Adapting to climate change in rural Colombia: The role of water governance

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1. Executive summary

The goal of this project has been to understand the role of local knowledge for water governance and climate change adaptation in mountain areas of Colombia. We have incorporated notions and theories of water justice into our research on climate change adaptation; and have achieved balance in our results between the academic rigour of international scientific publications and the development of tools of practical application for our partners at the local level.

We have focused on generating impact in community water organizations (CWO) through capacity building so that our partners become experts in the use of knowledge and water management tools to ensure water security at the community level.

The project started with seven partner CWOs that are members of AQUACOL or FACORIS, two associations of CWOs. Two new organizations joined the project early in the third year: Acuabuitrera and Acuanariño that are also members of AQUACOL. Representatives of these CWOs spontaneously began to participate in workshops and became active partners. Acuabuitrera has self funded the acquisition of monitoring equipment for precipitation and stream flow for their main water source (Rio Lili) and we are committed to instructing them on equipment use, software and basic data analysis. The participation of Acuanariño started with the involvement of Jorge Amaya, a 26 year old student of social work who is also a member of the board of this organization. Jorge undertook an internship with the project, but also initiated very active participation representing his CWO at AQUACOL, where he has played a key role in promoting shared leadership within this organization. Not only did he develop a manual for CWOs to access subsidies (that they are entitled to), but he applied his new knowledge and presented a request to the municipality of Tuluá to obtain subsidies for Acuanariño in 2014. Based on his recently acquired skills and knowledge, his leadership, and his desire to make an impact on CWOs, Jorge was elected as the executive director of AQUACOL in May 2014. This has renewed the confidence of AQUACOL members, who had been disappointed about the lack of transparency and individualistic style of management of the previous director. Jorge has a very big challenge ahead as he is assuming his new position with high expectations and limited resources. He started this 2 year period with an ambitious work plan that includes the dissemination of two of the tools developed in this project: access to state subsidies and improvement of CWOs' financial and administrative information.

Perhaps the biggest achievement of this project has been the development of several products that the board members of AQUACOL and FACORIS can offer to member and non-member CWOs. The template and knowledge to operate a basic accounting system, calculate tariffs according to the national regulation, the guide to apply for subsidies, a manual for the acquisition of strategic areas for water source protection, and the capacity to collect and report information to the national information system (SUI) are examples of these products developed jointly with support from key CWOs in both associations. In fact Jorge, together with three other active project participants (Edgar Vivas, Anyela Torres and Yadira Gutierrez) obtained on January 11,

2014 the first contract to advise the organization ASDAL in Tuluá on costs, tariffs and reporting to the SUI; demonstrating not only the local capacity built by the project, but also the applicability of our toolset.

Edgar and Yadira at a meeting with ASDAL (Tulua) in January, 2014. AQUACOL has the knowledge, tools and confidence to advise other CWOs.

Within AQUACOL, we have been supportive of member CWOs in their efforts to move the organization toward collective leadership and transparent administration, so that the knowledge and expertise of advanced members becomes an asset of AQUACOL. On December 22nd, 2013 the research team was invited as a guest to the general assembly of the community of La Sirena to support the current management team that is running for a third term in office. We were happy to participate in this assembly and talk about La Sirena's involvement in the project, since as we were able to demonstrate through our research, that La Sirena is one of the most efficient CWOs with a genuinely community orientation. This management team was re-elected for another term, in March, 2014.

The project benefited enormously from the participation of students, particularly those who came to the project unsolicited. High school students participated in the collection of data through the household surveys conducted at each community. Approximately 100 youth participated in this research. We were very inspired by the participation of students from Mundo Nuevo who had an impressive knowledge of their territory and a critical perspective on national and international affairs.

Youth at La Sirena (above) and at Robles (below) getting prepared for data collection

Youth at Mundo Nuevo after receiving training for collecting data through surveys

Two US students from CUNY (New York) did an internship on water quality during the summer of 2012. Through IDRC's website we were contacted by two Canadian students from University of Trent and Queen's University who had different interests in the project. Andreina Pulido, from Trent came to Cali in the summer of 2013 and conducted the field work for her MA on sustainability studies. And Madeleine Belanger from Global Development Studies at Queen's University contacted the project to investigate the support that is given to community water organizations to maintain the local control of water supply services. We also had two students from the faculty of land and food at UBC who conducted data analysis of water use and water availability; and climate data analysis for the pilot sites. All students made significant

contributions to the project; Andreina Pulido, a Colombian studying in Canada was particularly active in developing the project's accounting tool for small water providers.

The project has generated new knowledge on the links between climate change adaptation and equity. We have demonstrated that the capacity to adapt to variable conditions of water quality and quantity depend as much on the actual biophysical availability of usable water as on the capacity of CWOs to access rights within the Colombian constitution (such as subsidies and water source protection). We have also learned that community organizations need to have secured all the basic technical, administrative and managerial capabilities, before they can successfully undertake climate and stream flow monitoring on their own. Tribunas Córcega is an example of one such organization within the Project with the administrative and technical capacity to undertake more advanced monitoring.

In the last three years we produced 11 papers or reports that are either published or have been submitted for publication in national and international journals, books or the project website; and we attended 9 international conferences both as researchers and as representatives of CWOs. We produced more than 10 videos to highlight products of the research done, and generated a blog and several guides for CWOs with the interest to monitor climate and stream flow, as well as a manual to guide community organizations with the interest to initiate the quest to access state subsidies. We established contact and initiated collaboration with Universidad Nacional (hydrology), CENSAT Agua Viva (water justice) and Justicia Hídrica (coordinated by Wageningen University).

2. Context

48% of the Colombian population has a high probability of experiencing water scarcity[1]. Climate change is having a significant impact on water stocks and on the length and intensity of dry and wet seasons in Colombia and many other regions in Latin America. Predicted changes in precipitation in the Andean region due to climate change include an increase in precipitation in the wet season and decrease during the dry season[2]. Water scarcity occurs both during the dry season due to too little rain and during the wet season due to torrential storms that produce landslides and soil erosion which translate into heavy loads of sediments in stream water[3].

It is recognized that the poorest and most vulnerable groups will disproportionately experience the negative effects of 21st century climate change, and that climate change will most likely

[1] DDP (Defensoría del Pueblo), 2009. Diagnóstico del cumplimiento del derecho humano al agua. Bogotá. http://www.defensoria.org.co/red/agua/intro.html

[2] Vuille, M., Francou, B., Wagnon, P., Juen, I., Kaser, G., Mark, B.G., Bradley, R.S., 2008. Climate change and tropical Andean glaciers: past, present and future, Earth-Science Reviews 89: 79–96.

[3] Heavy sediment loads in stream water can force the shutdown of water intakes; high sediment requires settling prior to treatment for potable water and results in infilling of infrastructure.

impact developing world countries where natural-resource dependency is high[4]. The capacity of rural, traditionally poor communities to adapt to more variable conditions of water availability is related to the ability to plan and cope with the impacts of climate change at the local scale, and more broadly to their ability to influence municipal, regional or national policies that can potentially reduce their vulnerability.

In Colombia water services in rural and peri-urban areas are provided by small community-based organizations (CWOs) that have limited recognition by the state and even more limited access to state resources. In Colombia it is estimated that these organizations add up to around 12,000[5] although some analysts calculate that there could be more than 25,000[6]. Community-based water provision, without an appropriate support from the state, does not necessarily represent a viable alternative to other forms of water provision (public, private or mixed). CWOs usually maintain costs in balance with the capacity of the community to pay, which means that large amounts of volunteer work are required and maintenance and infrastructure improvements are neglected. However the non-profit nature of these organizations suggests that they can maintain lower costs and have a higher benefit-cost ratio on investments than large water enterprises[7].

The state's participation in supporting and regulating community-based water provision has been acknowledged as necessary to provide a level ground for urban, rural and peri-urban areas and facilitate spatial and social cross-subsidies to support universal provision[8]. But the large number of community-based water providers makes support and regulation a challenging task.

Water providers in the rural areas of the Colombian Andes are typically small organizations lead by a board of five members democratically elected by the community. The organizations usually employ a technician who is responsible for managing the water intake, the operation and maintenance of the treatment and distribution systems; and a secretary who is responsible for

[4] Thomas, D. S. G. and Twyman, C. 2005. Equity and justice in climate change adaptation amongst natural-resource-dependent societies. Global Environmental Change Part A 15(2): 115-124.

[5] Fernández, D. 2004. Sector agua potable. Informes de base: Colombia; desarrollo económico reciente en infraestructura (REDI) Banco Mundial, Washington, D.C.

[6] Pérez Rincón M.A., 2001. Balance y gestión en empresas de servicios de acueducto y alcantarillado de pequeña escala en Colombia. Análisis comparado para diferentes formas organizativas y escalas de servicio. UNIVERSIDAD DEL VALLE-CINARA, Cali, 29 p.

[7] Roa García, M.C. 2013. Indicadores de justicia hídrica para organizaciones comunitarias del agua en Colombia, en Budds, J., Roa-García, M.C. (Eds.) (en proceso) Justicia Hidrica: poder, conflicto, acción social. Instituto de Estudios Peruanos, Universidad Católica, Lima.

[8] Bakker K., 2008. The Ambiguity of Community: Debating Alternatives to Private-Sector Provision of Urban Water Supply. Water Alternatives 1(2): 236- 252

billing, accounting, reporting and in general for direct contact with water users. Less than 15% of these organizations report data to the SSPD – Superintendent of Public Utilities which is a requisite to access subsidies from municipalities to which they are entitled. This and the low fees received from a generally low income user base, make rural water providers vulnerable stakeholders when facing water shortages and needing to improve sources or water storage capacity.

Conflicts related to water are very common in these regions. Traditionally conflicts have revolved around land use with a direct impact on the water regulation capacity of ecosystems such as forestry and cattle grazing. Increasingly conflicts generated by new mining projects in the vicinity of small water sources pose a risk of pollution and compete for the use of scarce water. The regulatory agencies have limited capacity to grant and enforce water concessions that produce an efficient and equitable water distribution and use, due the lack of effective protocols, data and resources. This results in over-allocation of streams and is aggravated by the location of water intakes. In many cases water intakes for different water providers are immediately downstream from another, impacting the lower one in times of low flows.

The goal of this project was to understand the role of local knowledge for water governance and climate change adaptation in mountain areas of Colombia. The specific objectives of the project were:

- Comparison of national scale information on access to water in relation to equity
- To design and test a set of bio-physical and socio-economic indicators for water management; and to establish a local scale monitoring mechanism and information transfer.
- To strengthen institutional capacity of CWOs to address vulnerabilities, particularly institutional (accounting capabilities, access to subsidies, access to concessions) and ideological (capacity to argue and defend community economies)
- To diagnose the information needs and required procedures to grant water concessions that could help communities adapt to current and expected climate change.
- Generate local scenarios of water allocation, availability and use, based on collected data and different policy alternatives; and to use these scenarios to propose alternatives for higher efficiency, improved water allocation and infrastructure development.
- To develop teaching materials to be used in training and capacity development of water sector professionals in the academic, governmental and water provider institutions.

Our research partners have been seven CWOs as shown in the following table.

Organization	CWO	Number of connections
AQUACOL	Acuasur	2,525
AQUACOL	Asocascajal	325
AQUACOL	La Sirena	888
AQUACOL	Acuabuitrera	1,623
AQUACOL	Golondrinas	497
FACORIS	Mundo Nuevo	324
FACORIS	Tribunas Córcega	2,074

3. Main methods

For climate and hydrological monitoring we used World Meteorological Organization standard methods, and have developed protocols for data collection based on these standards available at the project website (http://www.landfood.ubc.ca/swc/projects/ACCCR/monitoreo.html#Protocolos) and project blog (http://blogs.ubc.ca/ceroa/). From the analysis perspective we have taken a slightly different approach to data analysis given our target audience is community organizations as opposed to hydrologists and meteorologists. We used excel and common tools within excel such as solver and pivot tables for climatological and hydrological data analysis including daily, weekly, monthly and seasons assessment of precipitation, stream flow and water yield at each site. Standardized graphs were produced along with comparisons to water use data to assess scarcity and vulnerability. A guide (protocol) for this analysis was developed for use by community water organizations.

The soil study was conducted in two micro-catchments: Sonora and El Chocho, which have Andisol and Inceptisol soils respectively. Sonora is located on the central branch, and is a 1st order stream in the headwater of the Barbas River in the Quindio (coffee growing) region. The El Chocho catchment is located on the western branch in the peri-urban region of the city of Cali. Both study sites are located at mid-elevation (1700-2300 m). 20 in Sonora and 18 profiles in El Chocho were assessed for soil characterization using standard methds, including: texture, bulk density, soil-water retention, pH, soil organic matter, oxalate extractable Al_o, and Si_o, and pyrophosphate extractable Al_p. Allophane was calculated using the relation $(Al_o\text{-}Al_p)/Si_o$.

For the collection of socio-economic data we conducted several surveys / questionnaires using structured and semi-structured formats. Specifically a “water issues” survey which compiled information on priority issues and knowledge gaps in the water sector; and a database of subscribers for each participating community water organization which compiles information on demographics, productive activities and household level infrastructure. This data was analyzed using SPSS to characterize each community of water users. We also used national information available from the SUI to generate a national characterization of CWOs to compare with the

situation of the seven research partner CWOs.

For the analysis of water allocation we obtained the national database of water concessions compiled for the Institute of Hydrology, Meteorology and Environmental Studies (IDEAM). Allocation criteria were analyzed for each type of use (agricultural, domestic, commercial / industrial, hydro-power generation and other). Equity in water allocation was assessed through the calculation of Gini coefficients.

The project enngaged communities through participatory research that were particularly strong in the design, collection and analysis of indicators.

4. Themes, achievements and products

As part of CINARA's evaluation and planning process, the project was invited to present results within the climate change line under the Integrated Watershed Management Program (GIRH). Clara gave a 45 minute presentation (included in Appendix 1) summarizing the goals, objectives, results, impacts and products of the project. As a result of this, they want the team to play an active role in CINARA's activities, develop teaching materials for the MSc program, develop research projects with other research lines (such as modeling), and to coordinate a concurrent session at AGUA 2015. They will also post project publications on CINARA's website.

4.1. Climate change adaptation: vulnerability and knowledge

Strategies for adaptation to climate change

Historic precipitation data, downscaled general circulation models (CGM), regional circulation models (RCM) and empirical models such as MRI-JMA, PRECIS and WorldClim respectively indicate varying trends in precipitation for Colombia. Benavides and Leon (2007)[9] analyzing trends in historic precipitation data (1971-2000) found a positive tendency in Armenia, and a decreasing trend for Cali. Ruiz (2010)[10] using an ensemble multi-model and combined scenarios found an average change in precipitation for the 21st century of -7.7% and -7.6% for Valle and Quindio respectively. Pabón (2012)[11] found differences in annual precipitation by region with reduced precipitation in Valle and the coffee region, for both scenarios A2 and B2. While Ramirez-Villegas et al. (2012)[12] found a 4.2% increase in annual total rainfall for both Valle de

[9] Benavides Ballesteros, H.O., and G.E. León Esperanza. 2007. Información técnica sobre gases de efecto invernadero y el cambio climático. Nota Técnica IDEAM-METEO-008-2007. Bogotá, Colombia.

[10] Ruiz Murcia, J.F. 2010. Cambio Climático en temperatura, precipitación y humedad relativa para Colombia usando modelos meteorológicos de alta resolución (Panorama 2011-2100). Nota Técnica IDEAM-METEO/005-2010. Bogotá, Colombia.

[11] Pabón Caicedo, J.D. 2012. Cambio climático en Colombia: tendencias en la segunda mitad del siglo xx y escenarios posibles para el siglo xxi. Medio Ambiente, 261-278.

[12] Ramirez-Villegas, J., M. Salazar, A. Jarvis and C.E. Navarro-Racines. 2012. A way forward on adaptation to climate change in Colombian agriculture: perspectives towards 2050. Climate Change 115: 611-628.

Cauca and the coffee belt. IDEAM has adopted the more conservative scenario projecting a decrease in precipitation of over 10% for the Andean region with an increase in extreme events. These will increase the risk of floods in inter Andean valleys, large landslides and loss of crops and animals, as well as soil degradation and water scarcity for domestic water providers[13].

When project partners were asked at a strategies workshop (Nov. 15, 2013) about what they would do now if they faced climate events similar to the worst they have experienced in the past, responses were mainly focused on preparedness and prevention of severe scarcity resulting from extreme events. Responses revolved around four main ideas:

- Contingency plans have to be implemented both for droughts and for floods. For droughts, there are two types of strategies: 1) protecting the headwaters via reforestation and acquisition of land by the CWO to ensure their protection; and 2) the exploration of groundwater sources. For floods there are also two kinds of strategies: 1) creating the capacity among community members to store and use rain water when sedimentation of the streams forces the CWO to shut down the treatment plant; and 2) the construction of reservoirs of untreated water from small streams that are not affected by sedimentation (Claudia Villamarin, Acuabuitrera).
- To work collectively as a community of CWOs to demand action and responses from the state, to demand the rights to solidarity and equity proclaimed in the constitution (Diego Palacio, Acuabuitrera). CWOs need to act collectively to demand access to subsidies (Jorge Amaya, Acuanariño). Knowledge exchange between equals is a key to learn from experienced organizations (Margarita Moreno Bravo, Golondrinas). It is necessary to have collective leadership as opposed to individual leadership (Diego Palacio, Acuabuitrera).
- Technical capabilities are important but sound administration is crucial for the sustainability of community water provision (Rodrigo Chaparro, Acuanariño). Organizations need to understand and be aware of the strengths and weaknesses of the community water provision model; community organizations have common weaknesses and they need to solve administration issues that can facilitate additional adaptation strategies (Jorge Amaya, Acuanariño). Institutional vulnerabilities are very important and until issues such as reporting to the national authorities, full costs and tariffs are resolved, it will be hard to address environmental problems (Margarita Moreno Bravo, Golondrinas).
- Knowledge of the water source, the watershed, climatic conditions, the characteristics of the community, and the law can make a large difference in how CWOs request help in times of need. Good information is essential to address any source of emergency funding and gives managers confidence to present requests in written and oral formats (Henry Popó, Acuasur). Knowledge needs to be open and shared, and some networks of CWOs, such as

[13] IDEAM, 2010. Segunda comunicación Nacional ante la Convención Marco de las Naciones Unidas sobre Cambio Climático.

AQUACOL[14], need to change leadership to become an ally of all member CWOs (Yadira Gutierrez, AQUACOL).

In summary CWOs perceive that responding effectively to extreme events of climate variability depends to a large extent on institutional capacity, and knowledge of local conditions and the law as well as on technical solutions. These opinions were collected and compiled on video available at: http://www.landfood.ubc.ca/swc/projects/ACCCR/index.html

Out of this debate with project partners, we learned about a major challenge that peri-urban organizations are facing. Climate change adds significant uncertainty to a well known process of unplanned growth of peri-urban communities. CWOs are in many regions replacing municipal authorities in regulating the expansion of housing projects by communicating the limits of water sources. However CWOs have no power to effectively limit the expansion of development. In many cases the negligence of planning authorities is perceived as complacent because once the houses are built, water organizations are forced to provide water and distribute scarcity equally.

Vulnerability indicators

Variability in climate and water availability are major concerns for water providers, but the vulnerability of CWOs is not only about water scarcity, but their limits to adapt to water shortages. Working together with community partners, we identified four types of vulnerabilities:

- Source water vulnerabilities include water scarcity related to low streamflow and to turbidity, as high sediment loads necessitate bypassing treatment plants;
- Technical vulnerabilities relate to infrastructure and include leakage and water storage;
- Institutional vulnerabilities include access to resources such as state subsidies; and
- Organizational model (community versus enterprise) assesses leadership, costs of production and the implications of community organizations operating within a regulatory framework designed for enterprises.

Indicators were compiled for each type of vulnerability using project monitoring data, questionnaires with water providers in the 7 pilot sites, and more broadly with members of AQUCOL and FACORIS (the two association of water providers working with the project). For the pilot sites, administrators, directors and technicians ranked their vulnerabilities from highest to lowest; the results scaled between 0 and 10, with 10 being the greatest vulnerability (Table 1), indicate that institutional and organizational vulnerabilities are of equal or greater importance to CWOs than biophysical constraints.

In the case of Aquacol members, first priorities are access to subsidies and land use in headers. None Aquacol members receive subsidies. Land use in the headwaters is a challenge because

[14] AQUACOL has recently been lead by a single individual who has monopolized knowlege and power to benefit personally from the organization, leading to member organizations pushing for collective leadership and a transparent administration. With the election of Jorge Amaya in May 2014 as the new executive director, AQUACOL expects to initiate a new era of community water management.

most land in the headwaters is privately owned, and therefore practices to protect the sources are difficult to implement. Interestingly, non-revenue water, leadership and ownership of infrastructure are all rated above precipitation and turbidity (water shortage) vulnerabilities. In comparison, Tribunes Córcega (which receives subsidies) classifies low rainfall and the length of the network as their highest vulnerabilities. Bearing in mind the small sample size, this change in high vulnerability reflects a change in thinking towards vulnerabilities in source after achieving financial stability in the organization.

Many programs for adaptation to climate change, such as the National Adaptation Fund created after the 2010-11 La Niña phenomenon, invested significant financial resources in infrastructure[15]. But the results of this study indicate that institutional and organizational vulnerabilities are potentially of equal or greater importance for community water organizations.

Table 1. Prioritization of vulnerabilities (0 = low, 10 = high vulnerability)

Vulnerability	Priority* without subsidies	Priority** with subsidies
Limited access to subsidies	**10**	1
Land use in headwaters	**10**	7
Non-revenue water	9	5
Voluntary leadership / lack of continuity in administration	8	n.a.
Ownership of infrastructure	8	2
Precipitation – dry season	7	**10**
Turbidity	5	5
Length of pipe network	5	**10**

*Members of Aquacol which do not receive subsidies (n=6)
**Tribunas Corcegas which receives government subsidies (n=1)

Strategies for adaptation of individual water providers are shown in Table 2. Buying land in the headwaters was the number one strategy, both actual and potential; followed by increasing storage capacity. Interestingly raising awareness of efficient water use was seen dominantly as a potential (future) strategy. Collective strategies developed by the team related to indicators and access to subsidies. Environmental and socio-economic monitoring are seen as important for:

- Local data generation to support decision making;
- Assessment of water availability and scarcity; and
- Database of water users providing information to improve adaptation strategies and to provide a solid knowlegde base for when the management team changes.

[15] República de Colombia. 2013. Fondo adaptación. http://fondoadaptacion.gov.co/los-recursos-2/, accessed August 2013.

Access to subsidies has been a challenge for many CWOs, and as a consequence the project developed two specific tools:

- Accounting system based on the requisites to obtain subsidies (CRA – comisión de regulación de agua) in excel
- Manual for community water organization to support their application for subsidies (based on legal norms)

Many small community organizations are not familiar with the CRA procedures for calculating subsidies, thus this simple to use tool fills an important gap. Applying for subsidies requires knowledge of a number of different norms and decrees, which have been compiled into a step-by-step guide by the project. Additionally within the limits of the City of Cali, community water organizations have been working together with the city to obtain the official socio-economic stratification (a step in the subsidies application process which must be undertaken by the municipality).

Table 2. Actual and potential strategies of individual water providers to reduce their vulnerabilities.

Strategy	Actual (% of organizations)	Potential (% of organizations)
Buy land in headwaters	60	80
Increase storage capacity	60	40
Ecological restoration	40	20
Capacity building / interchange of experiences	40	-
Reduction / regulation of water pressure	40	20
Awareness campaigns – efficient water use	20	40

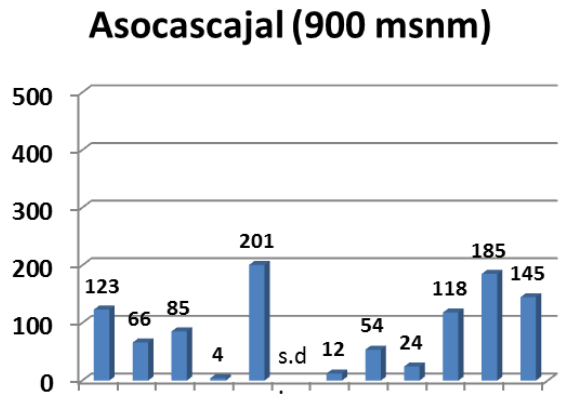
For CWOs, institutional vulnerabilities and their organizational model are of equal or greater importance than technical or physical vulnerabilities. Considering climate change, all four types of vulnerabilities affect the sustainability of community water organizations and their ability to adapt to water scarcity. Tools to support accounting and the application for subsidies build institutional capacity at the local level, but the importance of institutional vulnerabilities need to be conveyed to policy makers in the development and implementation of climate change adaptation strategies. A shift from a dominantly biophysical focus to a more balanced institutional focus is needed.

This work was presented at the University of British Columbia in September 2013, at AGUA 2013 in October, and a paper has been published as conference proceedings. The paper is included in Appendix 2 and can also be found on the project's website: http://www.landfood.ubc.ca/swc/projects/ACCCR/publicaciones.html

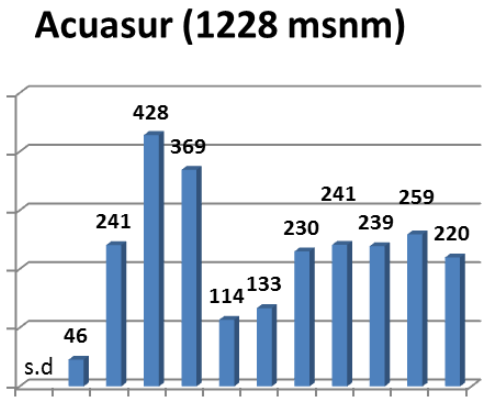
Precipitation and vulnerability

The comparison of climate data between pilot sites facilitated the understanding of vulnerability differences between communities. The two sites Golondrinas and La Sirena located on the eastern side of the western branch of the Andes (mountain rain shadow) have significantly less precipitation than the other mountain sites, but share the water source with a larger population.

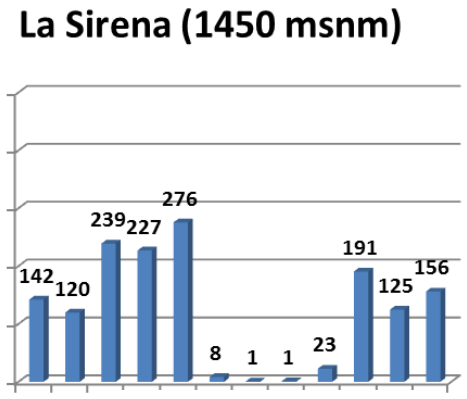
Precipitation, water level and stream flow monitoring



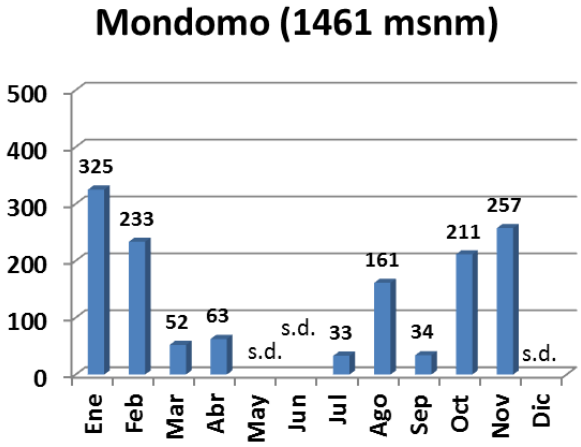
Annual 1,045 mm



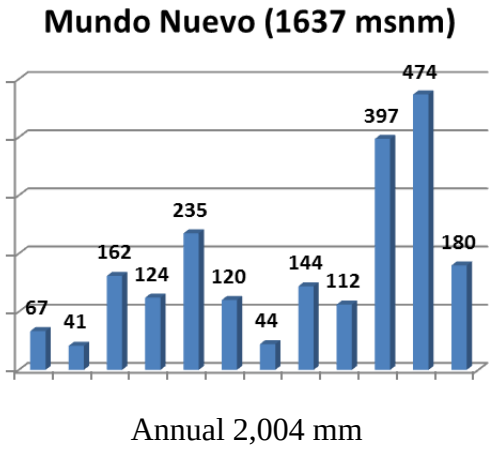
Annual 2,600 mm*



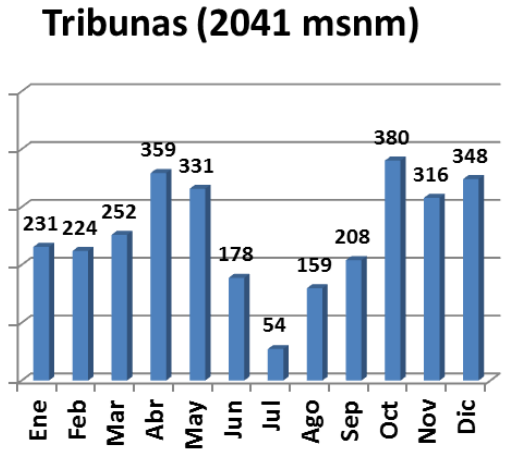
Annual 1,517 mm



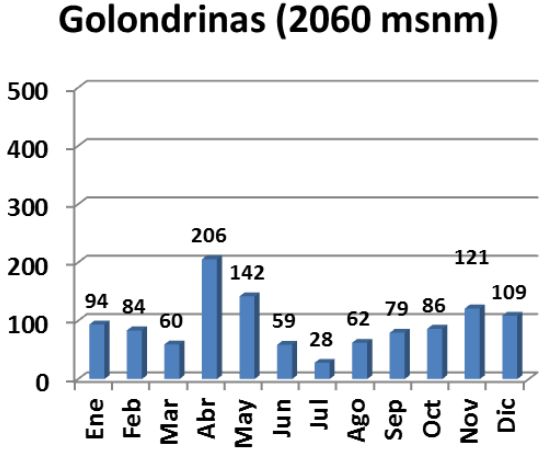
Annual 1,400 mm (nearby station)



Annual 2,004 mm



Annual 3,000 mm*



Annual 1,205 mm

Figure 1. Monthly average precipitation at pilot sites
*Approximate values due to missing data

Figure 1 shows monthly average precipitation at each pilot site from lowest to highest elevation. Tribunas and Acuasur have the largest precipitation with approximately 3,000 and 2,500 mm per year respectively. La Sirena and Golondrinas reported very low precipitation in the dry season. La Sirena had an extremely dry year in 2012 when they had no precipitation during the months of June and July.

The rain gauges that had the best performance during the three years were Golondrinas, Tribunas and La Sirena. Golondrinas had no data gaps, while Tribunas had 5 months of incomplete or no data and La Sirena had 7 months with data gaps. From June 2013 some rain gauges started to present failures particularly at Asocascajal and Acuasur. Due to the organizations' interest, we decided to replace the data loggers.

Generating local precipitation data is seen as important for both water management strategies (e.g. storage), and for support from municipal programs such as headwater protection where rainfall data is used by regional environmental authorities such as CVC in their decision making on the protection of critical areas.

Stream flow measurements

Stream flow measurements are a lot more demanding than precipitation data. Stream flow measurements in particular require expertise in hydrology and a well delineated research question in order to motivate good quality data gathering. Since Clara Roa (PhD candidate) is doing a comparative study between the soils at Golondrinas and Tribunas in terms of water regulation, stream-discharge curves are being developed for these two sites as shown in Figure 2 for Rio Barbas.

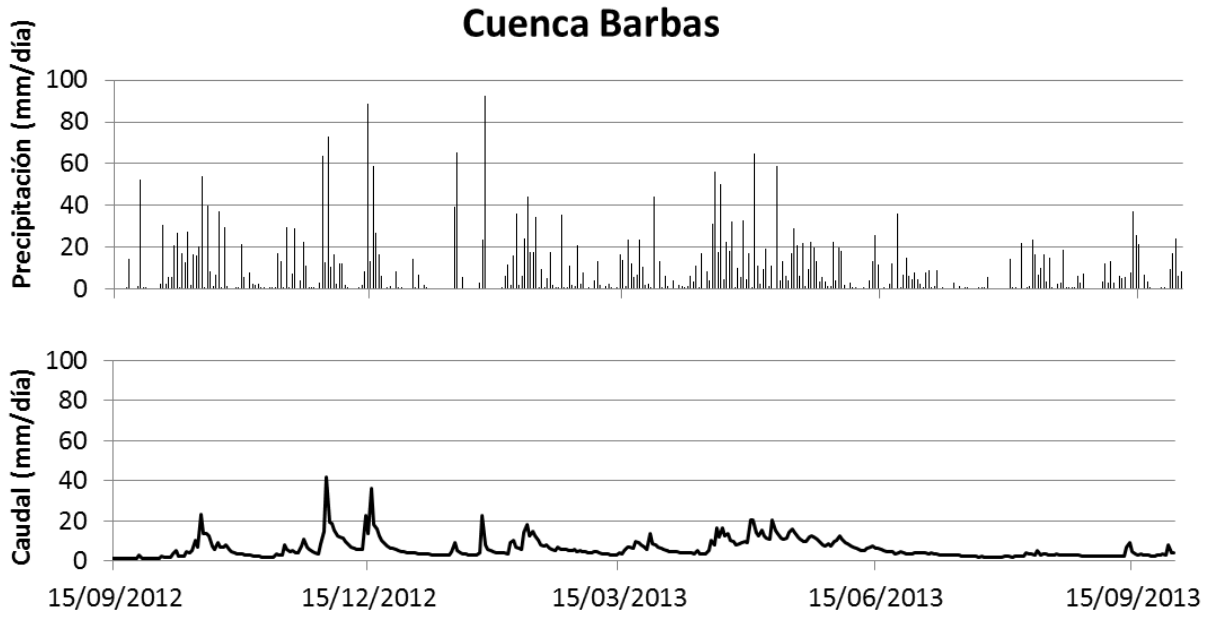


Figure 2. Precipitation and stream flow for the Barbas watershed

In order to complete the generation of data for comparing water availability in relation to soil types and land use in her two research sites, Clara has obtained a second grant from the International Foundation for Science for US$10,000. With these resources Clara will be able to finalize the data collection for a hydrological comparison. She expects to finish this data collection in 2014 and generate the comparative analysis in 2015.

To failitate the analysis of stream flow from water level data (collected by project partners) and stream discharge data (collected under the supervision of Clara Roa), Amanda Girard, a senior undergraduate student in UBC Forest Sciences, developed a series of excel macros which calculate daily, weekly and monthly totals, and determine summary statistics and graphics. Given the large size of streamflow datasets, developing a "program" for analysis permits community partners to synthesis their precipitation and streamflow data in standard formats. However these macros demand percise data formating, and verification of input data and calculated streamflow by a reseracher with experience in hydrological monitoring is highly recommended. These results were published in a report and can be access at the project's website: http://www.landfood.ubc.ca/swc/projects/ACCCR/publicaciones.html.

Water use and vulnerability

For the first time CWOs had access to maps showing land use on their headwaters, allowing them to identify vulnerabilities of their water source. The maps generated in year 1 together with data on water scarcity due to sedimentation allowed organizations to identify key strategies to reduce vulnerability to climate change.

We began the identification of community vulnerabilities and adaptation strategies through the collection of data from the water organizations (information collected monthly), surveys with all water organizations within AQUACOL and FACORIS, and a household survey for the pilot site watersheds. This survey allows a quantification of water storage capacity within the community and the perception of the community regarding their water provider.

Antonia Kolic a senior undergraduate student in Land and Food Systems UBC, analyzed water use data for five water providers that had the most complete data set and provided a preliminary analysis of factors that might have an influence on water use at the community scale. Her analysis compares water use in terms of:

a) number of connections
b) socio-economic stratification
c) water use – total monthly, versus concession, per subscriber, per estrato
d) variability in water use – wet versus dry season (per estrato)
e) water use versus precipitation
f) potential land use influences

It appears that land use has a significant impact on how water is consumed in each of the regions, especially at those sites with significant agriculture. Domestic water use was less variable than non-domestic water use, and precipitation levels in the sites did not appear to influence

consumption. The full results were published in a report and can be access at the project's website: http://www.landfood.ubc.ca/swc/projects/ACCCR/publicaciones.html

Soils and vulnerability to climate change

Clara Roa has made good progress on her PhD project on the properties of soils and their water holding capacity in relation to climate change. She is comparing Andisols (Barbas watershed – Tribunas) and Inceptisols (Chocho watershed – Golondrinas). The soils of the two cordilleras play an important role in the retention and release of water, and Clara has found significant differences in terms of water holding capacity. The western branch is dominated by weakly developed soils (Inceptisols), while the central branch is influenced volcanic ash (Andisols). From the soil-water perspective, Andisols have a high water holding capacity (Fig 3a), related to the ash and the higher organic matter content of these soils.

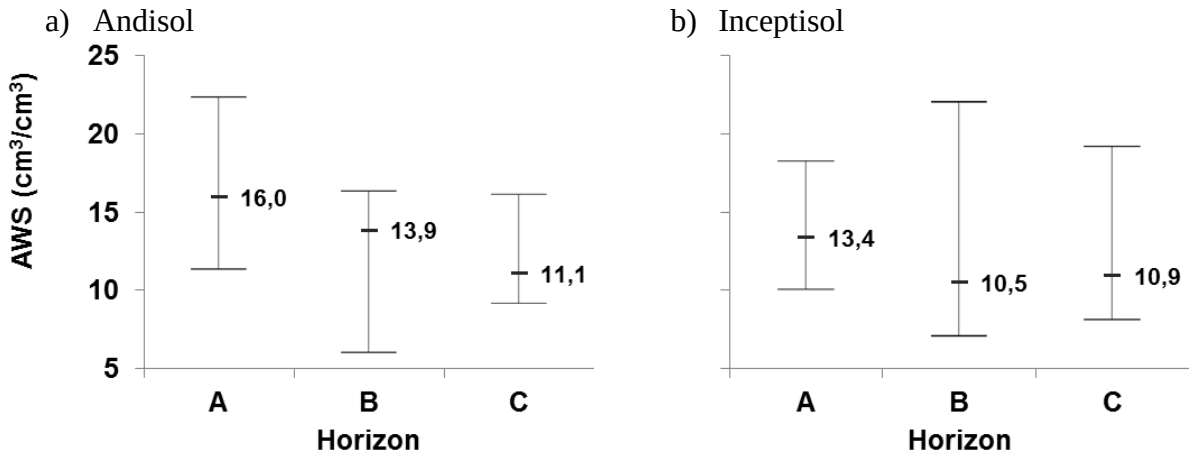


Figure 3. Soil water retention capacity.

As Clara opted for a journal article format for her thesis, each of her central chapters will be a journal article. She is currently finishing the first draft of one of these articles that she is co-authoring with Sandra Brown, entitled "Soil water retention properties of Andisols and Inceptisols in the Colombian Andes". The abstract of this article is:

> Andisols and Inceptisols comprise more than 70% of the soils in the Colombian Andes, yet detailed soil data is limited. Water retention characteristics of Andean tropical soils are particularly important for understanding and modeling stream flow, plant available water and the impact of land management. Pedotransfer functions (regressions using texture and soil organic matter) based on data from temperate regions are often used, but there is evidence of significant differences between temperate and tropical soils, and a need to characterize the water retention of soils in the Andean region. This study evaluates Andisols (volcanic ash soils) and Inceptisols in two watersheds of the Colombian cordillera, with the aim of comparing between soil types and understanding the factors influencing soil water retention. Although no differences were seen in plant available water content or gravitational water, significant differences between soils were found in volumetric soil moisture (θ) at saturation (θ_{sat}), field capacity (θ_{FC}) and

permanent wilting point (θ_{PWP}). These differences are important to consider in hydrological modelling as default data for soil parameters will not reflect the characteristics of Colombian soils, nor their regional variability. Factors influencing soil water retention differed between the soils, with soil organic matter (SOM) contributing to differences between horizons in Inceptisols, while in Andisols SOM contributed to water retention in the A horizon and allophanes (amorphous aluminum-silicate mineraloids) in the B horizon. These differences are important for management consideration, particular practices which impact soil organic matter. The data generated by this study will add accurate data for modeling stream responses to climatic variability, and may be important for estimating water retention by Pedotransfer functions using tropical data sets.

Clara and Sandra expect to submit this article to Geoderma (The Global Journal of Soil Science) within the next month.

Clara sampling soils with Sandra (left) and preparing soil samples for analysis

Sandra Brown (UBC) has been analyzing volcanic ash soils in relation to water release. Land use was shown to impact soil-water retention and release (Fig 4), but had limited influence on other soil-water properties. Surface (0-10 cm) pasture sites display flatter curves indicative of higher soil-water retention and lower release. The high soil-water holding capacity of allophanic soils (noted by both Sandra's and Clara's work) has implications for communities who depend on these upland regions for agricultural production and as water sources. While these soils have a large capacity to hold water, they do not release water, resulting in a high soil-water content, potentially greater surface runoff and flashier stream flow. A poster summarizing Sandra's work is available on the project website http://www.landfood.ubc.ca/swc/projects/ACCCR/publicaciones.html.

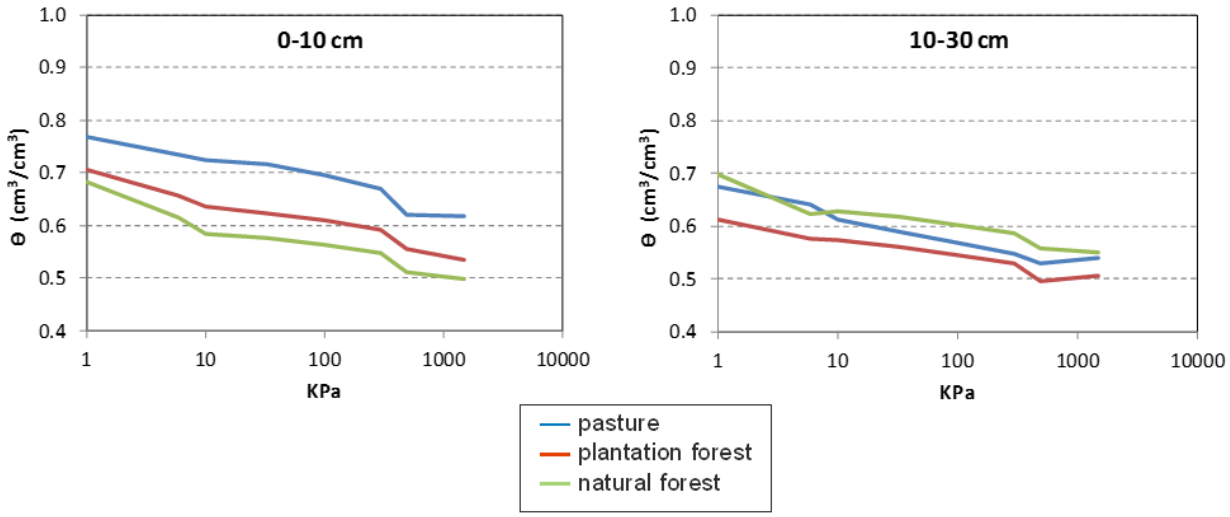


Figure 4. Average soil water retention curves of volcanic ash soils in the central Andes

The implications of these results are particularly relevant in supporting the infiltration trade-off hypothesis which explains the more pronounced storm discharge during the rainy season that seriously impairs the recharging of the soil and groundwater reserves feeding springs and maintaining baseflow, through reduced rainfall infiltration in cleared areas due to either continued exposure of bare soil to intense rainfall after forest clearance, or compaction of topsoil by machinery, or overgrazing[16]. Providing more support for this hypothesis in tropical environments is very important to contribute to debunk the myth of trees as water sources, and explaining the interrelations between soil and land use in water flow regulation. This is considered a key argument that CWOs can use in their struggle to protect headwaters located in privately owned farms where productive activities take place.

4.2. Climate change adaptation: capacity building for water administration and management

Subsidies

Responding to the request by project partners to explore mechanism for access to state subsidies for low income communities, we started to work on two major obstacles: an accounting system and the calculation of tariffs according to the method designed by the national government.

Trent University's student Andreina Pulido developed an excel template that allows for the estimation of tariffs, and the average cost of treating and delivering a cubic meter of water. This template is based on the methods established by the Regulatory Commission of Potable Water (CRA) which provides a Unique Plan of Accounting (PUC) specific for public utilities and also

[16] Bruijnzeel, L.A., 2004. Hydrological functions of tropical forests: not seeing the soil for the trees? Agriculture, Ecosystems and Environment, 104: 185–228.

adapted for small providers of less than 2,500 connections. The excel file separates the costs that are paid from those that are not paid such as voluntary work by managers, board members, the use of personal equipment and the like.

The template was also compared with the Information Platform for Small Providers (PIPP) developed by Luis Velasco and that has not been released to organizations. The results were almost identical. The excel file developed is significantly easier to use, excel is a widely accessible software, the format is easy and transparent, and all the information and formulas are shown. This tool has made visible the reality that water organizations do not require the hiring of expensive consultants to calculate their tariffs, and to maintain and update their operational and administrative costs. Some small organizations have paid 1 million pesos to independent consultants to help them calculate costs and tariffs, as this information is required by the SUI. Training on full cost accounting has been provided to Yadira Gutierrez (previously at Acocascajal, now with AQUACOL) and Anyela Torres (La Sirena). This training has consisted of spread sheet management and data gathering on all fixed and variable costs required by the CRA (Comision Reguladora de Agua). They have already started using this template to help other organizations calculate costs and tariffs (e.g. ASDAL, Tuluá).

Based on her use of the template with five community organizations and the financial data for 2012, Andreina is writing her MA thesis whose objective is to understand the reasons for financial and institutional vulnerabilities of CWOs. She has identified the following issues as the most frequently mentioned:

- State subsidies payments are delayed and threaten the financial sustainability of CWOs that have to cover those delayed payments with their own resources or obtain bank loans.
- Without the socio-economic stratification of population CWOs cannot apply to subsidies despite the stratification process being a municipal responsibility.
- The application process to be eligible for subsidies is complicated and takes too long.
- Change of CWO management can result in a loss of information, irresponsible spending, among other financial problems.
- Under estimating water tariffs undermines the financial sustainability of CWOs, therefore an accurate cost estimation is critical for the correct operation of CWOs.
- Water users defaulting on payment also undermines the financial sustainability of CWOs.

Initial data analysis indicates additional crucial threats to the institutional and financial sustainability of CWOs, including:

- CWOs often operate below break-even levels because an accurate cost estimation would have incremental effects on water tariffs for their communities. Future investments is usually the most underestimated cost.
- There is a knowledge gap of the existing legislation that benefits CWOs. CWOs are more aware of their duties than of their rights.

Some of the key elements of success for a CWO to be sustainable (as mentioned by Oscar Gómez, Tribunas Córcega CWO Manager) are:

- Have a strong legal knowledge: in Colombia the law is in place to protect CWOs and their sustainability, however ignorance of their rights and duties make CWOs vulnerable.
- Accountability to the community: if a CWO is fully accountable and periodically shows results to its community it will have its support and participation.
- Work together with the local government rather than against: as far as possible the CWO should become an ally of the local government and vice versa.
- Maintain a communication channel with the community: for instance a newsletter, meetings, activities, etc.

Andreina's thesis will be completed and defended in September 2014. Based on her work, Andreina wrote an article that she expects to publish this year entitled: **Lessons learnt from rural water supply players in search for a sustainable rural water system.** This paper is provided in Appendix 3.
Andreina also produced a short video with the opinions of some CWO's managers about factors of financial vulnerability. It can be watched at: https://www.youtube.com/watch?v=qFf_IGGrYI8

Silvia Corrales, project researcher, has written an article about the challenges for CWOs whose managers are close to retirement and have limited options for replacement among the younger generation. This article is included in Appendix 4.

Socio-economic survey and synthesis

In 2012 we conducted a socio-economic survey in six communities, summarized in the table below, and covering more than 80% of all households in these communities.

Community	Number of surveys
Mondomo	450
La Sirena	570
Acuasur	1,211
Golondrinas	224
Mundo Nuevo	150
Asocascajal	287

The surveys covered questions related to water use, water availability, land use, economic activity of the household, income level, perception about water quality, and opinion about the water organization. We had originally planned to link each individual survey to the corresponding water use data registered by the CWOs to analyze water use in terms of household information. This however was not possible, as the ID code corresponding to each household's water bill was omitted. Additionally we found that there was a significant proportion of missing data, which would not allow us to make statistical comparisons across communities. For these reasons we decided to synthesize the data for each community into a dissemination tool that CWOs could use. We produced banners for Acuasur, Asocascajal, La Sirena and Golondrinas and

a full report with data analysis for Mundo Nuevo, whose data was more complete. Banners are included in Appendix 5 and on the project's website, and the report on Mundo Nuevo is included in Appendix 6.

The highlights of this work are:

- The efforts of Acuasur to reduce the time of response to leakages, is manifested in the reduced individual storage capacity. In a significant number of households, tanks that were used previously to store water, remain empty or have been replaced by buckets. This was a positive feedback for the administration of Acuasur since it demonstrates the results of an adequate response system.
- Golondrinas faces severe water scarcity and most users have to store water daily, since each household has water service only during two hours a day. Surprisingly, only 61% of respondents collect rain water and 41% reuse gray water.
- Both Golondrinas and Asocascajal are making great efforts to expand their service to include sanitation which their communities currently do not have.
- All communities are aware of the impacts of climate change on water availability, and although the risks are perceived to concentrate primarily in the dry season, there is an important perception of the risk of water scarcity during the wet season related to impacts on infrastructure due to landslides and to the amount of sediments in the water sources during storm events.

Headwater protection

The strategy to protect water sources by acquiring control over key areas in the headwaters was identified as both a current and a potential strategy. Considering that the Colombian law has developed instruments to facilitate the acquisition of these strategic areas for conservation (Art. 111 of Law 99 of 1993), we decided to develop a manual to facilitate the process of land acquisition for water source protection. This manual was developed by the Centro de Asistencia Legal Ambiental – CELA and it's director, the environmental lawyer José María Borrero, in collaboration with CWOs and the project team. The manual is included in Appendix 7. The picture below shows the participants of one of the two workshops we carried out at "Herencia", one of José María's two farms near Jamundí.

As part of this product, we participated in some of the steps that the community of Golondrinas is taking to acquire (through the municipality of Cali) a farm of 67 has located in the headwaters of the Chocho river (total area of the watershed 2,025 hectares). This farm has an important area in secondary forest and includes 7 water springs that are important contributors to the Chocho River. The pictures below show a visit to this farm organized by the community, with the purpose of formally initiating the process which starts with the request to environmental authorities to provide a technical opinion about the importance of the area for water source conservation. This visit took place on April 8, 2014 with the participation of the farm owner, the environmental authorities CVC and DAGMA (the environmental authority of the city of Cali) and representatives from 7 CWOs that depend on this water source to supply water to their communities. These communities are:

Community	Population
Campoalegre	4,000
Golondrinas	3,500
La Paz	1,000
Los Limones	200
El Rosario	300
Montebello	15,000
Lomitas	4,000
Total	**25,000**

The owners of the farm have the intention to sell and have designated as their representative, a woman who is also a board member of one of the CWOs that depends on the Chocho river. The strategic importance of this property was obvious to the environmental authorities who visited it this day. Currently the Chocho river requires an inter-basin transfer of water from the neighbouring watershed El Aguacatal (6,225 has) which is done through an 8 inch pipe. This is the only way to supply water to 25,000 people in this rural area of Cali.

In the manual developed, we have emphasized the role of CWOs in identifying and communicating the importance of specific areas within their watersheds. Although CWOs have no decision making power, their interaction with land owners and their knowledge of the water sources, give them the authority to propose land acquisition by their municipalities.

4.3. Water justice across scales: from CWOs in Colombia to constitutions in Latin America

Henry Popó (Acuasur) mentioned in our wrap-up workshop, how much they have appreciated discussing equity openly throughout the project. Water justice issues are generally present in all the work they do, but it is important for CWOs to discuss notions of justice and equity, and improve clarity about their meanings and components. Acuasur has been the CWO that motivated us to work on these issues, as they have struggled for over four years to obtain water subsidies for their community.

We have addressed water justice from different angles and across scales. At the national scale we looked at the differences between data reported to the national information system (SUI) by large water enterprises and CWOs finding that while 100% of large companies report, less than 15% of CWOs currently report to the SUI. This makes it hard to have national policies that address their problems, given the lack of information at the national scale. A short article describing the SUI and the challenges CWOs face when reporting was published on the project's website: http://www.landfood.ubc.ca/swc/projects/ACCCR/investigacion/sui/SUI_rural_articulo.pdf

Cecilia summarized some of the data collected to provide a general overview of equity indicators for CWOs. This work was presented at the Water Justice meeting in Cusco in October 2012 and a chapter will be included in the book "Water Justice: power, conflict, social action" to be published this year. This chapter is provided in Appendix 8. An internal report in Spanish summarizing key results is posted on the project's website: http://www.landfood.ubc.ca/swc/projects/ACCCR/investigacion/concesiones/equidad_agua.pdf

Cecilia and Andreina wrote an article that illustrates the differences in capabilities of CWOs to apply for water subsidies and how a system designed to be a tool for equity has produced an opposite result. The paper has been accepted for publication on Univalle's journal "Ambiente y Sostenibilidad" and is included in Appendix 9 (and will be posted on the project website when published in December 2014). The paper is entitled "T**he challenge of urban-rural equity in water access for domestic use in Colombia"** and its abstract follows:

> The subsidy mechanism for water access in Colombia has been applied differently in urban and rural areas. While in urban areas the subsidies are administered by large commercial enterprises, in rural areas the intermediaries between communities and the state are community organizations that in most cases have limited capacity to demand these resources from the state. In this article we present five examples of community organizations with diverse managerial capabilities and analyze the difficulties they have faced to access water subsidies their subscribers are entitled to. We argue that although some organizations see an advantage in maintaining independence from the state and choose not to embark on the quest for subsidies, access to these resources by community organizations is necessary not only to ensure their sustainability but to help reduce the inequality gap between urban and rural areas.

We produced a step by step manual that CWOs can use in their quest for subsidies for their communities. Jorge Amaya, a student of social work at Univalle and a board member of Acuanariño, collected all the legal information related to the requisites for applying, and met with the two CWOs that have obtained the subsidies from their municipality. With this information and the help of Johanna Vidal (media designer) we produced a document that serves to motivate and guide CWOs to initiate their process of application. Parallel to his work on the manual, Jorge convinced the board of Acuanariño to apply for subsidies and by July 15 2013 (the required date to submit applications for the following year) he presented the documentation in Tuluá. The manual is accessible from the project's website, CINARA's website, FEG's website, on ISSUU (http://issuu.com/sandrabrown08/docs/cartilla_subsidios) and 300 copies were printed and disseminated among members of AQUACOL and FACORIS. The full manual is included in Appendix 10.

Oscar (manager of Tribunas) teaching us about access to subsidies

The group at the subsidies workshop

The "Cartilla"

As part of Cecilia's post-doctoral project, she published two articles in Geoforum: one with Leila Harris entitled: **Recent waves of water governance: constitutional reform and resistance to neoliberalization in Latin America (1990-2012)** included in Appendix 11; and a second one

with Patricia Urteaga (Peru) and Rocio Bustamante (Bolivia) entitled: Water laws in the Andes: a promising precedent for challenging neoliberalism, included in Appendix 12.

These articles discuss recent changes in constitutions and water laws in the Andean region, present the tensions and contradictions and propose broader ways to analyze resistance to neoliberal conceptions of water and nature. This work helped to bring a stronger equity focus to the project and a fuller understanding of the importance of constitutional law and the Colombian constitutional court in upholding the human right to water in Colombia. The focus on water laws as tools for social emancipation helped the research team to explore specific legal tools that already exist in water related laws and that constitute structural opportunities for a more equitable society.

4.4. Water justice, water allocation and climate change adaptation

Water concessions in Colombia

One of our focus topics in relation to equity was water allocation, that in Colombia is done through the instrument of concessions. From our early collaboration with IDEAM we were able to obtain a database of 28,104 registered concessions (Rudas, Lleras, 2010) of which 27,876 have information on the volume of the concession as well as the type of registered use. If concessions are to be effective as a tool for equitable water allocation it is important to understand how the number of concessions relates to the volume of water allocated, overall and for the major categories of water use.

Sandra and Cecilia have analyzed this data base and have written an article for publication etitled: **Assessing equity and sustainability of water allocation in Colombia.** The abstract of this article is:

> Based on the national database of 28,104 water rights (concessions) granted in Colombia, this paper presents and analysis of how the principles of equity and sustainability are reflected in water allocation. Concessions appear to be an exclusionary mechanism since only a minority of water users have them and the distribution of water volumes among those who have them is extremely inequitable. The 2009 Gini coefficient calculated for water concessions granted for agriculture was 0.90 compared with the rural land Gini of 0.88 (both indicators grouping holdings under the same entity). More than half of the Colombian departments have a higher Gini coefficient for water than for land, suggesting that access to water is at least as inequitably distributed as land, in one of the most inequitable countries in Latin America. Water allocated to domestic, agriculture and hydropower use indicate lack of consistency of water allocation criteria across regions. In the case of hydropower generation allocation does not reflect neither required flows for turbine operation, or evaporative losses. The volumetric and administrative attributes of water allocation in Colombia, do not account for environmental flows or the concerns of marginalized groups of society that have limited access to the mechanism. Water allocation as a technical task, with limited transparency and secluded from public scrutiny, does not contribute to the solution of increasing water related conflicts.

Water allocation in the Andean region

Realising how water conflicts are increasing in the Andean region led to our investigation of how water is being allocated. Based on the data Cecilia collected in her post-doctoral project in Colombia, Ecuador and Peru, she addressed the question: what do laws tell us about the values and guiding principles that these societies have chosen to allocate water? The underlying question is how countries are dealing with the trade-offs and potential complementarities between equity, efficiency and scale in water allocation. Cecilia wrote a paper entitled: **Equity, efficiency and scale in water allocation in the Andes: trade-offs in a full world**; that was published in Water Alternatives in June 2014. The paper is provided in Appendix 13.

A parallel paper drawing from the same dataset was presented in Spanish at AGUA 2013 with the title **Equity, efficiency and scale in water allocation in Andean countries: synergy or conflict?** This paper is included in Appendix 14 and is also available at the project's website: http://www.landfood.ubc.ca/swc/projects/ACCCR/publicaciones.html

5. Dissemination

5.1. Workshops and websites

We used multiple strategies for communicating project results to partners and beneficiaries as well as scientific findings. For project results, our main dissemination channel was through workshops with project partners. We had on average 5 workshops every 6 months. We used the project website (http://www.landfood.ubc.ca/swc/projects/ACCCR/) to publish internal reports, videos of project partners and short articles. The Fundacion Evaristo Garcia's website also publishes research results and highlights the project's main activities and achievements (http://lfs-feg.sites.olt.ubc.ca/)

Clara developed a very useful tool to disseminate climate and stream flow monitoring methods (http://blogs.ubc.ca/ceroa/) and she published and presented her analysis of this tool at AGUA 2013. The paper is included in Appendix 15, and on the project's website under publications.

5.2. Publications

Table 3 summarizes the articles published, under review or in preparation that are products of the project. Publications marked in gray are completed and the ones in white are currently in draft form to be finalized and submitted in the next month. The titles with an * are those that could not be completed during the duration of the project due to lack of good quality data: the comparative analysis of precipitation and stream flow; the analysis of the socio-economic data in relation to water use; and the one on the generational transition in CWO management. The first paper will be completed within the next year, as Clara obtained a small grant from IFS to finalize the data collection required. The second paper was replaced by dissemination banners for the communities. The third one was not submitted by the author.

Table 3. Publications

Title / topic	Author(s)	Date	Notes
Stream closure and water allocation in the Colombian Andes www.inderscience.com/current_issues/ijw.rss	MC Roa S Brown L Lavkulich	2014	International Journal of Water
Role of Inceptisols and Andisols on water regulation	CE Roa	Jul-2014	First draft
Comparing precipitation and stream flow of small watersheds feeding potable water systems *	CE Roa MC Roa	Jun-2015	Additional funding approved
Indicadores de justicia hídrica para organizaciones comunitarias del agua en Colombia	MC Roa	Dec-12	In press Water Justice book
Vulnerability of rural communities and adaptation needs. Comparing socio-economic survey data. Tools for vulnerability assessment *	S Brown MC Roa	N.A.	Dissemination banners
The challenge of urban-rural equity in water access for domestic use in Colombia	MC Roa A Pulido	Dec-2013	In press
Equidad en la generación y acceso a la información sobre acueductos rurales en el contexto del SUI	MC Roa S Corrales	Jun-2013	Project website
Assessing equity and sustainability of water allocation in Colombia	MC Roa S Brown	Jul-2014	First draft
Water laws in the Andes: a promising precedent for challenging neoliberalism www.sciencedirect.com/science/article/pii/S001671851300256X	MC Roa R Bustamante P Urteaga	Nov-2012	In press – Geoforum
Equidad, eficiencia y escala en la asignación del agua en los países Andinos: sinergia o conflicto? www.landfood.ubc.ca/swc/projects/ACCCR/publicaciones/MCRoa_EES_Agua2013.pdf	MC Roa	2013	Proceedings of AGUA2013
Equity, efficiency and scale in water allocation: trade-offs in a full world www.water-alternatives.org/index.php/alldoc/articles/vol7/v7issue2/248-a7-2-2	MC Roa	2014	Water Alternatives
Recent waves of water governance: constitutional reform and resistance to neoliberalization in Latin America (1990-2012) http://lfs-feg.sites.olt.ubc.ca/files/2013/08/Harris_L_M_et_al_Recent_waves_water_governance_2013.pdf	L Harris MC Roa	2013	Geoforum
Retos de las organizaciones comunitarias del agua como organizaciones sin ánimo de lucro en el contexto del relevo generacional *	S Corrales	Dec-2013	Not published
La vulnerabilidad de organizaciones comunitarias del agua frente al cambio climático en Colombia www.landfood.ubc.ca/swc/projects/ACCCR/publicaciones/Brown_Vulnerabilidad_Agua2013.pdf	S Brown MC Roa I Restrepo	2013	Proceedings of AGUA2013
Estructura financiera de los acueductos rurales: economías comunitarias y sostenibilidad	A Pulido MC Roa	Dec-2014	First draft
Uso de herramienta virtual para el aprendizaje de una técnica de monitoreo de caudales en pequeñas quebradas www.landfood.ubc.ca/swc/projects/ACCCR/publicaciones/CERoa_Monitoreo_Agua2013.pdf	CE Roa	2013	Proceedings of AGUA2013

5.3. Conferences

We attended 13 international conferences, presented project results and received feedback.

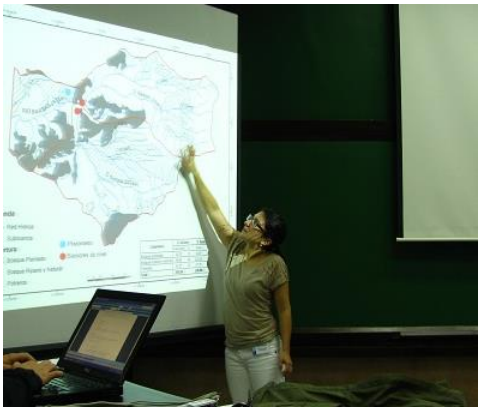
Table 4. Conferences attended

Conference	Location	Date	Attendee	Presentations
Justicia Hidrica	Cusco, Peru	Nov-11	Cecilia	Water equity and efficiency in the Andes: approaches and preliminary findings
Justicia Hidrica	Cusco, Peru	Oct-12	Cecilia	Indicadores de justicia hídrica para organizaciones comunitarias del agua en Colombia http://justiciahidrica.org/wp-content/uploads/2012/01/Informe-4to-Encuentro-JH-nov-2012-FIN.pdf
Planet Under Pressure	London, UK	Mar-12	Ines	Rural Community Organizations in Water Science For Climate Change Adaptation http://www.landfood.ubc.ca/swc/projects/ACCCR/publicaciones/planet_under_pressure.pdf
Latin American Studies Association	Washington, US	May-13	Cecilia	Equity, efficiency, scale in water allocation in the Andes: trade-offs in a full world
III Encuentro Latinoamericano de Organizaciones Comunitarias	Cuenca, Ecuador	Sep-12	Silvia, Edgar, Yadira, Luis	Round table discussion
AGUA 2011	Cali, Colombia	Oct-11	Edgar, Yadira, Jose Noe, Anyela, Clara, Silvia, Cecilia	Cambio climático en la Colombia rural: experiencias de los acueductos comunitarios http://www.youtube.com/watch?v=SZbxui7dXRY
AGUA 2013	Cali, Colombia	Oct-13	Edgar, Yadira, Jose Noe, Anyela, Raul, Henry, Maria Eugenia, Claudia, Bernardo, Clara, Silvia, Cecilia	La vulnerabilidad de organizaciones comunitarias del agua frente al cambio climático en Colombia http://www.landfood.ubc.ca/swc/projects/ACCCR/publicaciones/Brown_Vulnerabilidad_Agua2013.pdf Uso de herramienta virtual para el aprendizaje de una técnica de monitoreo de caudales en pequeñas quebradas http://www.landfood.ubc.ca/swc/projects/ACCCR/publicaciones/CERoa_Monitoreo_Agua2013.pdf Equidad, eficiencia y escala en la asignacion del agua en los Andes: sinergia o conflicto? http://www.landfood.ubc.ca/swc/projects/ACCCR/publicaciones/MCRoa_EES_Agua2013.pdf
IMHEA	Piura, Peru	Jun-13	Clara	Comparative analysis between inceptisols and andisols in relation to water holding capacity
World Wide Workshop Young Enrvironmental Scientists	Paris, France	Jun-13	Clara	The role of two soil types (Andisols and Inceptisols) in water retention for water supply
Watershed management and environmental services	Quito, Ecuador	Jan-12	Cecilia	Distribución de tiempos de respuesta y de tránsito del agua en pequeñas cuencas de los Andes Colombianos
Latincouver	Vancouver, Canada	Apr-12	Cecilia	Water equity and climate change adaptation in the rural Andes
Land-Water Systems seminar series, UBC	Vancouver, Canada	Oct-13	Sandra	Vulnerability of Community Water Providers to Climate Change in the Colombian Andes
UNEP, Regatta Webinar*	Andean countries	May-14	Cecilia	Vulnerability of Community Water Providers to Climate Change in the Colombian Andes http://www.copandes.org/#!webfvi/cot3

*Regional gateway for technology transfer and climate change action in Latin America and the Caribbean. Attended by 120 people from 5 countries

World Wide Workshop for Young Enrvironmental Scientists

Water Justice meeting 2012



Andean Ecosystems Hydrological monitoring workshop, 2012

Agua 2011

Vulnerability workshop, CINARA 2013

5.4. Videos

To highlight the CWO's strengths, demonstrate monitoring equipment installation, summarize the CWOs' perception on climate change and other topics, we produced more than 20 short videos. For the videos focused on CWOs, each organization chose the topic. The videos are available on the project's youtube channel: https://www.youtube.com/user/ACCCRvideos and linked via the project website. The videos on CWOs' strengths are the following:

- Acuasur: A model of community participation
- La Sirena: An efficient management for water and community sovereignty
- Tribunas Corcega y ASAMUN: long and fruitful struggle for equity in water access
- Acuabuitrera: feasibility of the community water management model

The video that collects the opinions of our research partners about their plans and strategies to face climate events according to past experiences is called: community organizations meet the challenges of climate change.

5.5. Banners

Several partner organizations use banners in their offices to help community members get familiar with the organization and learn about local challenges. Partners opted for banners as a project dissemination tool to pull together the information generated during the project including land use maps, climate data, a brief history of the system, a description of the water source, the watershed, the organization, the community; financial information in some cases and challenges for the immediate future. These banners are shown in Appendix 16. We also decided to use this method to summarize the survey findings and make the communities aware of their water issues but also the resilience of their CWOs. The picture below shows the meeting we organized to share the information of the banners and distribute the manual on subsidies.

Feb 14, 2014. Banners and subsidies manual meeting at CINARA

6. Capacity building

6.1. Students

The students involved in the project are at different stages of progress:

- Clara Eugenia Roa is doing a PhD thesis at UBC on the effects of soil properties and land use on low flows in two of the pilot sites. She has finished data collection on soils and will concentrate on the hydrological component in the next few months. She is planning to defend her thesis in 2015. A draft of her PhD chapter 3 is under review and she plans to submit this article for publication in August 2014.
- Silvia Corrales is doing a MSc thesis at Univalle on the role of the instrument of concessions for water allocation in relation to equity. No results are available to date.
- Isabel Bolaños completed a MSc thesis at CINARA on the development of a methodology for climate change adaptation in rural Andean watersheds. She was involved in the collection of water quality data for several pilot sites. She defended her thesis earlier this year.
- Jorge Amaya finalized his Univalle (Social work) internship on access to subsidies by rural community water providers. The results of this internship include a manual for the application to the FSRI (subsidy fund) by CWOs included in this report. He also participated in the analysis of the survey database and he wrote the summary of findings for Mundo Nuevo.
- Andreina Pulido is doing a MSc at Trent University. Her thesis project deals with financial and social sustainability of rural water providers. She will defend her project in September 2014. She is the co-author with Cecilia on a publication accepted by the Journal Ambiente y

Sostenibilidad that will be published in December 2014. She has also written an article on sustainability of CWOs that is still in draft form to be submitted later in 2014.

6.2. Evolution of CWOs

After three years of involvement in this research project, our CWO partners have developed significant knowledge of technical, administrative and legal tools to make community water organizations sustainable, and to access rights such as subsidies and the protection of strategic areas for water conservation. Project partners consistently and actively participated in workshops, and lead the team to focus on issues of relevance and urgency for the current socio-economic and biophysical circumstances. Through the project, the key issues faced by small rural CWOs became visual; access to subsidies in the context of urban versus rural equity, the substantial demands of the centralized government on small systems with limited technical resources to comply with online reporting; and the poor national information system about small water providers. CWOs became aware of the importance of fully accounting for their costs in order to achieve financial sustainability; full cost accounting as a requirement to access subsidies was understood by CWOs as a logical condition. For the seven CWOs involved in the project, understanding their biophysical base (climate, stream flow, land use, soils) allows them to communicate confidently with municipal and environmental authorities, to express their vulnerabilities, and to understand their local conditions in a broader context. Through this project CWOs realized that community principals (e.g. not-for-profit) are compatible with sound enterprise-like management. This hybrid model combines the principles and goals of the community based model with the tools and techniques of privately run corporations, and allows them to integrate both to their advantage. The knowledge and confidence gained by CWO leaders is allowing them to assist other organizations which have not been involved in the project.

Dec, 2013. Year end team celebration

Dec, 2012. Year end partner gathering

7. CWOs in research: challenges and suggestions

7.1. Leadership of CWOs

Change in leadership at the technical, managerial or board levels, creates significant knowledge gaps in small community organizations, and was a significant hurdle for the CWOs and our team. La Sirena lost a senior technician due to health issues, Golondrinas' senior manager retired, and Asocascajal underwent an entire change in board; all resulting in significant challenges for these organizations. These incidents lead to the realization of the importance of continuity and establishing a system that is less vulnerable to changes in management. Documentation of roles and responsibilities and developing CWO's management guides for specific topics can help new administrators in their transition. Both the excel based accounting system and the guide for application of subsidies outlining the legal requirements are documents which support transitions in staff or managers / directors respectively. Additionally the community database contributes to making a transition easier both for the community and the new administration, as it provides an overview of the subscribers and their water needs.

7.2. Individual versus collective leadership

Challenges in leadership may also arrive within the networks of community organizations. AQUACOL is an important example, where leadership was monopolized by an individual who ran the organization without transparency. The project has supported CWOs within AQUACOL to develop their capabilities, and provided products that the board members of AQUACOL can offer to member and non-member CWOs. The template and knowledge to operate a basic accounting system, calculate tariffs according to the national regulation, the guide to apply for subsidies, the manual to promote the protection of strategic areas for water source conservation, and the capacity to collect and report information to the national information system (SUI) are examples of these products developed jointly with support from key CWOs in both associations. With their advancement in individual capacities and communication between groups working with this project, member organizations made a move for collective leadership and a transparent

administration within AQUACOL by electing a new executive director and a new board in May 2014. The knowledge and expertise of the more advanced members has become an asset of AQUACOL and a source of income for the organization. On January 11, 2014 Jorge Amaya, Edgar Vivas, Anyela Torres and Yadira Gutierrez (all from different CWOs) obtained the first contract to advise the organization ASDAL in Tuluá on costs, tariffs and reporting to SUI. This is perhaps the most significant achievement of the project: building capacity within individual CWOs and seeing that capacity applied to advance both their individual organizations and their higher order network of water providers.

7.3. Changing government priorities

The superintendent of domestic public services (SSPD) compiles information from all organizations that provide water and sanitation services within Colombia into a national information system (SUI), but only some 15% of rural organizations report to the SUI, and this lack of information is a concern for the design of relevant public policy. The coordinator of the SUI for small providers (Daniel Arcila) within the Superintendent of Public Services was supportive of our project and interested in collaborating on ways in which the representation of small water providers in the SUI may be improved. Unfortunately our key contact with the Superintendent left this position and the new coordinator developed a different set of priorities. Consequently we shifted away from a focus on working with the Superintendent on developing a basic information set within the SUI for small water providers to working with CWOs on generating and inputting that basic information set to the SUI.

7.4. Weak enforcement of equity principles

A major block for many CWOs in the application for subsidies is socio-economic stratification. Without stratification of households, CWOs cannot apply to subsidies despite the fact that defining socio-economic levels is a municipal responsibility. Without this classification of population, the financial sustainability of CWOs is threatened, as they are not compensated financially for the high proportion of low income households which pay rates below the cost of water provision. This situation creates additional inequity between rural and urban water providers as large enterprises (providing water to urban areas) receive subsidies while the majority of CWOs do not. We contacted the city of Cali, and arranged for representatives from municipal planning to attend one of our workshops to discuss obstacles within this process. An outcome of this workshop was an agreement that members of AQUACOL within the jurisdiction of Cali would work together with the municipal planning to provide the necessary information, in the correct format to the city to facilitate stratification in these peri-urban regions. To date, this process is ongoing.

7.5. Working in rural areas: displaced persons and violence

Many rural areas within Colombia will likely continue to be zones where high numbers of

displaced persons and/or violence are concerns. Golondrinas, La Sirena, and Acuasur all deal with potential violence, and working in these regions can be challenging. Our approach to minimize risks has been to continue to support local partners, to work in the region when possible, but to realize that in some circumstances work may need to be delayed.

Asocascajal received news that the municipality is planning to develop a housing project for displaced people in their area of influence and that they would be required to provide water to an additional 1,000 people. This announcement has generated panic among Asocascajal's board, given their precarious financial situation and their limited leadership experience to confront the municipality. Asocascajal, Golondrinas, La Sirena, and Tribunas Corcega are all seeing rapid growth. Tribunas Corcega has developed an open dialogue with municipal and regional government authorities about their capacity to supply water as the region grows. Smaller organizations such as La Sirena and Golondrinas have less capacity to negotiate. Similar to the situation with stratification, we have encouraged these organizations to work through AQUACOL (the network) where as a collective they have greater influence. The case of Asocascajal is somewhat unique in that they recently replaced their entire board of directors and manager with individuals with no practical experience. Ourselves and AQUACOL continue to support this organization, however their confrontational management style will likely create challenges for them over the next few years. In contrast, La Sirena is an example of an experienced board beginning its third period (for another three years) and will most likely face new challenges as they transition to a new set of directors in the future.

7.6. Climate and streamflow monitoring

Climate and stream flow data collection was a challenge throughout the project. With the exception of Mondomo, all project partners have been supportive of data collection and have facilitated transport, equipment and tools to collect data. They recognize the importance of this knowledge but require support to maintain equipment, and collect and analyze data. It is understandable that CWOs that need to solve critical technical and managerial issues cannot afford to use valuable resources in data collection. For these reasons we recommend that data collection and analysis should be done by researchers with the time and resources to support CWOs in getting to know their water source. Collaborative agreements between CWOs and university or NGO partners is strongly encouraged.

8. Project implementation and management

The administration of the project has been in close collaboration between CINARA and FEG. This has been a strong partnership, allowing scientists to work on research, facilitating the involvement of students (including students from Canada). Ines Restrepo (Cinara's previous director) has connections with numerous community organizations, and her prior work with networks of water providers was key in establishing working relationships with local partners. CINARA's oversight of financial reporting has allowed FEG to concentrate on research for

development, working collaboratively with CINARA researchers and local project partners.

The University of British Columbia (UBC) provided scientific support, particularly in the monitoring and indicators themes, and in the dissemination of research results. Having Colombian nationals undertaking graduate degrees at Canadian Universities and working with the project has been very successful, supporting a high standard of student research within the project. Perhaps our strongest contribution in terms of project implementation has been our horizontal approach; working together with local organizations as equal partners.

The involvement of students has had an overall positive impact on the project. As expected, student progress was variable with some students performing above expectations, and other underperforming. Colombian students studying abroad performed extremely well. The MSc project on financial mechanisms was efficient, effective and resulted in both academic publications and practical tools for CWOs. The PhD project on soils has strong data and preliminary analysis, and is being written in journal article format which requires each chapter to make an independent research contribution, involving more time. National students demonstrated variable capacity to do research, and the direction and supervision provided by their university programs influenced, in our view, the quality of their performance. The intern form Univalle's social work program, received substantial supervision form his faculty, which together with his direct involvement with a CWO, resulted in a very positive outcome. For future projects: it is important to have clarity of the schedules of the students' programs (courses versus field work) and the project timeline; ideally advertising, interviewing and screening students early in the project; and involving students / interns who are personally connected to the theme or the communities.

9. Acknowledgements

The research team and our partners believe that this project was an exceptional opportunity to learn and address very important issues for rural water provision and water justice. We gratefully acknowledge the financial support received from IDRC, and the professional and personal support of our project officer Marco Rondon. We wish to recognize the dedication of our Community Water Organization partners in making this project relevant, and to acknowledge the environmental authorities CARDER, CRC and especially CVC for data sharing and participation of staff in project activities. We would also like to acknowledge IDEAM for sharing their concessions database, the SSPD for their initial support of the project, and CELA for their participation in developing the manual on the acquisition of strategic land for water conservation.

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