

# Examining poverty and equality in water resources planning

A Colombia case study

SEI working paper. July 2018

Laura Forni

Marisa Escobar

Angélica Moncada





**Stockholm Environment Institute**

SEI US - Davis Office  
400 F Street  
Davis CA 95616 USA  
Tel: +1 530 753 3035

Author contact: Laura Forni

[laura.forni@sei.org](mailto:laura.forni@sei.org)

Editing: Emily Yehle

Layout: Richard Clay

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## 1. Introduction

Ensuring access to drinking water for all requires the development of strategies that integrate sustainability, poverty reduction and equality into water management (Peña 2011). This is not only an issue for the world's poorest countries, but also for middle-income countries, in which two-thirds of the world's poorest people now live and where water management challenges increase with population growth, economic development and climate change (United Nations 2018). However, social equality and poverty are often overlooked in water resources planning and modelling, as addressing them adds complexity to an already complex process.

SEI's Water Evaluation And Planning (WEAP)<sup>1</sup> tool helps decision-makers understand complex water resource challenges and thus develop sustainable policies. In this study, we used WEAP to develop indicators that allow users to explore how various policy options affect poverty and inequality. We focused on the watershed of Campoalegre, Colombia, working with the area's main environmental institutions to support their planning under increasing uncertainties regarding population growth and climate change.

In 2011, Colombia was the first country in the world to adopt a national poverty reduction plan using a multidimensional poverty measure (OPHI 2018), which makes it a particularly interesting case study. It also has adopted the 2030 Agenda for Sustainable Development; one of the Agenda's 17 Sustainable Development Goals (SDGs) is to “*end poverty in all its forms everywhere.*” This implicitly recognises that poverty has many dimensions, and can mean a lack of non-monetary resources such as health, education, and services (World Bank 2018). Another SDG pledges to “*leave no one behind,*” which implies that efforts are needed to reduce inequalities and give priority to the needs of the poorest and most marginalised people (Stuart and Sammon 2017). However, while the Colombian government recognises the multidimensional nature of poverty, it struggles with inequality. According to the inequality measures, such as the Gini coefficient, Colombia is the second-most unequal country in Latin America. And, despite economic growth, many people still struggle to gain access to basic social services (Universidad Nacional de Colombia 2018).

In order to effectively evaluate poverty reduction policies, an in-depth understanding of poverty is needed. The Swedish International Development Cooperation Agency (Sida) developed a multidimensional poverty analysis (MDPA) to foster a better understanding of who is living in poverty and how that poverty is experienced. In this study, we used Sida's MDPA framework to develop poverty-related indicators within WEAP.

This working paper contains a description of the water resources challenges of the Campoalegre watershed, provides an overview of the MDPA framework, and describes the WEAP results on access and poverty related to urban and agricultural water demands. We then examine one of the key aspects of the armed conflict in Colombia – unequal land distribution – and its impacts on the household income and poverty levels of coffee growers.

## 2. Colombia case study: Campoalegre Watershed

The Campoalegre Watershed is located in one of the main coffee regions in the centre-west of the country, spanning the departments of Caldas and Risaralda. The hydrographic area of the Campoalegre River and other direct tributaries into the Cauca River is 640.5 square kilometres in total. It covers the municipalities of Palestina, Villamaría and Chinchiná in the department of Caldas and the municipalities of Dosquebradas, Pereira, Marseille and Santa Rosa de Cabal in the department of Risaralda. About 78.5% of the area is in Risaralda, with the remaining 21.5% in Caldas (Figure 1 and Table 1).

“Inequality damages the social fabric of the whole society. More equal societies turn out to be healthier and happier” (Raworth, 2017).

<sup>1</sup> www.weap21.org

Figure 1. Campoalegre watershed and main cities

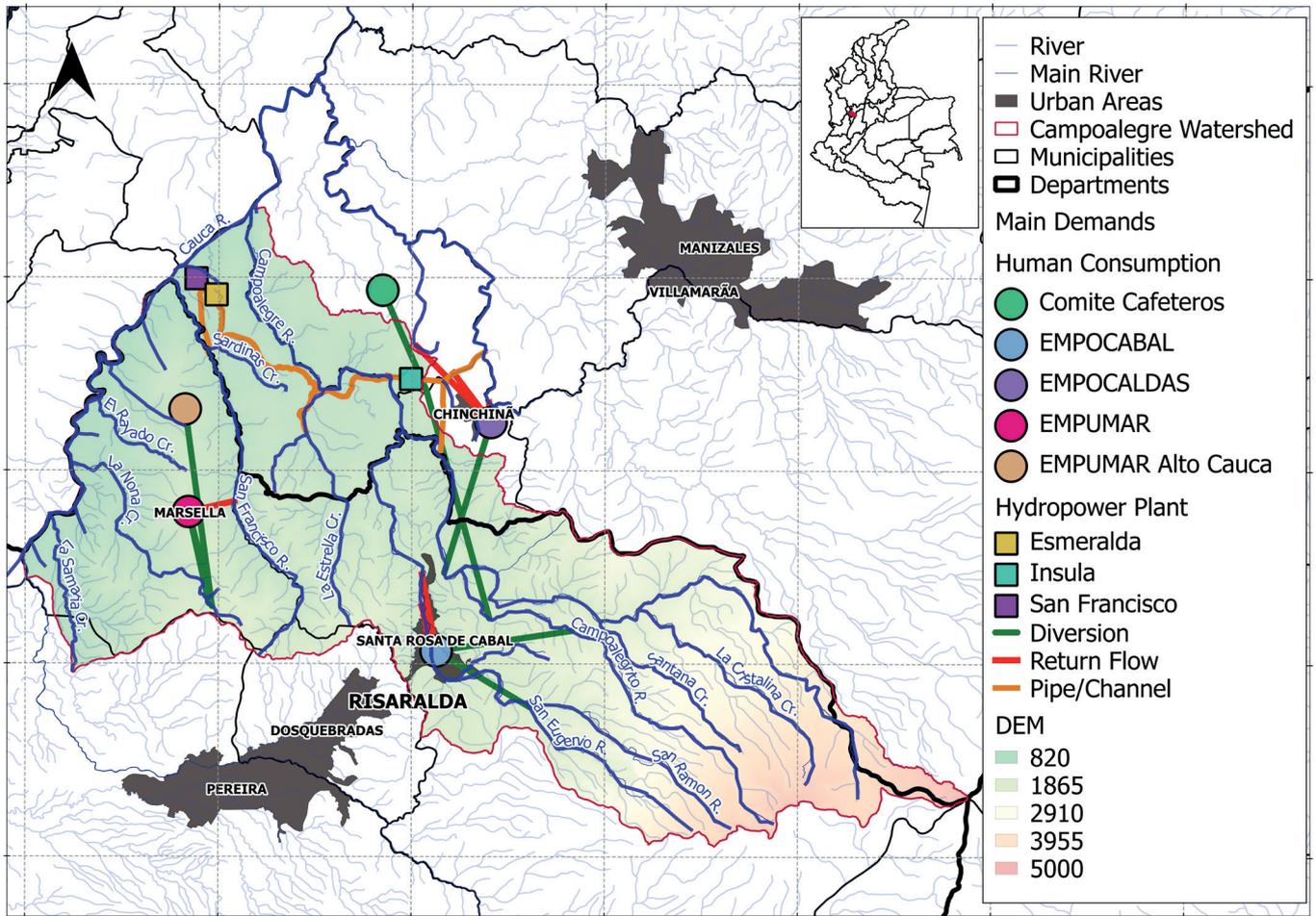


Table 1: Campoalegre Watershed Characteristics

Main Environmental Institutions and Energy Company		CORPOCALDAS, CARDER, CHEC
Area	640.5 km <sup>2</sup>	
Population	272,600 people in the watershed	
Main Municipalities	Palestina, Villamaría y Chinchiná (Caldas) and Dosquebradas, Pereira, Marsella and Santa Rosa de Cabal (Risaralda)	
Water utilities	EMPOCABAL, EMPOCALDAS, EMPUMAR, SERVICIUDAD, and Comité de Cafeteros <sup>2</sup>	
Main Productive Uses	Hydropower generation, water for human consumption, agriculture (coffee)	
Elevation range	850 metres - 5000 metres	
Annual Precipitation	1000 - 3200 millimetres (annual average of 1800 millimetres)	
Monthly Temperature	5 °C - 26 °C	

<sup>2</sup> EMPOCABAL is a sanitary services company for the city of Santa Rosa de Cabal. EMPOCALDAS is a sanitary services company for the city of Chinchiná, and the Departmental Coffee Committee of Caldas (which covers the rural areas of Palestina and Chinchiná). EMPUMAR is the public utility of the city of Marsella. SERVICIUDAD is the domestic public utility of the city of Dosquebradas.

Campoalegre Watershed enjoys high agricultural productivity and is representative of the economically stable coffee regions of Colombia (Pinilla 2017). The rationale for the selection of this site was to highlight that even in this relatively prosperous region, there are inequalities that need to be addressed. While the income poverty is relatively low, there is poverty in regards to access to public services like water. The Campoalegre region also was more heavily impacted by conflict than many other regions in Colombia (Pinilla 2017), so it is an important region to study in the context of Colombia's implementation of a 2016 peace agreement. Several themes of the agreement relate to land access, territorial plans, and food security.

In the Campoalegre watershed, 21% of the population does not have their basic needs met (according to the Unsatisfied Basic Needs index)<sup>3</sup>, compared to the national average of 53%. The percentage of people in extreme income poverty – those living on less than USD 1.9 per day – is 4%; in comparison, the national average is 13.2% (Roser and Ortiz-Ospina 2017; Trading Economics 2015). Table 2 shows a list of indicators of extreme income poverty and multidimensional poverty (MPI) for Colombia and the Caldas-Risaralda-Quindío region (Sub-national level), where the Campoalegre watershed is located. The Global MPI is composed of ten indicators that are equality weighted: years of schooling, school attendance, child mortality, nutrition, electricity, sanitation, drinking water, flooring, cooking fuel, and assets (University of Oxford 2011).

**Table 2: Basic economic and social data**

Indicator	National Level	Sub-national Level	Source
% of Population in extreme income poverty	15 %	4 %	(Hoekman and Kostecki 2001)
MPI (Multidimensional Poverty Index)	0.022	0.009	(University of Oxford 2011)
Gini coefficient on inequality	-	0.53	(University of Oxford 2011)
Indicator of access to water sources	0.04	-	(OPHI 2018)



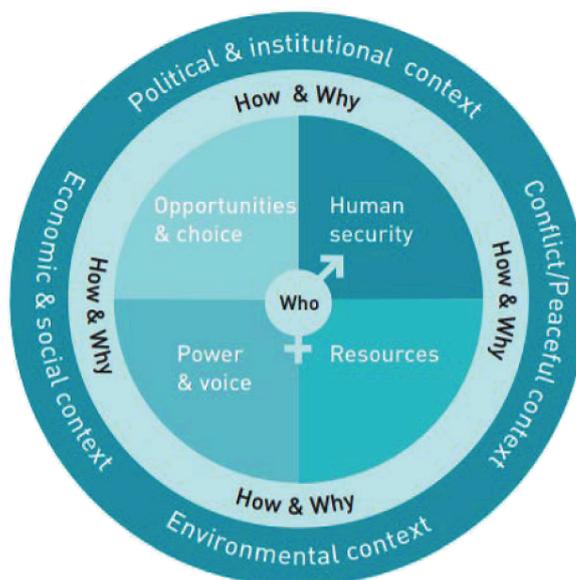
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<sup>3</sup> Through simple indicators, this index seeks to determine if basic needs for the population are being met. More information at: <https://www.dane.gov.co/index.php/estadisticas-por-tema/pobreza-y-condiciones-de-vida/necesidades-basicas-insatisfechas-nbi>

### 3. Multidimensional Poverty Analysis (MDPA) Framework

Equitable societies emerge from intentional policy-making processes that focus on economic development and on sustainable and fair use of natural resources (Raworth 2017; 2008). Whereas poverty previously was primarily defined in terms of a single monetary dimension, such as income, an increased recognition of the complexity and multidimensional characteristics of poverty has resulted in poverty measures taking into account non-monetary dimensions. There are currently many ways in which poverty is understood and that drives the way it is also analysed; for example, it could be defined as an absolute condition to meet the basic needs of survival or as a relative condition based on capability deprivation between groups (Loewen 2009). This study does not analyse poverty in each of its components and conditions; however, we aim to find the relevant aspects of poverty that need to be considered when evaluating water management strategies. We thus used Sida's multidimensional poverty analysis framework<sup>4</sup> to identify patterns of poverty and the structural constraints within the water resources domain. The Sida framework first analyses "who" is poor by exploring different dimensions of poverty in terms of individuals' opportunities and choice, power and voice, human security, and resources. The framework also analyses "how & why" poverty exists in a particular society by examining the different structural factors and contexts that influence poverty: political and institutional, economic and social, environmental, and conflict and peace (Figure 2).

**Figure 2.** This Sida model illustrates the four dimensions of poverty (inner circle) and the four structural and contextual factors explaining why people are poor (outer circles) (Sida 2017).



#### 3.1 Poverty dimensions of water

Examining the *dimensions* of poverty allows a closer look at who is poor and in what way (SIDA 2002). For this work, we first defined the relationship between the dimensions and water issues, and then developed a set of water-related indicators to observe how these performed under different conditions. The set of indicators were narrowed down from a wide set of possibilities based on available data and relevance. They constitute an initial and partial exploration of conditions inside the watershed and their connection to poverty.

**Resources:** This dimension concerns the access one has to the resources (material and non-material) that sustain a decent living standard, meet basic needs and improve one's life (SIDA 2017a). SEI focused on the urban water demands, as they represent the majority of the watershed's population and are given higher

<sup>4</sup> <https://www.sida.se/contentassets/f3e30b6727e8450887950edb891c05af/22161.pdf>

priority in terms of allocation in Colombian law. In the Campoalegre watershed, this was tested by looking at the capacity of the system to supply water to the urban sector. SEI also focused on the location of urban demands, as some may receive better water coverage due to water availability and site-dependent infrastructure.

**Opportunities and choice:** This concerns the available opportunities to develop and/or use resources to move out of poverty. It assesses access to education, health clinics, infrastructure, energy, markets, and information (SIDA 2017b). Based on the information available in the Campoalegre watershed, this was evaluated by analysing the water infrastructure constraints in providing water to all users in the watershed.

**Power and Voice:** This concerns the ability of people to articulate their concerns, needs, and rights in an informed way and to take part in decision-making – either by having the ability to shape decisions or by being heard (SIDA 2017a). This dimension is harder to connect to a water access indicator. For the case study, we focused on access to land, which increases people’s capacity to shape decisions about resource allocation. An analysis of distribution of land and population shows who has power (in this case, a few large landowners).

**Human Security:** Violence and insecurity constrain the ability of individuals and groups to exercise their human rights and to find paths out of poverty, and in turn, poverty generates the conditions for violence and insecurity (SIDA 2017a). In this dimension, we focused on paths out of poverty that come from having access to resources and income that are above basic needs. This was determined by using the family food basket as the baseline economic level for human security conditions.

### 3.2 Poverty contexts and their connection to water

The outer circle of Sida’s MDPA provides an explanatory framework for the degree and dimensions of poverty (or the “why”). By assessing the developmental contexts, the framework aims to identify the opportunities and constraints for inclusive and sustainable development, as well as for people living in poverty to change their situation (Sida 2017).

In Campoalegre, SEI connected these developmental contexts specifically to the conditions in the watershed.

**Environmental Context:** Natural resources availability directly impacts poor people. Those in poverty are more vulnerable to impacts of climate change and environmental deterioration or changes, such as loss of biodiversity, soil degradation, pollution, drought, and floods (Field et al. 2014; SIDA 2017a).

**Social and Economic Context:** Reducing poverty through economic growth is easier in countries with an equitable distribution of resources (land, capital, enjoyment of human rights, education, etc.) than in countries with a highly unequal distribution (SIDA 2002; United Nations 2018). Therefore, efforts to build economic growth must happen in tandem with tackling existing inequalities. Most of the world’s poor live in rural areas where agriculture is the main income source (Field et al. 2014). Institutional support and regulatory frameworks to support economic growth need to understand the development challenges in agriculture, including the challenges of accessing water in order to maintain production.

**Political Context:** A focus on democracy and human rights can translate poor people’s needs into rights, and affirms individuals as active subjects and stakeholders. All levels of decision-making (national, sub-national, district, local) should include participation and freedom of expression as this creates the space to exercise human rights. Unequal power relations and exclusionary practices, by contrast, accentuate poverty (Moncrieffe 2004). This applies to water management; participation of stakeholders in decision-making processes about water resources is key to ensure shared benefits from water access.

**Peace and Conflict Resolution Context:** Conflict in Colombia negatively impacted national public investment, including those related to water. However, this study does not deeply explore the connection between this context and watershed conditions.

## 4. Analysing multiple poverty dimensions using WEAP

Data and information for the development of the WEAP model was obtained in collaboration with key stakeholders from the local environmental institutions (CARDER and CORPOCALDAS), energy company (Central Hidroeléctrica de Caldas – CHEC) and university (Universidad Nacional de Colombia – UNAL). The project lasted eight months, during which SEI worked closely with these groups, interacting via e-mail and holding four workshops. These interactions enabled both data sharing and the validation of the model. These organisations also provided input on the development of future scenarios based on their knowledge about future conditions and the policies that they are currently considering.

The WEAP modelling tool uses existing environmental, economic and social data to obtain an accurate representation of a watershed. We developed a Campoalegre WEAP application that contains a representation of the current water requirements and hydrological processes in the watershed. We used a calibrated version of this application to evaluate a list of scenarios based on potential risks related to climate, population growth, and water distribution priorities from key stakeholders. In addition, we used this model to examine the impacts of new policies to reduce water losses. The expectation is that reducing water losses could mitigate potential water shortages by more efficiently distributing water and, hence, contributing to more equitable access. WEAP's scenario tool was used to evaluate an ensemble of 32 scenarios based on the combinations of the projections described in Table 3.

**Table 3: Projections used in scenario ensemble analysis**

Policy Option Considered	Climate Impacts on water supply
1) Current Management 2) Reduction of water loss	1) Historical 2) IDEAM <sup>5</sup> 3) Dry 4) Very Dry
Population Growth Projections	Water Access Inequality
1) DANE's projection <sup>6</sup> 2) Alternative projection <sup>7</sup>	1) Based on proximity to water sources 2) Based priority by law

*The scenario ensemble analysis was composed using four aspects: 1) the potential policy to reduce water losses in the system, 2) climate uncertainty and its impact on water supply, 3) population growth, and 4) water access inequalities based on people proximity to water sources. The number of scenarios results from all the possible combinations of these projections (2\*4\*2\*2 = 32).*

Despite some data gaps and a lack of detailed information on water use, we were able to incorporate variables that help identify the contexts of the watershed and associate them with the dimensions of poverty (Sections 4.1 and 4.2). The water-related poverty dimensions also included demographic and socio-economic data from government databases that was validated by the key stakeholders in the final workshop. Table 4 shows aspects considered in the analysis of water resources and the aspects evaluated to inform poverty reduction efforts.

We analysed the data and communicated the selected metrics to key stakeholders by using a visualisation application called Tableau. An interactive visualisation of the complete analysis can be accessed at <http://bit.ly/campoalegre>. This dynamic view of the data contains all the WEAP results examined related to water resources analysis and the application of the MDPA framework. The next few sections of this paper highlight a few of the results related to poverty and equality.

<sup>5</sup> Institute of Hydrology, Meteorology and Environmental Studies, <http://www.ideam.gov.co/>

<sup>6</sup> National Administrative Department of Statistics, <http://www.dane.gov.co/>

<sup>7</sup> The alternative projection for population growth was based on increasing DANE's estimate of population growth for each city by 50%

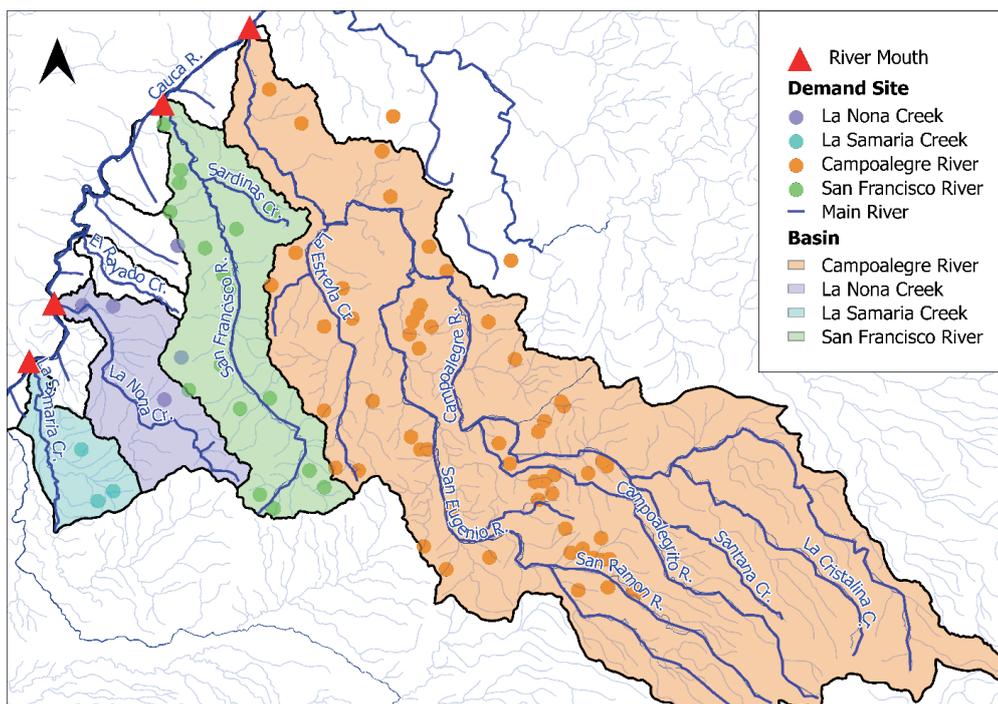
Table 4. Analysis of Water Resources and Poverty Dimensions in Campoalegre

Poverty Dimension	Parameters and indicators analysed	Findings
Resources	Climate change impacts on river flows (using national model or downscaling of global models). Ability of the system to provide access to water to all social groups located in various places in the watershed.	Water transfers between watersheds have the principal human impact. Water law ensures that human consumption should be the first priority in distributing water; however, communities located in remote places may not have access to water.
Opportunity and Choice	Consideration of water infrastructure constraints – to evaluate satisfaction of human and agricultural water demand – by creating design capacity variables (DCI and IWS shown in results below)	Evaluation of water supply shows that some regions face water shortages that could worsen in the future because of changes in climate and population growth.
Power and Voice	Distribution of agricultural area, number of farms, their size and property size categorisation.	A large number of small coffee growers are located in remote areas with limited water access. Under the current conditions, it is impossible to obtain information on water access for all families.
Human Security	Relationship of land distribution and income from coffee growers.	Because of the distribution of land in small parcels, coffee growers are unable to produce enough income to sustain basic human needs.

#### 4.1 Disaggregating water demand to ensure water access for all

A common metric to evaluate water stress levels in Colombia is the Water Use Index (Índice del Uso del Agua – IUA). This metric is based on aggregated values of water demands and available water supply at the river mouth, which in these basins has larger water flows than upstream locations. The red triangles in Figure 3 show the river mouths for the four basins evaluated in the Campoalegre watershed. The IUA estimates water demands for each river basin as the sum of all demands in that basin (shaded areas in orange, green, purple, and blue). Therefore, the metric used to estimate water stress “hides” the differences in water access occurring at a finer scale. For that reason, we chose to develop a more refined index by disaggregating the water demands in each basin (coloured nodes per basin) to show water

Figure 3. Delineation of aggregated values of demand and supply for the estimation of the Water Use Index (Índice del Uso del Agua – IUA).

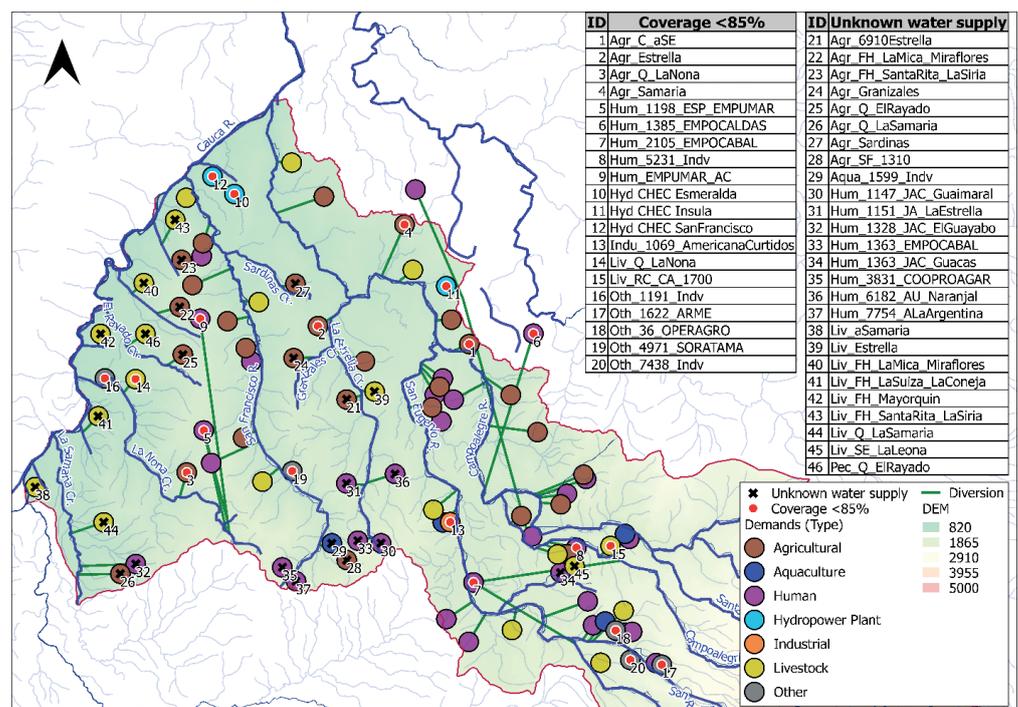


extraction levels at each demand site. These sites include cities, as well as grouped demands in various parts of the watershed related to agriculture, aquaculture, recreational and industrial water uses, livestock activities, and hydropower stations. This disaggregation is important in understanding the potential impacts of population growth and climate change on water supply for the different urban and agricultural areas.

For each demand in Figure 3, water supply is based on the river flows at the water extraction points, which depends on the hydrology and the current infrastructure distributing water. Water demands for human consumption were estimated based on the water utility that provides the water and per-capita water use. Water for energy was estimated based on the installed capacity of existing power plants; water for agriculture was estimated based on land cover and its water requirements. Agricultural area is 24% of the total area of the watershed. Most of the agricultural area corresponds to coffee production. Coffee requires water for in-situ processing before being transported for commercialisation; water demand for traditional coffee processing was thus included as an agricultural water demand, at 40 litres per kilogram of coffee. Other demands – such as those from the recreational and industrial sector – were estimated based on statistics provided by the environmental authorities.

In the process of creating a representation of the watershed in WEAP, with the disaggregated demands, we were able to predict with a degree of confidence (within +/-10%) the water demand and supply for the sites where observed streamflow data existed. For the demand sites with no observed streamflow data (remote places with small river flows), the estimates of water supply and demand included assumptions that cannot be corroborated with solid data. For 15% of all demand nodes, 85% of total water needs are not met (shown in Figure 4 as nodes with red dots). For 28% of all demand nodes, it was not possible to estimate water coverage because of lack of data (shown in Figure 4 as nodes marked with an “X”). Therefore, these nodes – which represent mostly livestock, agriculture, and people living in rural areas near the headwaters of small streams – have a higher degree of uncertainty in the estimates. As such, it is not possible to know whether they have access to appropriate water levels. The equality issue highlighted here is the information gap between the urban and rural areas, particularly for rural communities that are farther away from the large urban centres.

Figure 4: Demand nodes represented in the model



The colours in the circle represent the water use type. Nodes with an 'X' have no data to verify estimates of the supply and demand. Nodes with a red dot have less than 85% water demand satisfaction.

In order to analyse which social groups have water shortages, water demand information was also disaggregated by water use type for the entire watershed (represented by demand node colour in Figure 4). The demands represented in the model correspond to: agricultural (coffee production or pasture), aquaculture, human consumption, hydropower, industrial, and livestock.

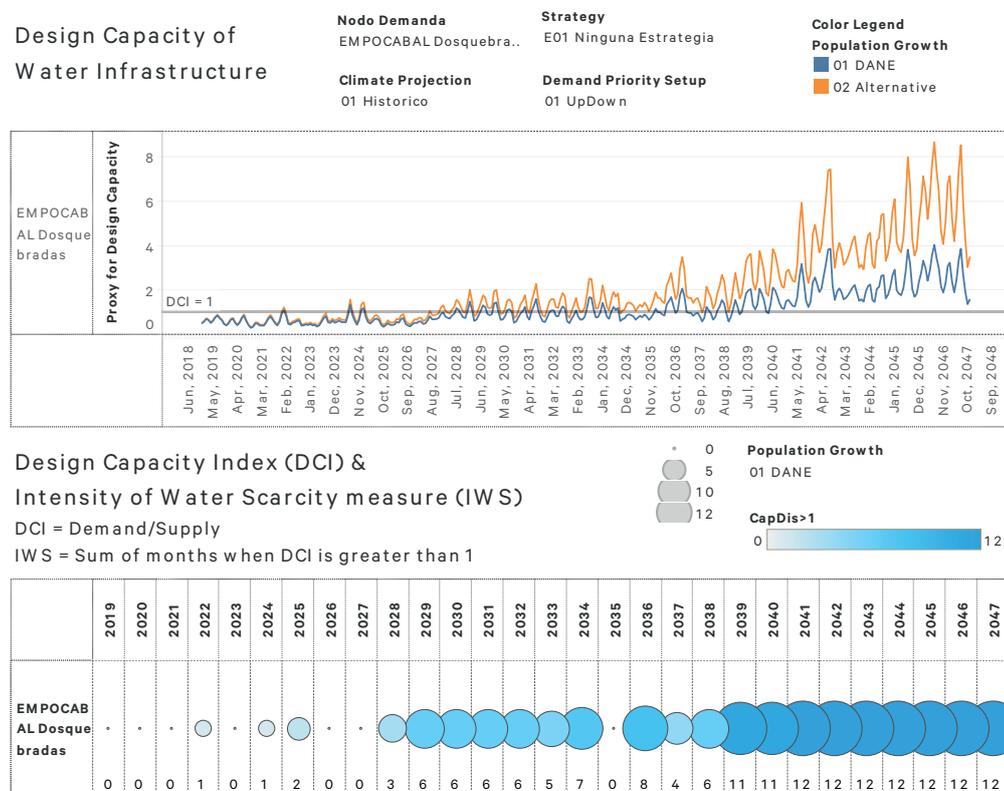
### 4.2 Reliable water access for human consumption

Water for human consumption is given the highest priority under Colombian law, and thus our analysis looked at water access for human consumption (purple nodes in Figure 4). In this section, we examined the main four urban centres in the watershed. Three of those centres have water coverage of less than 85%. These are Empocabal, Empocaldas and Empumar, shown with the respective IDs of 7, 6, and 5 in the table in Figure 4.

Water shortages not only depend on river flows at the point of water captured, but also on the capacity of the water infrastructure to distribute that water. In order to represent the current design of the water infrastructure, a new variable was created in WEAP, called the Design Capacity Index (DCI). This variable models the physical capacity of the infrastructure to distribute water to urban centres with growing demands. The DCI is calculated as the water required by urban demands divided by the capacity of the aqueduct to supply that water. The estimation of these values depend on the considered population growth, water losses, per capita water use, and water consumption patterns included in WEAP.

The DCI was evaluated under two projections of population growth, as shown in the top graph of Figure 5. This graphic was designed using the Tableau Public platform, which allows an interactive exploration of the

Figure 5: Design Capacity Index (DCI) and Intensity of Water Scarcity (IWS)



Top: Design Capacity Index (DCI) for all urban nodes. A DCI of 1 means that the supply equals the demand. A DCI value of 5 means that the demand is 5 times greater than the supply.  
 Bottom: Intensity of Water Scarcity (IWS). This metric is estimated as the number of times per year the DCI is greater than 1, i.e. a shortage occurred on that month. In mathematical terms: IWS = SUM (DCI Occurrence). DCI Occurrence = if DCI > 1 then 1 else 0.

scenarios evaluated. The DCI acts as a proxy of water shortages because of the lack of capacity to satisfy the different urban demands; a DCI greater than 1 means a water shortage. The bottom graph in Figure 5 shows the Intensity of Water Scarcity (IWS), which sums the number of times (i.e. number of months) the DCI is greater than 1 for each year. As population increases, the capacity of the current infrastructure to supply water to its inhabitants decreases, showing that the difference between IWS and 1 becomes greater as it approaches 2050.

### 4.3 Water access for coffee production

The main crop produced in this region is coffee. Coffee producing areas are represented in WEAP as agricultural nodes (brown nodes in Figure 4). As mentioned previously, the main water use for coffee production is in the processing after it is harvested. This is estimated to be 40 litres per kilogram of coffee. In this region there are two coffee harvests, one in April-May and another in November-December. Throughout an entire year, there are 30 days where water demand peaks for coffee production. Each hectare of land can produce about 1,000 kg of coffee. On average, water demands for processing coffee is 0.87 cubic meters per second.<sup>8</sup> Therefore, on average, the watershed has the capacity to cover these demands. However, there is no data on whether all of the water demands and its distribution networks can actually cover that demand (as presented in Figure 4, brown coloured nodes with “X”), and thus it is not possible to assess whether this amount of water is available throughout the watershed. Because the current land distribution contains thousands of small plots, it is hard to know if these plots have direct access to water. This makes water management complex, as it requires coordination between a great numbers of land owners – in this case 4,296.

### 4.4 Unequal land distribution

The unequal distribution of land is a key issue that causes inequalities that generate conflict (Gillin 2015). Integrated rural land reform is a pivotal issue in the Colombian peace agreement and consists of identifying mechanisms and programs for producers without land or with insufficient land. Figure 6

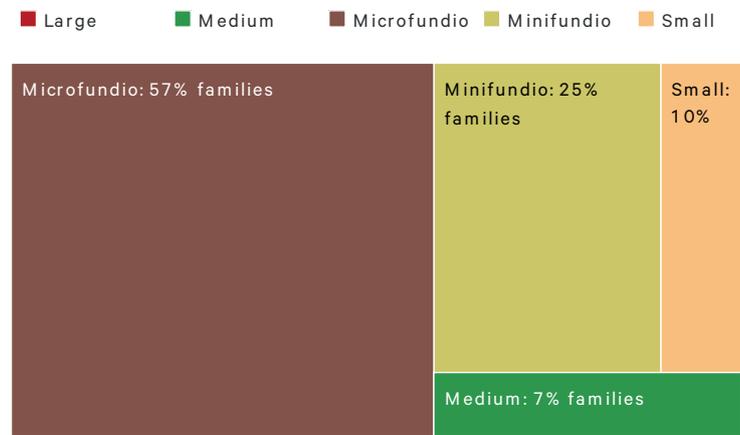


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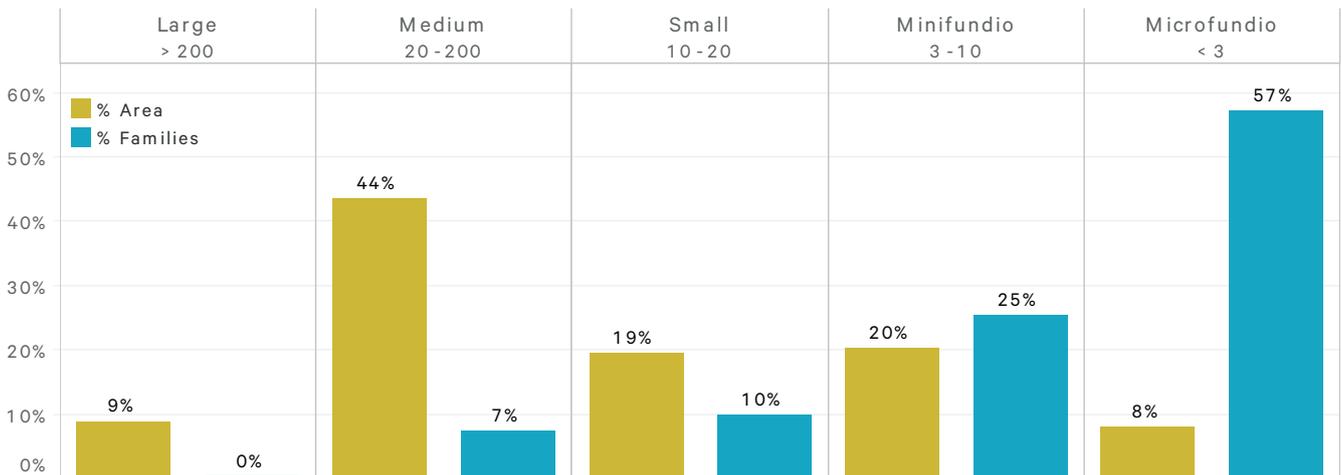
<sup>8</sup>  $56,773 \text{ hectares} \times 1000 \text{ kg/hectares} \times 40 \text{ litres per kilogram} / 1000 \text{ litres per cubic meter} / 30 \text{ days} / 86,400 \text{ seconds/day} = 0.87 \text{ cubic meters per second.}$

Figure 6: Land distribution

Distribution of land and people  
Percentage of area and of families per land size type



Property	Size (ha.)	# Families	Ha. (total)
Large	> 200	8	3,229
Medium	20 - 200	382	16,056
Small	10 - 20	518	7,150
Minifundio	3 - 10	1,315	7,439
Microfundio	< 3	2,981	2,989

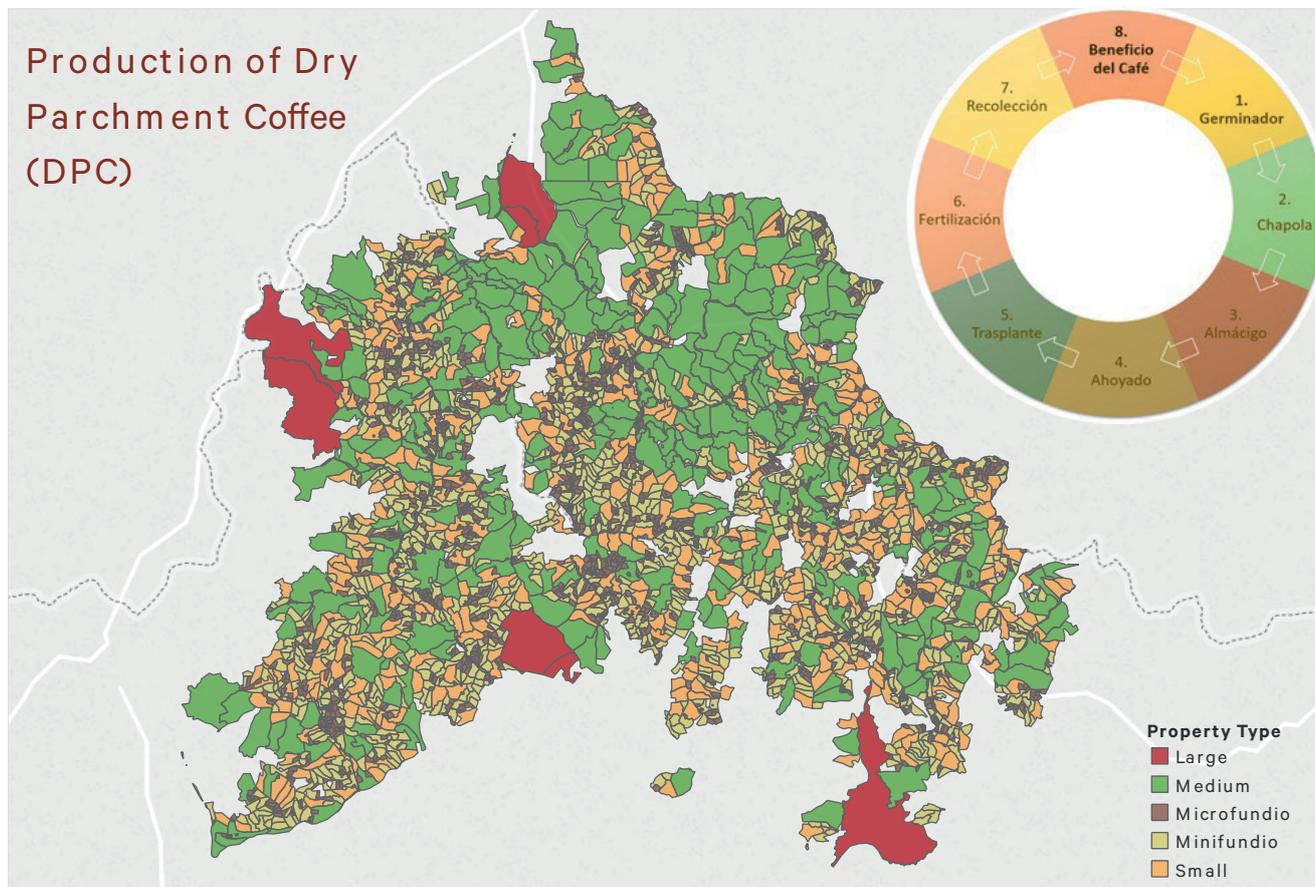


The graphic in the top left shows the percentage of total families on each property size. The table at the right shows the type of property, the corresponding size, the number of properties and the total hectares occupied. The lower graphic summarises the different property types in relation to total area and total number of families in the Campoalegre Basin.

describes the land distribution based on farms (microfundio, minifundio, small, medium, and large). The top graphic shows that a large percentage of the agricultural area are farm sizes of less than 3 hectares (microfundios). Those farms are home to 2,981 families, or a little over half of the population. The table on the right shows the classification criteria for the farm types, the corresponding hectares, and the number of families living within each type. The bottom graph in Figure 6 summarises this information by showing that 57% of the families in the rural areas live on less than 8% of the land, in microfundios of 3 hectares or less.

While this information was used to represent agricultural areas in the WEAP model, the analysis presented above on land distribution was developed outside of WEAP. Nonetheless, this information has implications for water access and its management. Such a large number of small farms makes it difficult for the government to enforce water use and wastewater management, as it is impractical for officials to inspect all these sites with regularity. In order to visit all sites in one year, the government’s environmental authority – in this case CORPOCALDAS and CARDER – would need to deploy a field team to visit 12 farms daily for an entire year, which is impossible given the required time and resources. This is an impediment to obtaining water use information, as well as the water quality information that is one of the main environmental concerns of coffee production. Creating incentives for farmers to use clean

Figure 7: Production data for dry parchment coffee



Production of Dry Parchment Coffee		Net Annual Income		Poverty Line:	
<b>Revenue from DPC (max) per ha, per year:</b>	6,560,000	<b>Property of 3 ha:</b>	720,000	<b>Family Basket (4 people/year)</b>	3,960,000
<b>Production Costs of DPC per ha, per year;</b>	6,320,000	<b>Property of 10 ha:</b>	2,400,000	<b>Minimum Annual Wage</b>	9,374,904
<b>Net Income per ha, per year:</b>	240,000	<b>Property of 20 ha:</b>	4,800,000		

This map shows the location of the types of properties. The colour of the properties corresponds to the farm size. The top right image describes the production stages for coffee, and the tables at the bottom provide estimated production and income data correlated with farm size and poverty indicators.

technologies becomes an affordability issue, since coffee production on small plots make it difficult to afford capital investments.

### 4.5 Coffee production costs and income

WEAP contained information on the water requirements for processing coffee, which is when most of the water is needed. But in order to address the socio-economic problems related to poverty, the analysis on coffee production was expanded to include information outside of the WEAP model related to coffee production costs and farmers' income.

After the coffee fruit is harvested, most rural families in the watershed work on the production of dry parchment coffee. This method of processing coffee beans includes removing the pulp and mucilage of the cherry and then washing and drying the beans until they reach a 12% humidity level.<sup>9</sup> Figure 7 shows the location of farmers with large, medium, small, minifundio, and microfundio farms. Obtaining cost and income data from coffee production in the region was nearly impossible, though we know that there were high poverty levels in the coffee region based on feedback from local authorities. Through an interview

<sup>9</sup> In the wet process, the fruit covering the seeds/beans is removed before they are dried. Coffee processed by the wet method is called wet processed or washed coffee.[3] The wet method requires the use of specific equipment and substantial quantities of water.

**Figure 8. Net income for producers owning 3, 10, and 20 hectares of land, compared with the annual cost of a family food basket.**

### Estimated Net Revenues for an average family in the region



with a local producer, we were able to get a rough estimate of the cost of production and the income level per hectare of dry parchment coffee, which gave us some indication of the poverty levels.

The estimated cost of a rural family food basket – or the cost of food for a family of four – is COP 3,960,000 (USD 1,400). Figure 8 compares that with the estimated average net incomes of farms of different sizes. It shows that the estimated net income per hectare for producers with farms of 3 to 10 hectares is below the cost of the family food basket. In other words, 82% of the rural families in the watershed do not have sufficient resources to pay for food.

People unable to cover their basic human needs are unable to afford water fees, and therefore tend to use informal ways of accessing water, causing health problems to adults and children (WHO and UNICEF 2000). In addition, they are unable to implement waste-water technologies that can reduce the amount of water contaminants caused by the production of dry parchment coffee.

## 5. Discussion and conclusions

This case study shows how an integrated water resources management analysis can be adapted and applied to gain insights on multiple dimensions of poverty. It uses Sida's multidimensional poverty analysis framework, a powerful conceptual tool that helps practitioners go beyond the simplistic poverty metrics (such as per capita income) and provides a useful structure for engaging stakeholders in developing more effective poverty reduction strategies.

A more in-depth understanding of poverty and its complexity is also key for countries to design more efficient poverty and inequality measures. This is key for countries like Colombia to be able to deliver on its commitments under Agenda 2030 to eradicate poverty in all its forms and leave no one behind. By defining indicators that measure the economic implications of varied water access in the region, we were able to examine the key developmental contexts that cause inequality and conditions for conflict. The inequalities identified in this watershed relate to water infrastructure, data availability about water demands and supply, land distribution and access to water, and coffee income by land size. Highlighting these inequalities can help identify solutions to address them. These indicators, produced in the context of water management, can help water managers identify priorities for providing access to water and reducing inequalities in the watershed. Decision-makers, including the government's environmental authorities, actively participated in this study. Their data sharing, feedback and input was crucial.

The peace process also provides an opportunity to address issues of equality. The 50-year-old conflict arose in part from inequality, so the peace agreements are targeted towards reducing the inequalities that generated the conflict. Comprehensive rural reform will help reduce the inequality touched on in this study. The existing unequal land distribution not only creates economic challenges – as illustrated by the data showing that 82% of the population has plots too small to sustain a family; it also creates a water governance challenge. Some of the rural reform measures could improve economic conditions for small farms by improving access to markets and adding value to coffee production with designation of origin. It could also help organise, and therefore make visible, water users located in isolated “microfundios” and “minifundios”. This could ensure that the government's environmental authorities are better able to attend to their needs. Studies have also shown that the presence of conflict has reduced agriculture productivity (Pinilla 2017), with small producers being the most affected. The end of conflict could therefore have a positive impact on productivity in Campoalegre, which would improve the local economy. In turn, this could lead to population growth and the improvement of infrastructure to accommodate such growth. Many studies have detailed the economic benefits of the peace agreement. Campoalegre suffered the effects of the conflict but is now a relatively stable economic region. The peace agreement provides an opportunity to improve the conditions in this watershed, to reduce inequities and to create paths out of poverty. Improved water governance, better access to information about water use and demand, and enhanced planning of water infrastructure for future growth will be key to sustaining a positive change in Campoalegre.

One of Colombia's key environmental regulation processes – El Plan de Manejo y Ordenamiento de una Cuenca (POMCA), or the Plan for the Management and Regulation of a Basin – is currently in its planning phase in the Campoalegre Watershed. This provides the possibility to incorporate the results of this analysis into this planning process, as well as others, such as the regional Water Resources Management Plans (PORHs). Decision-makers also highlighted the importance of integrating indigenous communities of the Suratena and Altamira reservations in Marsella into future processes and analyses. This will require data that currently doesn't exist, collected via surveys, in order to understand the water use, needs and patterns of these communities. This data could be incorporated into the watershed context and highlight potential dimensions of poverty that may affect these communities. To design effective policies, it is key for policy-makers to have a sufficient understanding of how the various dimensions of poverty and deprivations are experienced by different communities.

In conclusion, this study demonstrates that there are many opportunities to connect water management with equality considerations by exploring the context and dimensions of poverty. Water management is complex, and the inequalities that occur at the watershed scale may be overlooked in the pursuit of solutions for more salient problems. Water managers can use innovative indicators – such as the ones presented here – to highlight the various needs of the people living within the watershed. This could

help ensure equitable water supply conditions and contribute to the reduction of poverty. Illuminating the social while studying the physical is challenging but critical. Failing to analyse how to narrow social inequalities in the implementation of water resources strategies could reinforce existing inequalities and inhibit the impacts of poverty reduction efforts.

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**SEI Stockholm  
and SEI HQ**

Linnégatan 87D Box 24218  
104 51 Stockholm Sweden  
Tel: +46 8 30 80 44  
info@sei.org

---

**Louise Karlberg**  
Centre Director

---

**SEI Africa**

World Agroforestry Centre  
United Nations Avenue  
Gigiri P.O. Box 30677  
Nairobi 00100 Kenya  
Tel: +254 20 722 4886  
info-Africa@sei.org

---

**Stacey Noel**  
Centre Director

---

**SEI Asia**

15th Floor Witthayakit Building  
254 Chulalongkorn University  
Chulalongkorn Soi 64 Phayathai Road  
Pathumwan Bangkok 10330 Thailand  
Tel: +66 2 251 4415  
info-Asia@sei.org

---

**Niall O'Connor**  
Centre Director

---

**SEI Tallinn**

Lai str 34 10133  
Tallinn Estonia  
Tel: +372 627 6100  
info-Tallinn@sei.org

---

**Lauri Tammiste**  
Centre Director

---

**SEI Oxford**

Florence House 29 Grove Street  
Summertown Oxford  
OX2 7JT UK  
Tel: +44 1865 42 6316  
info-Oxford@sei.org

---

**Ruth Butterfield**  
Centre Director

---

**SEI US  
Main Office**

11 Curtiss Avenue  
Somerville MA 02144-1224 USA  
Tel: +1 617 627 3786  
info-US@sei.org

---

**Michael Lazarus**  
Centre Director

---

**SEI US  
Davis Office**

400 F Street  
Davis CA 95616 USA  
Tel: +1 530 753 3035

---

**SEI US  
Seattle Office**

1402 Third Avenue Suite 900  
Seattle WA 98101 USA  
Tel: +1 206 547 4000

---

**SEI York**

University of York  
Heslington York  
YO10 5DD UK  
Tel: +44 1904 32 2897  
info-York@sei.org

---

**Lisa Emberson**  
Centre Director

---

**SEI Latin America**

Calle 71 # 11-10  
Oficina 801  
Bogota Colombia  
Tel: +57 1 6355319  
info-LatinAmerica@sei.org

---

**David Purkey**  
Centre Director