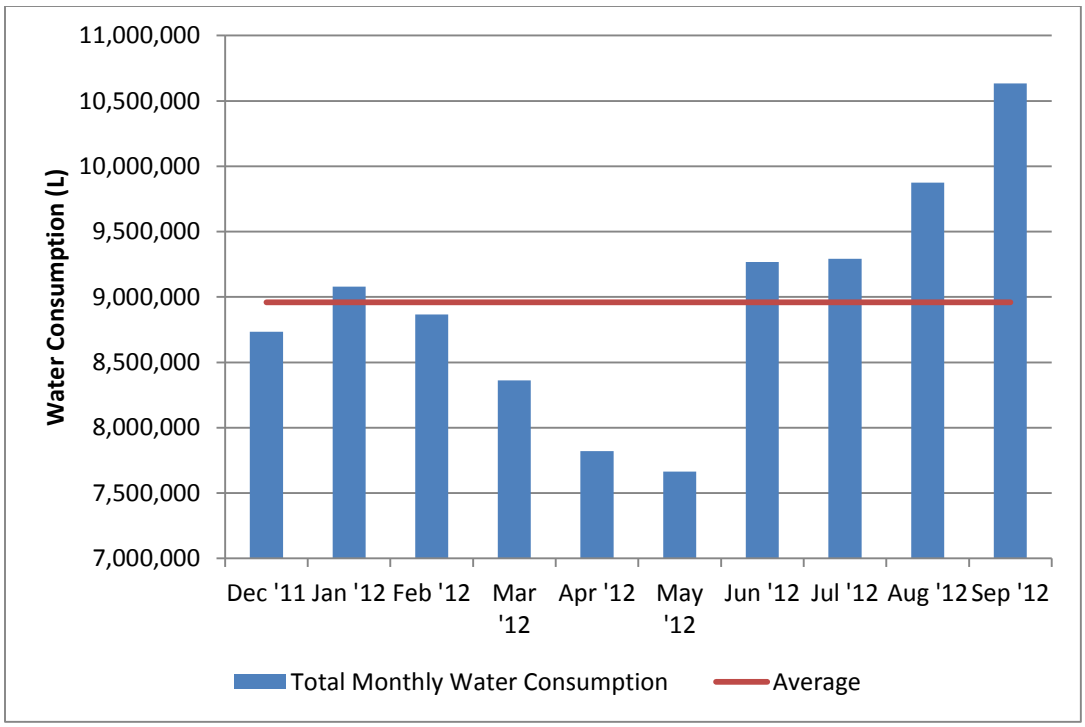


Figure 5 - Monthly water consumption in each estrato at Golondrinas

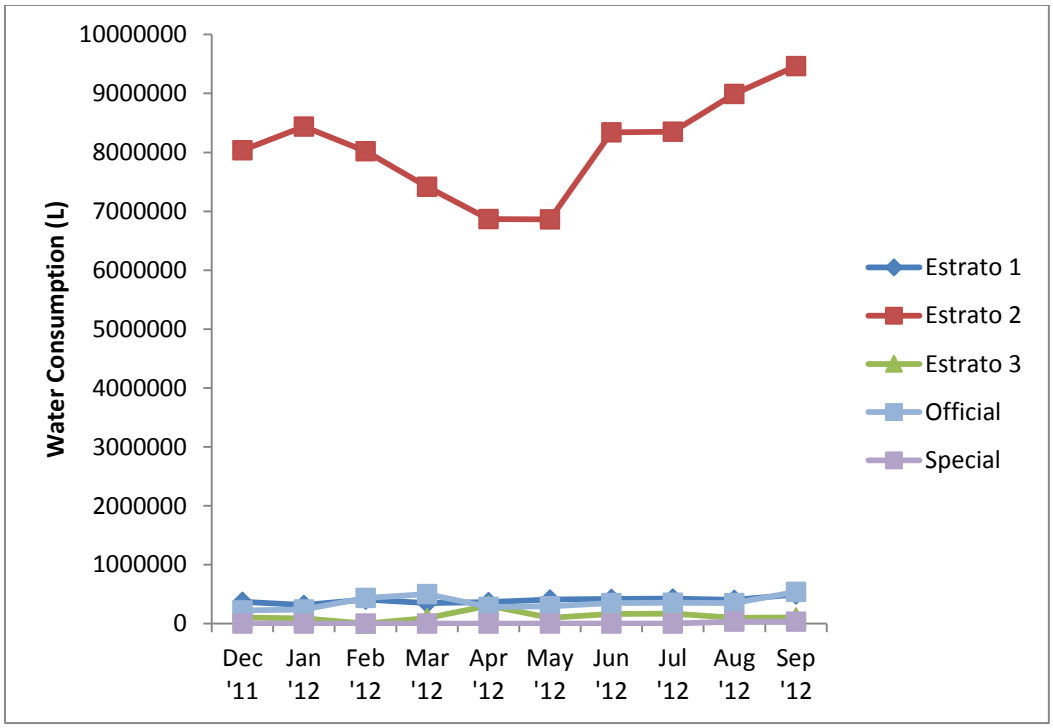


Figure 6 - Monthly water consumption in each estrato at Mondomo

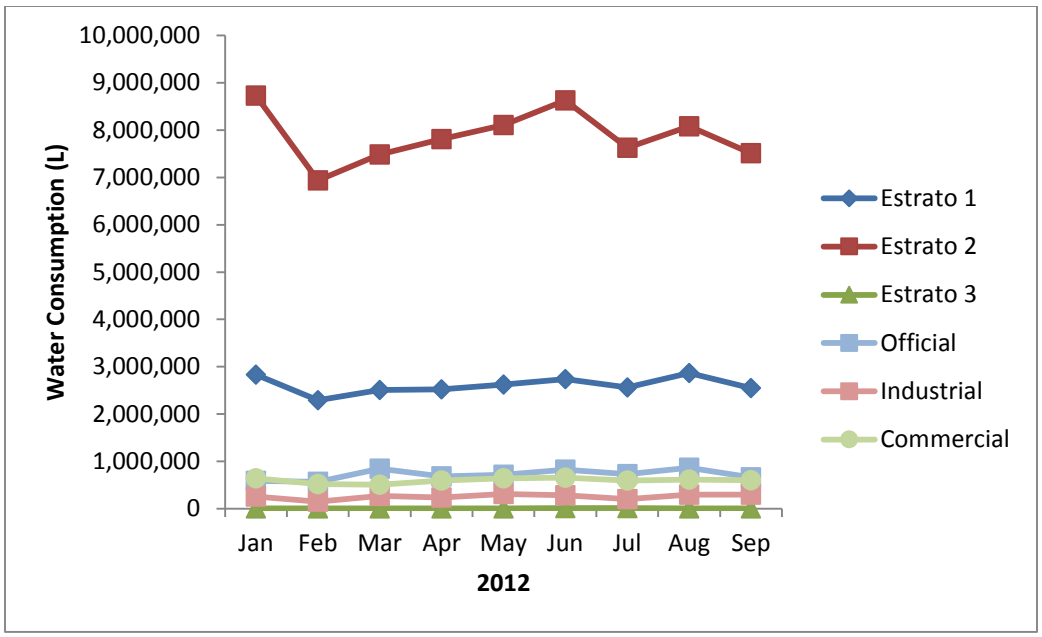


Figure 7 - Monthly water consumption in each estrato at Mundo Nuevo

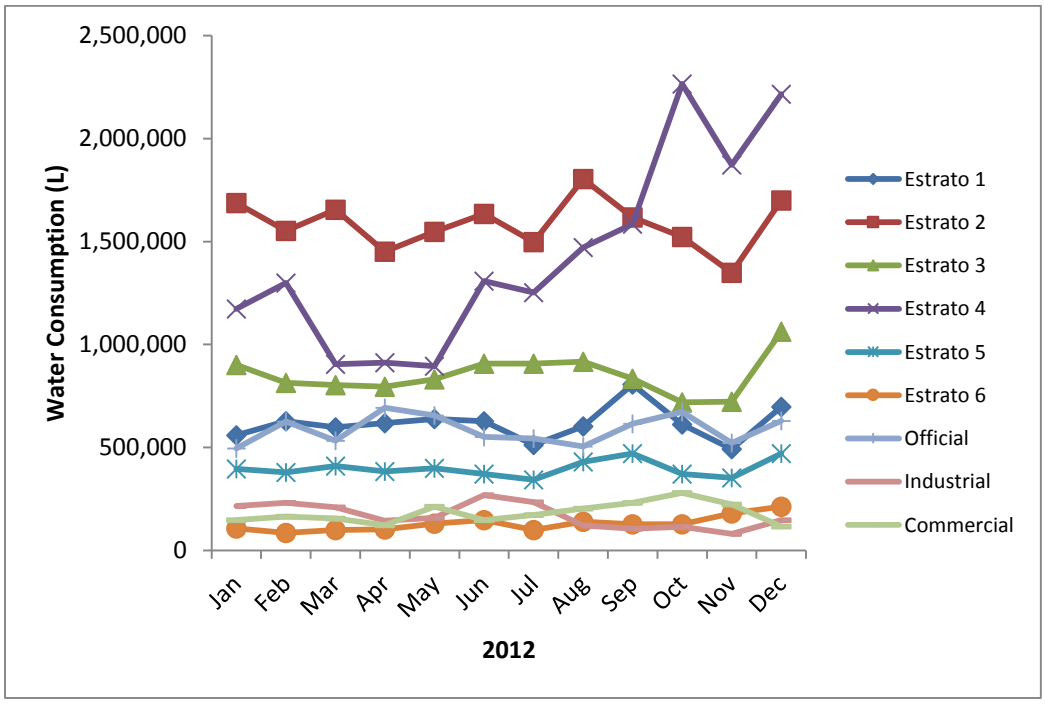


Figure 8 - Monthly water consumption/subscriber in each estrato at Tribunas Corcega

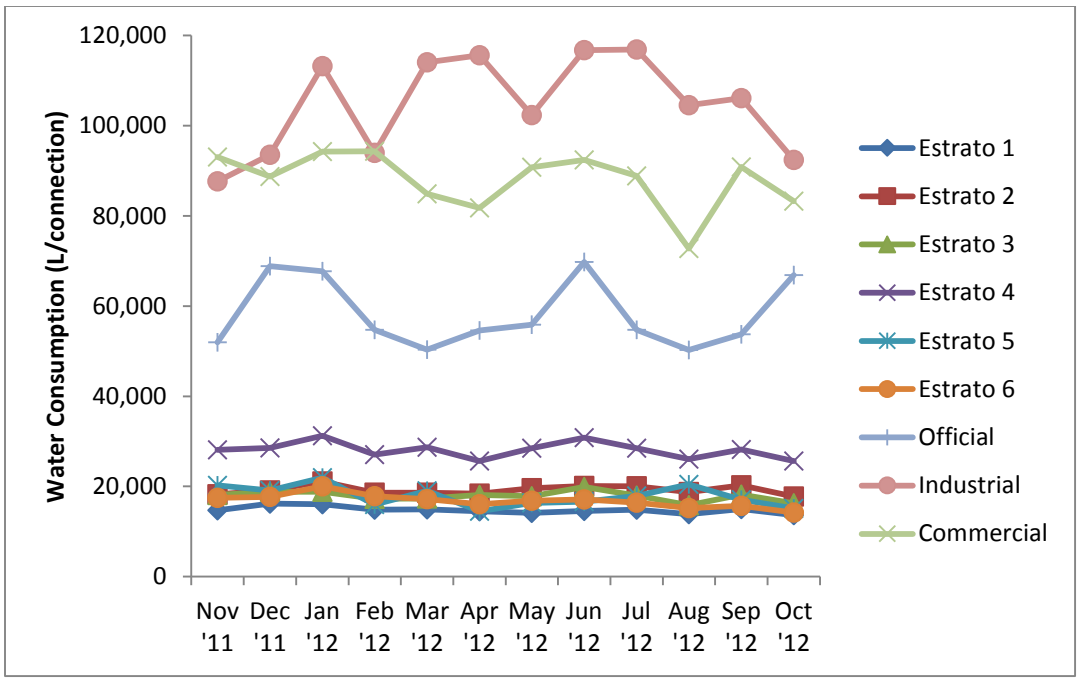
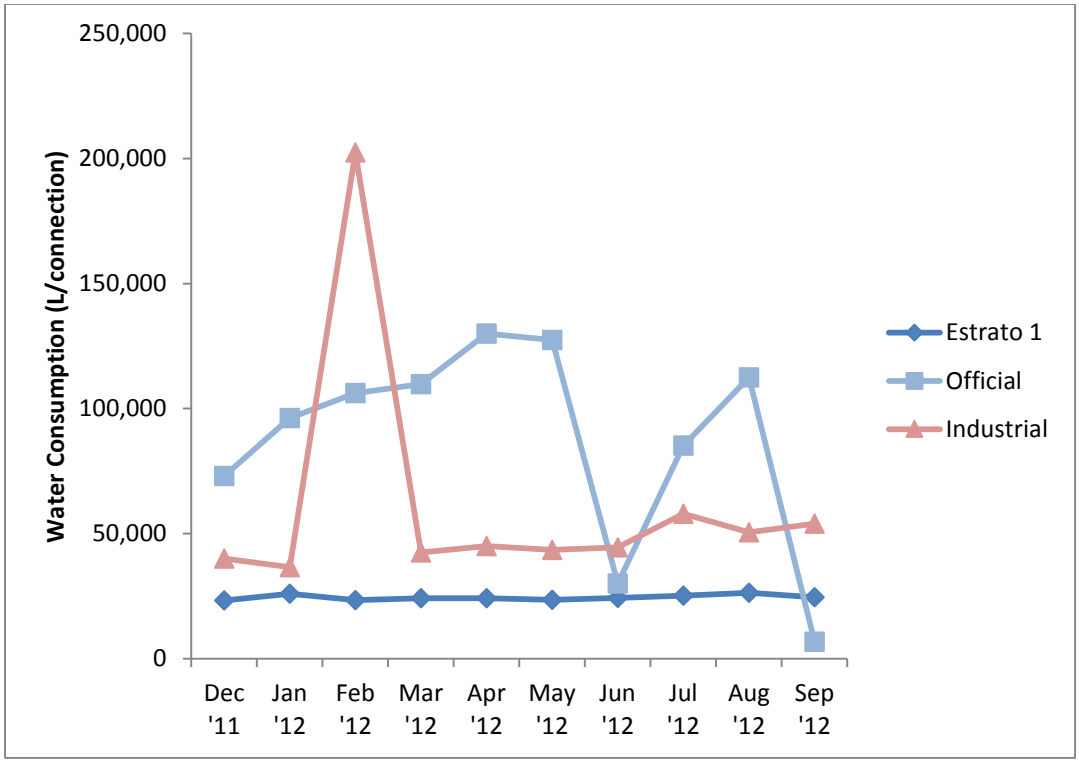


Figure 9 - Monthly water consumption/subscriber in each estrato at La Sirena



Appendix 3

Table 1 - Variability in seasonal water consumption at Mondomo

		Dry Season	
Estrato	Annual Average	Jul/Aug/Sep	% Difference
1	2,610,778	2,658,333	1.8%
2	7,881,556	7,739,667	-1.8%
3	6,333	7,000	10.5%
Official	719,667	751,333	4.4%
Industrial	253,889	264,000	3.9%
Commercial	594,111	600,333	1%

Table 2 - Variability in seasonal water consumption at Golondrinas

		Dry Season	
Estrato	Annual Average	Jul/Aug/Sep	% Difference
1	395,200	439,333.3	11.2%
2	8,079,200	8,935,333	10.5%
3	121,409.3	121,666.7	0.02%
Official	356,600	413,666.7	16%

Appendix 4

Figure 1 - Monthly water consumption in relation to precipitation at Mundo Nuevo