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Informal Irrigation in the Colombian Andes: Local Practices, National Agendas, and Options for Innovation

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Knowledge about the extent of irrigated land in Colombia is scarce because most irrigation is done informally and therefore not registered. Informal irrigation in Colombia has not been investigated, its national presence has not been identified, and its characteristics are still unknown. The present article aims to help fill this gap. Because of topographical and agricultural patterns, Andean informal irrigation is impossible to identify or characterize using standard methods. To provide information on the scale of informal irrigation systems in Colombia, their type, the users they serve, and the type of water sources they use, a large-scale partial inventory was made combining statistical analysis, questionnaires, interviews, and field trips. The findings indicate that informal irrigation is widespread in the country's mountainous zones, in a great diversity of environments, characterized by an equally great diversity of local uses and water-use strategies. This diversity has resulted from the coexistence of very different community and state institutions, posing challenges for planning and organizing water-resource management more efficiently and sustainably for producers, the government, and other stakeholders.

Keywords: *Informal irrigation; Colombia; household farming; production strategies; Andes.*

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Introduction

In the Andes there is widespread irrigation (Zimmerer 2010) and a long tradition of local water management (see, for example, Morlon 1996; Zimmerer 2000; Trawick 2003; Branch et al 2007; Robles Mendoza 2010), which had begun by 1550 BC (Zimmerer 1995). According to Trawick (2001: 363), the irrigation systems in the Andes have been through three historical processes: (1) the establishment, in pre-Hispanic times, of methods that attempted to manage a scarce resource; (2) a massive reduction of water and soil use during the colonial era; and (3) a gradual reintensification as part of the green revolution.

Since late 1970s, the expansion of irrigated agriculture in the tropical Andes has been encouraged by lower prices for irrigation technology; local producers' integration with market dynamics; the subdivision of land, which forces farmers to establish more productive farms through intensification; and the introduction of new cash crops (Dinar and Keck 1997; Forero Álvarez 1999; Angeliaume-Descamps and Oballos 2009) as an important source of income. This is especially true of fruits and vegetables grown for urban markets; two examples are tomatoes in Fómeque and Villa de Leyva, Colombia, which are mainly grown for Bogotá markets, and garlic and lettuce in the Merida highlands of Venezuela, which are mainly grown for Caracas and Maracaibo markets. Another key factor in the expansion of irrigated agriculture is the introduction of green revolution technologies (Zandstra et al 1979; Tulet 2002; Forero Álvarez 2009).

Along with the tendency toward increasing irrigation areas through large-scale and technically supported irrigation, a high number of small-scale producers and some medium- and large-scale producers have established what is called "informal irrigation," which the Food and Agriculture Organization (FAO 2012) defines as "schemes under local responsibility, controlled and operated by local people in response to their perceived needs. In many areas with potential, farmers have attempted to enhance food production by introducing some forms of irrigation. These schemes are often ad-hoc and therefore not reported."

Simultaneously with the expansion of irrigated areas, there has been a tendency in the Colombian Andes to introduce new arrangements for water-resource management. As a result, there have been conflicts regarding water governance because both informal and formal arrangements create competition over water resource use, and the collective resource is used to circumvent the traditional paths of water governance. To address these conflicts, there is a need for systematized knowledge about the location and spatial extent of

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irrigated areas in the Andes and the nature of the management systems used. Despite the strong presence of informal irrigation in the Colombian Andes, no systematic study of the phenomenon has been carried out so far; this is one of the goals of the present study.

There are methodological challenges to mapping and understanding informal irrigation in Colombia. It is known that irrigated agriculture in the tropical Andes is disseminated on a diffuse strip located between 1000 and 3500 m above sea level (Zimmerer 2010), where the climate and environmental conditions are favorable for agricultural production, and that its presence has transformed the landscape (Le Goulven and Ruf 1994). But because of the varied terrain, mountain irrigated agriculture is dispersed and difficult to monitor (Trawick 2003). This makes a combined approach necessary when measuring informal Andean irrigation: satellite image analysis, although useful as a preliminary approach, does not provide satisfactory results (Gutiérrez-Malaxechebarría et al 2013); statistical data are not completely reliable; and asking farmers, while useful, is not sufficient in itself, for reasons discussed later. A combination of approaches was thus used in this study to explore the different scales and types of irrigation systems, the users they serve, and the type of water sources they use.

The aim of the present study was to understand informal irrigation both at local and larger scales in the Colombian Andes and to derive evidence-based information that will benefit irrigation communities and other stakeholders, such as government agencies and neighborhood communities, who need to know about informal irrigation characteristics in the Colombian Andes so they can plan systems and build more sustainable water governance at the local level. Because informal irrigation exists on most tropical mountains, the methodology used may also help to support efforts to make water governance more sustainable in other mountain regions around the world.

Informal irrigation can be analyzed in various contexts, identified in different ways, and given different names. The following section reviews current approaches to the topic. This is followed by discussion of the mixed methods used in this article to find, document, and analyze informal irrigation, both in case studies and at the broader departmental scale. Finally, the results and discussion show how widely informal irrigation is distributed in the Andean parts of Colombia and what its particularities are.

Informal irrigation: a literature review

The first study of informal irrigation that included a definition of the term was the study by Cornish et al (1999), conducted in Kenya and Ghana, followed by the studies of Cornish et al (2000) and Hide et al (2001). Studies on this topic have also been carried out in West Africa (Drechsel et al 2006; Payen and Gillet 2007), sub-Saharan Africa (Watson et al 1998), a Malawian wetland (Chidanti-Malunga 2009), and Zimbabwe (Svubure et al 2011), the latter analyzing the relations between formal and informal irrigators. Informal irrigation has also been studied in Afghanistan (Anderson 2006) and Nepal (Rutkowski et al 2007). These studies show that informal irrigation uses different sources and water-delivery methods, takes advantage of growing urban markets, constitutes a strategy of improving livelihoods, is usually used in very small plots with intensive yields, and, in some countries, covers an area greater than the area under formal irrigation. Informal irrigation has also been studied in Bali by Lorenzen and Lorenzen (2008), who found that attempts to introduce formal institutions for water management led to confusion within the farming community.

Because informal irrigation is widely distributed around the world, it has been evidenced (but not necessarily studied) in a variety of other contexts—for example, relating to systems that use wastewater irrigation (Huibers et al 2004; Rutkowski et al 2007; Raschid-Sally 2010). It is sometimes called by other names: small irrigation (Palerm-Viqueira 2006); out-of-the-system irrigation, called *arrimantes* by Zimmerer (2010), and *hors casiers* by Brondeau (2004); unplanned irrigation; farmers' irrigation (Kumar et al 2006; Nabahungu and Visser 2011); and, the most common term in the case of the Andean countries, indigenous or peasant irrigation (Coward 1977; Norman 1997; Perreault et al 1998; Watson et al 1998; Bebbington 1999; Ruf and Mathieu 2001; Herrmann 2002; Trawick 2003; Boelens 2009).

The great variety of informal irrigation scenarios in the Colombian Andes includes different ways of creating new informally irrigated areas, very different topographical and climatic conditions, unreliable statistical data, multiple water governance strategies, and, usually, very small patches of irrigated lands distributed across very large regions. Therefore, to understand the national reality it is necessary to study different local experiences all around the country. Local informal irrigation experiences include homogenous groups or geographically similarly delimited groups of farmers with clearly identified irrigated agriculture strategies and patterns.

Methods

Selection of study zones

The departments and municipalities in which informal irrigation systems were most evident were identified. To do this, various national experts were interviewed and official statistics on cultivated areas analyzed, so that the most relevant zones could be identified for the production of 64 fruit and vegetable crops that, based on

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the research group's experience, most required informal irrigation. Information was collected in all the Andean departments except for Huila, using interviews, forms, and fieldwork. Figure 1 shows what municipalities were surveyed and what kind of information was collected.

Form filling

A form was designed to identify the characteristics of each zone that could be delimited geographically (according to departments, provinces, municipalities, and *veredas*, a political subdivision of rural municipalities) and that had relatively homogeneous socioecological characteristics corresponding to significant experiences in informal irrigation—for example, the Nasa indigenous group in the humid mountains of northern Cauca Department or peasant communities in the very dry Guanentina province of Santander Department, who have a century-old irrigation system). The forms were completed using the information provided by experts in structured questionnaires in the study zones, using a methodology similar to that used by Mulwafu et al (2003) in their study of water demand in Malawi. In the present study, some experts worked in government ministries or department secretariats of agriculture, were in charge of rural development in municipalities, or worked with regional environmental authorities; other experts were employees of universities, nongovernmental organizations, and businesses that commercialize consumables or agricultural products. A total of 28 forms were filled out between 2010 and early 2012, accounting for experiences in 94 municipalities in 10 Colombian departments; 92% of what are known as the Andean departments were thus covered. This did not cover 100% of the area of each department, as some departments have areas with non-Andean ecosystems (for example, parts of Antioquia are in the Caribbean and Magdalena Valley regions).

The information thus collected was entered into a database, where the value was registered for variables in the following areas:

- How farmers organize their agricultural production;
- Their social status, land ownership, and definition of typical agricultural arrangements;
- Organization of irrigation and technology used;
- Ways they access and transport water;
- Presence or absence of water-use agreements;
- Number of irrigators;
- Minimum and maximum average areas of productive systems in the identified zone;
- Irrigated area's percentage of total cultivated area and of total area.

Because the information collected referred to different scales, the association between the multiple variables was measured by Kendall's ranges nonparametric correlation coefficient. Two types of correlations were accepted for the analysis: those that showed significant correlations at 0.05 and those that showed significance at 0.01.

Interviews with regional experts

Semistructured interviews were conducted with regional experts, some of whom also provided information for filling the forms. The questions varied according to the interviewee's profile, which allowed for a focus on specific topics where appropriate. The interviews covered 143 municipalities, 94 of which were also reported on in the forms. Interviews focused on each zone's general agricultural characteristics and dynamics, commercialization strategies, irrigation history, and water conflicts and agreements. The information obtained from the interviews was registered in a logbook and then treated with the qualitative data analysis program Atlas Ti, based on grounded theory (Glaser and Strauss 1967), which enables the organization, analysis, and interpretation of qualitative data.

Fieldwork

The information reported in the forms and interviews was taken as a basis for field trips to 3 areas where informal irrigation is practiced and where its presence on mountain slopes has triggered the construction of specific socioecosystems, as defined by Gallopin (2003: 44)—systems composed of a combination of biophysical and human systems. Field trips took place in the following rural districts: Montebello and La Olga (Cali, Valle del Cauca), Las Hormas (Cajamarca, Tolima), and Susa (Fómeque, Cundinamarca), located in each of the 3 chains of the Colombian Andes, shown in red in Figure 1.

During fieldwork, direct observations and spontaneous conversations with local actors were followed by in-depth interviews with informal irrigators. The information was registered in a logbook and then analyzed with Atlas Ti. The information obtained during fieldwork made it possible to complete data, verify what the experts had said, and especially to understand terrain realities and informal irrigators' logic, motivations, and regional differences.

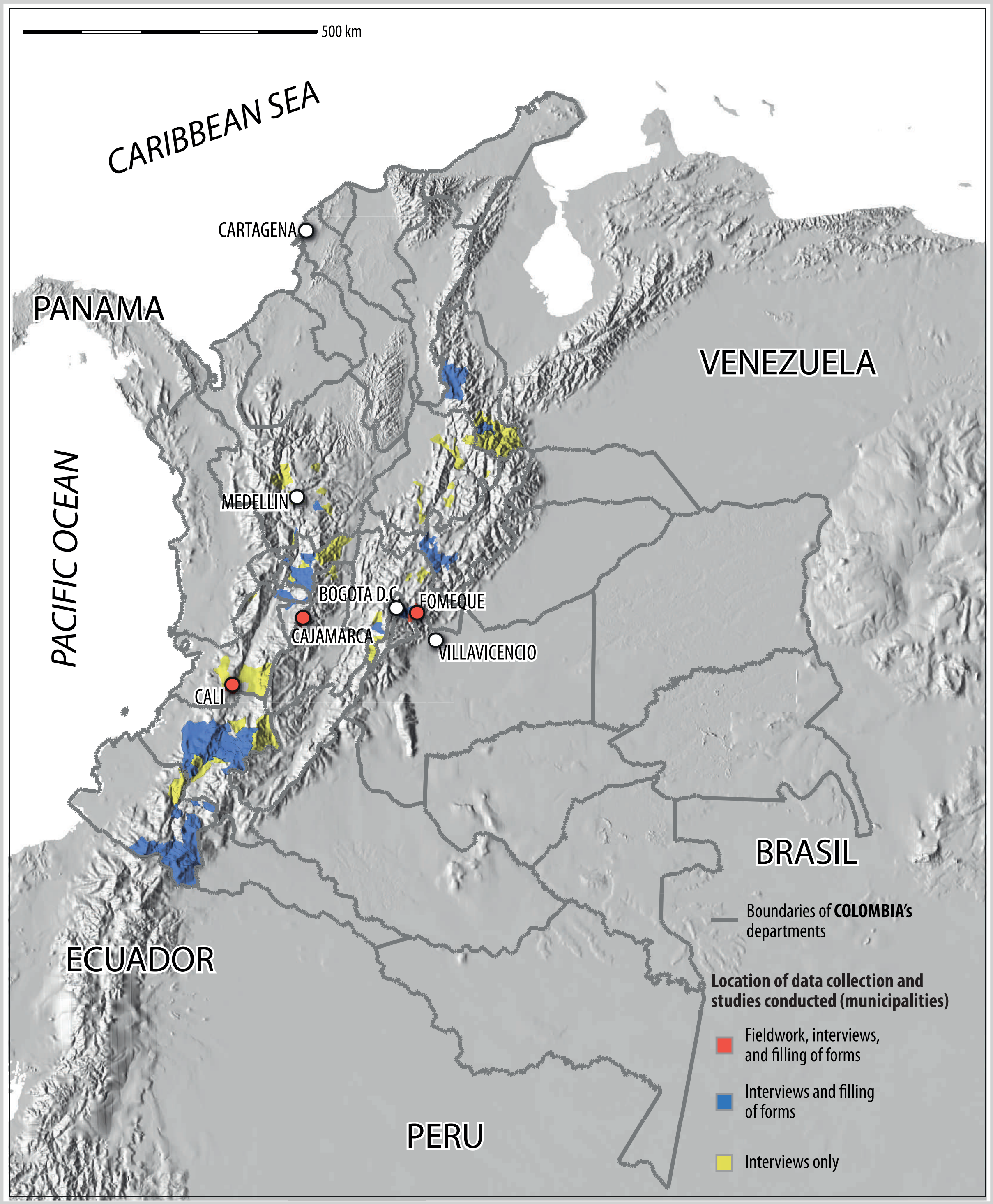
Results and discussion

This section presents the 3 case studies, which illustrate similarities and differences among informal irrigation systems. This is followed by the presentation and discussion of findings concerning the whole country. The section concludes with a redefinition of informal irrigation based on the findings of the study.

Case studies

Agriculture in these 3 zones has developed between 1500 m and 2300 m above sea level and is characterized by the presence of family farming, where informal irrigation plays an important role in the intensification of

FIGURE 1 How information was collected in each municipality under study. (Map by Juan Diego Giraldo Osorio)



agriculture using green-revolution methods; the systems have been directly implemented by the farmers, who designed them based on their own experience or the suggestions of equipment dealers. The 3 zones are strongly integrated with the market, as they are close to consumption or distribution centers and make good examples of what Forero Álvarez (1999) has called "intensification without mechanization." Water is

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transported through hoses, and the predominant irrigation mechanism is sprinklers.

Montebello and La Olga: The Montebello and La Olga *veredas*, located on the eastern slope of the western mountain range, specialize in the production of aromatic and medicinal herbs; these products are traded in Cali city, less than an hour away by car. There are also small poultry and mining operations in these districts. Water use is so varied that emerging conflicts have led the users to ask the state to regulate it.

Becuase of the low flow and multiplicity of users, serious restrictions of water use are common during the dry season, which has led to the emergence of informal agreements in the community; for example, access to water is allowed only 3 times a week (every other day). In order to use water more efficiently, the community turned to the environmental authority and were given micro-sprinkling systems for free. However, because of technological limitations, the systems worked poorly, and many of the users returned to traditional sprinklers.

In this zone, depending on how close the water sources are, there are collective and individual irrigation systems. By tradition, every family has the right to take water directly from a particular point in the river or stream.

Las Hormas: Las Hormas is a *vereda* belonging to the municipality of Cajamarca, Tolima, located on the eastern slope of the central mountain chain. It specializes in red beans, fruits, and *arracacha*, a root vegetable (*Arracacia xanthorriza*). This zone has a propitious climate for agriculture and fertile but highly erodible soils (Gutiérrez-Malaxechebarría 2011). It is close to the Pan-American Highway (which passes through the municipality), and Cajamarca is a center of production and distribution of agricultural products to the country's center and west.

The intensification of production, the incorporation of agrochemicals, and the fragility of the crops make it necessary to have irrigation systems that, although not used year-round as in the other 2 zones, support intensive production during the dry periods. In general, water collecting can occur inside a farmer's property or by means of agreements between neighbors or between small farmers and large-scale farmers whose lands are located in the high zones, where the streams have their sources; water is then transported through hoses to be released by sprinklers. Collective irrigation systems were not in evidence, probably because of the widespread availability of water.

Susa: The Susa *vereda*, in the municipality of Fómeque, Cundinamarca, is located on the eastern slope of the eastern mountain range. The road network allows easy access; it takes less than 3 hours to travel to big distribution centers in Bogotá and Villavicencio. Susa specializes in horticultural crops such as tomatoes, red peppers, and green beans.

Field observation showed that 41 of the 64 ha cultivated in the *vereda* (except for grass cultivation) are routinely irrigated, and that although there are pipes belonging to an irrigation district, they have never operated continuously. This is the reason producers have to provide their own informal irrigation systems, collective or individual, which take water from diverse sources, among which are springs on their own or their neighbors' farms, small nearby water courses, or streams with significant flow several kilometers away from their farms. Water access and permission for water networks to go through someone else's property are obtained through intricate and diverse agreements between family members or neighbors (Drouilleau 2010) and, in some cases, state authorities in charge of managing water. The informal agreements may vary over time, and excess demand generates conflicts, especially between users at lower and higher altitudes.

Irrigation technologies are varied; 3 systems are the most common: drip irrigation, used exclusively for tomato crops in greenhouses; sprinkler irrigation, used mostly for crops in open fields; and plant-to-plant irrigation, which consists of moving the hose around to irrigate each plant.

Generalized findings for the Colombian Andes

Origins and general characteristics: Unlike most of the agricultural areas in other Andean countries, in Colombia there is a relative abundance of water. This is why irrigated agriculture has developed only in relatively recent times and with the use of modern technology, and it is difficult to find evidence of ancient water-use arrangements.

Only 2 zones with ancient water agreements were found. Both are in dry forest ecosystems: the first in the Santafe area in Antioquia, where canals associated with the ancient haciendas still transport water for today's farms, and the second in Santander, where a local tradition of trading water access was reported—the farmers report having access to water sources such as springs or streams, with fixed schedules in some cases, because their grandparents or great-grandparents had bought the right to water from the owner of the land where the resource is located. Such agreements continue to be respected and can be sold or transferred to a third party. State authorities, however, ignore them.

Informal irrigation has increased since the 1970s because of the factors mentioned in the introduction. There is widespread informal irrigation in the Colombian Andes, especially in zones where there is intensive family farming, where the farmers own the land, on small-scale properties, and where access to large-scale consumption and distribution centers is easy—in other words, where the farmers have real opportunities to efficiently access

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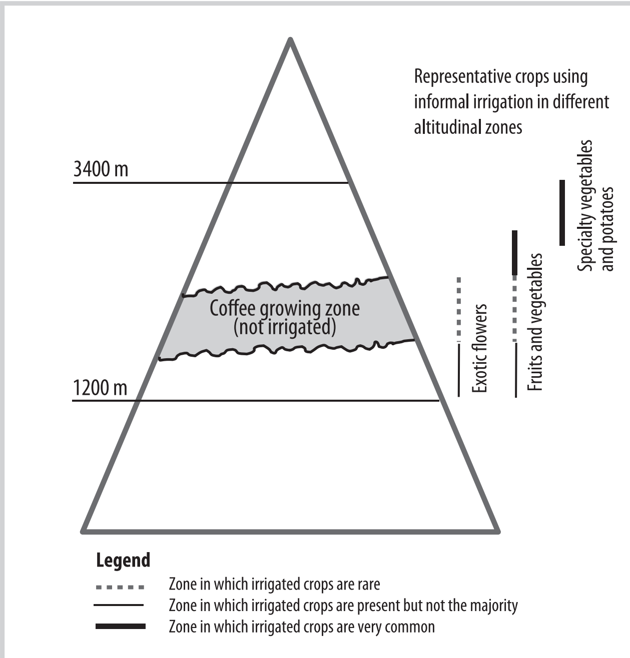
FIGURE 2 Altitudinal distribution of informal irrigation in the Colombian Andes



markets. Moreover, although there is irrigated agriculture at all altitudes, its presence is scarce in the strip where coffee is dominant, as coffee is grown in dry land (Figure 2).

These systems usually start on the farmers' own initiative; however, some nongovernmental organizations and state entities have indirectly encouraged them by promoting highly profitable crops such as strawberry and tomato, which require a reliable irrigation system.

Correlation analysis indicated the following predominant characteristics of current informal irrigation systems: (1) they are carried out by independent small-scale family farmers, (2) they are individual irrigation systems that do not involve agreements between producers, (3) water is transported through hoses, (4) sprinklers are used for irrigation, and (5) there are conflicts over water because of agricultural intensification. Some local variations exist. Although 70 variables were correlated, only the most significant correlations are shown in Table 1.

Extent of informal irrigation systems: Because of the informal irrigation systems' flexibility, seasonal use, dispersion, dynamism, and apparent invisibility, calculating served areas is an extremely complex task. However, an approximate value can be obtained by the

TABLE 1 Principal correlations.

Principal correlations within collective systems	
Individual irrigation systems; systems serving only 1 farm	−0.502*
Irrigators associated to make water use less expensive	0.483*
Irrigation implemented in indigenous communities	0.582**
Irrigators paying for access to water	0.548*
Water sources on irrigators' farms	−0.447*
Irrigators protecting water sources	−0.489*
Existence of use arrangements	0.545*
Principal correlations with the use of sprinklers	
Irrigators associated to make water use less expensive	0.455*
Local presence of conflicts over water use other than irrigation	−0.418*
Irrigators paying for access to water	0.455*
Individual irrigation systems; systems serving only 1 farm	0.426*
Principal correlations with the use of water transported through hoses	
Used by peasants	0.693**
Used in individual irrigation systems; systems serving only 1 farm	0.694**

*Significant correlation at 0.05.
**Significant correlation at 0.01.

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relation between irrigated and cultivated areas. For the collected data, this indicator is extremely variable, showing values from 1% for the municipality of Filandia in Quindío to 100% for sections of Pamplona, Norte de Santander.

It is also possible to determine the magnitude of informal irrigation based on data collected in the interviews. For instance, in Norte de Santander, an environmental authority employee mentioned that there are 500 registered users in the province of Pamplona and an estimated 1000 informal users. An employee of the agriculture secretariat in the same department said that although Zulia district formally irrigates 10,000 ha, there may be 5000 ha of informally irrigated land in its influence area (which would have similar characteristics to the *arrimantes*, defined by Zimmerer [2010], or the *hors casiers*, defined by Brondeau [2004]). Along this line, in Antioquia, an employee of one of the regional environmental authorities said that they have identified basins in the southwest of the department where around 60% of water collection is informal.

Water transportation and irrigation techniques: Although water pumping is used occasionally, farmers prefer to transport water by gravity, a trend also reported in other Andean countries, such as Peru (Bernet et al 2002; Robles Mendoza 2010) and Venezuela (Angeliaume-Descamps and Oballos 2009). For this reason, water is usually collected from sources that offer enough altitudinal difference, which is why it is common to use different sources, such as springs and mountain streams, simultaneously to avoid pumping costs. Nevertheless, unlike the watercourses that run along the valleys, these sources do not have enough flow to supply water all year long.

The predominant irrigation technology observed is sprinklers. Because of their wide geographical distribution, Table 1 shows that these systems correlate positively and simultaneously with variables such as associated and independent producers, with water access paid for and other types of access. It was found that they have negative correlations when there are conflicts over water use other than irrigation.

Although it is not very representative of the nation as a whole, there is an increase in the area irrigated by drip or micro sprinkling irrigation systems installed to supply sensitive crops that are highly profitable, such as tomatoes in greenhouses, heliconias, or deciduous fruit trees (peach, apple, pear, and plum). Furrow irrigation was reported only in 2 dry zones, where it was used for low-profitability crops.

Role of state water authorities: It is uncommon to have estimates of served areas like those described earlier. The environmental authorities know about the existence of informal water uses, and many of them have started campaigns to identify informal users and require them to apply for water use permits or face sanctions. However, the basins are generally not instrumented enough, and the environmental authorities do not have enough technical resources to define the available flows; most of the time, the flows are calculated in offices by people who are unaware of the real conditions; at best, flows are defined based on only one measure taken on a single day.

The flows granted to the farmers by the environmental authorities are defined according to a unique national formula that does not take into account each case's particular conditions and the source's ability to meet the demand. Environmental authorities favor, as a policy, collective permissions to access water over individual permissions; this, combined with other factors, should encourage association as a strategy to access water for irrigation.

Although some environmental authorities attempt to identify informal users and compel them to seek permission for water use, legalizing water collection will not formalize their irrigation systems, as it does not affect the systems' operation. Sometimes authorities deliberately let the informal systems exist because it serves the interests of the formal system and they do not need to spend money or time to structure the system, especially if they do not have enough trained technicians. There are no long-term programs seeking to adapt (via formal mountainside irrigation systems) or formalize the existing systems. Neither are there clear, long-term policies, so the efforts depend on the individual officials in charge. Efforts to formalize informal irrigation are inherently ambivalent, as discussed in the following sections.

Water-use agreements: Local agreements and water uses vary from one zone to another and depend on a great variety of factors. According to De Vos et al (2006), local rights to access water emerge from a combination of adaptation and extension of historical rights, acquired rights (for example, a source on the farmer's property), and rights granted by the state.

Although individual irrigation appears to be the most widespread kind of irrigation, collective systems are on the rise because of growing water scarcity and water conflicts, and because states and donor agencies encourage this kind of system. Generally, collective irrigation systems are located in zones in which rainfall is scarce or has great seasonal variability, there are conflicts over water access, groups with strong community identity are located, and there are collective producers. These systems represent the most interesting social dynamics, among which use agreements stand out, especially on defining water quantity and schedules for irrigation. Voluntary water source protection by the users and water access by means of legalized permissions, which are generally paid for, are also evidenced in these systems.

For other Andean countries, Boelens (2009) has stated that informal irrigators do not want to be found, and that state efforts to discipline irrigation are often undesired at the local level. This study found, however, that although asking spontaneously for water permits is not the norm, and although relations between farmers and state water authorities are usually uncomfortable, little by little an increasing number of farmers are asking state authorities for permission to access water. The purpose of these requests is to ensure use rights in the case of conflicts with their neighbors; in other words, the water access permit is a legal tool that protects them from competition over water.

As in other countries, it was found that use agreements combine a plurality of water rights in which state norms and various local traditions are mixed. This apparent chaos has the capacity to adequately respond to context-based needs, as has been shown by Boelens (2009), because the combination of formal and informal regulations helps to adapt management of and access to resources to local conditions.

Redefinition of informal irrigation

Although the FAO's (2012) definition of informal irrigation is quite thorough, results of this research have made it necessary to adapt the definition to local reality by including irrigation systems developed by farmers themselves, without meeting the state's formal requirements, that are not reported in national statistics. Informal irrigation systems can be further classified into individual and collective systems. *Individual irrigation systems* are those systems that a farmer builds by his or her own means, with a logic that serves only his or her own production system; *collective irrigation systems* can be subclassified as associative or communitarian: *associative* systems are developed to favor private production while saving resources through association, and *communitarian* systems are developed under a community logic that grants water access as a right.

Conclusions

The wide geographical distribution of informal irrigation systems in Colombia is encouraged by access to markets and shows small-scale farmers' capacity to adapt and appropriate technologies, confirming findings in Colombia and elsewhere by Forero Álvarez et al (2002), Lamarche (1992), and Llambí Insua (1998). For this reason, these systems share characteristics belonging to the production systems they supply: they adapt to the surroundings, are flexible, and are built according to criteria for optimizing resource use.

The advantages of informal irrigation systems are many; nevertheless, water demand could go beyond the environmental capacity of the areas concerned, and social conflicts could appear or intensify in zones where informal irrigation systems are growing rapidly and indiscriminately. All of this could negatively affect the environmental and socioeconomic viability of agricultural production in those zones.

Although this study was carried out in Colombia, it offers lessons that are applicable elsewhere: the formalization of existing systems worldwide and the creation of new irrigation adjustments should combine the advantages of informal systems with those of formal ones. In other words, (1) they should incorporate reality and the potential users' traditional knowledge about irrigation and water management; (2) they should be designed with an awareness of the environment and meet criteria of practicality; and (3) the decision-making and technical aspects should be designed to contribute to the systems' sustainability and to minimize the environmental impacts that a design made on the go may cause, at the same time as they augment the systems' benefits.

Hence, there is a need to study irrigation water governance in more depth, to investigate specific cases and to compare different zones in order to enhance sustainable mountain development. To do this, it is necessary to establish trained, coherent, and well-equipped teams of technicians, academics, and researchers, as well as to invest in knowledge about the water sources in the supplying basins. In a paradox similar to that described by Cremers et al (2005), strengthening local rights and community autonomy requires the central government to play a coherent, well-equipped, and empowering role.

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