

# Irrigated Family Farming Panorama in the Latin-American Highlands\*

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## Abstract

Although there are statistics and general cartography on irrigation systems in Latin America, this information does not permit to identify the irrigated family farming zones located in the highland areas. In this article we locate and quantify those zones through the use of cartographic methods that helped to identify the zones that meet three requirements: 1) they are irrigated areas; 2) they are located in zones above 1000 m; 3) Their rural population density is higher than 50 inhabitants per km<sup>2</sup>. The results confirm a wide presence of this type of systems in all Latin-American sub-regions. Nevertheless, due to the restrictions of quality and updating of the information from the available sources, the results given in the present document must be taken as a guideline.

## Keywords author:

Irrigation, family farming, highlands, cartography, Latin America.

## Keywords plus:

Irrigation, family farms, private plot agriculture, agricultural mapping.

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# Panorama de la agricultura familiar irrigada en las tierras altas de América Latina

## Resumen

Si bien existen estadísticas y cartografía general sobre los sistemas de riego en Latinoamérica, esta información no permite identificar las zonas de agricultura familiar irrigada localizada en zonas altas. En este artículo ubicamos y contabilizamos dichas zonas mediante la utilización de metodologías cartográficas que permitieron aislar las zonas que cumplen tres requisitos: 1) son áreas irrigadas, 2) están ubicadas por encima de los 1000 m. y 3) su densidad poblacional rural es superior a 50 hab/km<sup>2</sup>. Los resultados confirman la amplia presencia de este tipo de sistemas en todas las subregiones de América Latina. Sin embargo, debido a las restricciones de calidad y actualización de la información de base, los resultados presentados deben tomarse a nivel orientativo.

## Palabras clave autores:

Irrigación, agricultura familiar, tierras altas, cartografía, Latinoamérica.

## Palabras clave descriptores:

Riego, granjas familiares, parcelas agrícolas privadas, cartografía en agricultura.

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# Tour d'horizon de l'agriculture familiale de l'irrigation sur les zones montagneuses d'Amérique Latine

## Résumé

Bien qu'il existe des statistiques et cartographie générale sur les systèmes d'irrigation de l'Amérique latine, il n'est pas possible de distinguer les zones d'agriculture familiale irriguée situées en altitude. Dans cet article nous localisons et quantifions ces zones en utilisant des méthodologies de cartographie qui permettent d'isoler ce type de zones. Les critères retenus pour la sélection de ces zones sont : 1) la présence d'irrigation; 2) une densité de population rurale dépassant 50 habitants/km<sup>2</sup>; 3) une altitude supérieure à 1000m. Les résultats obtenus confirment une présence remarquable de ce type de production à travers du continent. Toutefois, en raison du manque de précision de certaines sources données, les résultats présentés sont à titre informatif.

## Mots-clés auteur:

L'irrigation, l'agriculture familiale, des hauts plateaux, la cartographie, l'Amérique latine.

## Mots-clés descripteur:

Irrigation, fermes familiales, privés des parcelles agricoles, cartographie agriculture.

# Introduction

The Latin-American family farming production systems, much of which uses irrigation, contribute significantly to the regional agricultural production. Although family farming takes place in very varied contexts, most of these production systems are traditionally located in the highland zones, where the climate variety and incorporation of green revolution practices, including irrigation, allow a wide and diverse agricultural production.

Latin America has a long irrigated agriculture history, which dates back to pre-Hispanic times, especially in Mexico, El Salvador, Guatemala and Peru. Although it is possible to find working pre-Hispanic systems, especially among the family producers, the current configuration reflects agricultural development processes encouraged within the 20<sup>th</sup> century. Irrigated agriculture is not widely developed, since the irrigation infrastructure has been developed only in a 17 per cent of the irrigation-suitable area, which is estimated to be 77.8 million ha (FAO, 2000).

Information about agricultural and irrigated areas is usually not updated, and its level of detail does not allow differentiation based on location or type of producer.

FAO, especially its tool AQUASTAT<sup>1</sup>, Siebert, Döll, & Feick (2007) and Thenkabail et al. (2009) are the main sources of statistical and cartographic data on irrigation. The two first are used in this paper. In order to identify the highland family farming irrigation systems areas, the information about the irrigated areas was cross-referenced with topographic information available in CGIAR-SCI (2008)<sup>2</sup> and rural density data from Geonetwork, one of FAO's (2007) tools<sup>3</sup>.

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1 FAO use 26 variables to describe irrigation and agricultural land use in the world. Data are principally obtained in <http://faostat.fao.org/> site that allows the generation of databases on land and water statistics. Water statistics are obtained from the AQUASTAT site, <http://www.fao.org/nr/water/aquastat/data/query/index.html>. These tools constitute the main world database which counts the irrigated agriculture surfaces according to the soil use (permanent crops, seasonal crops, permanent and temporary grasslands and pastures), irrigation types (sprinkler, flood, others), per country and per year (from 1960 or 1961 to 2009 or 2010). Nevertheless, not all the categories, countries or years are systematically available. Even so, a big quantity of data can be cross-referenced, at a Latin-American or each-country scale, in order to represent the percentage or maps of the actual situation and the evolution in time of soil used for agriculture in the region.

2 The Shuttle Radar Topography Mission consists in obtaining an elevation digital model of the globe's zone comprehended between 56 °S and 60 °N, so that a complete high-resolution digital topographic earth maps base is generated. It is an international project developed by the American National Geo-spatial Intelligence Agency, NGA, and the National Aeronautics and Space Administration, NASA. Data is available in <http://srtm.csi.cgiar.org/>

3 Taken from: <http://www.fao.org/geonetwork/srv/en/main.home>

## 1. Irrigation in Latin America

Figure 1 shows the regional distribution of the irrigated areas and their evolution for about half a century (1961-1997). Additionally, there has been a small growth of the irrigated areas, especially the ones originated by the state, since the 90's, few changes also occurred between 1997 and 2012.

The distribution of the irrigated areas is far from being homogeneous; more than 66 per cent of Latin-American irrigation is located in four countries: Argentina, Brazil, Mexico and Peru. Nevertheless, when pondering the current importance of areas equipped for irrigation with respect to each country's cultivated surfaces, it is possible to see that the countries with relatively high levels of irrigation infrastructure, such as Brazil, Mexico or Argentina, have that infrastructure on a very reduced portion of their agricultural surface.

In order to understand the irrigation dynamics, it is necessary to distinguish between the areas that have irrigation infrastructure and the ones that are actually irrigated, since not all the equipped areas are working. In Latin America, only 80% of the irrigation infrastructure is in use (FAO, 2012) and that proportion varies from one country to another, as it is shown in figure 2.

When adjusting the areas equipped for irrigation to the working areas, allows revising statistical data. According to Siebert et al. (2005), this gap is due to different causes: *“For most of the countries, these statistics refer to the area equipped for irrigation. Due to several reasons (e.g. crop rotation, water shortages, damage of infrastructure) the area actually irrigated may be significantly lower than the area equipped for irrigation”*. Another factor that makes us be cautious before data exactness and their interpretation is that, according to each country, there are different methods to count the irrigated areas. For instance, certain zones belonging to public irrigation districts in Colombia, are zones where dry agriculture is developed, but the whole of these districts is counted as irrigated area (FAO, 2010)

## The Unequal Distribution of Irrigation Equipments in 1961 and 1997/1998

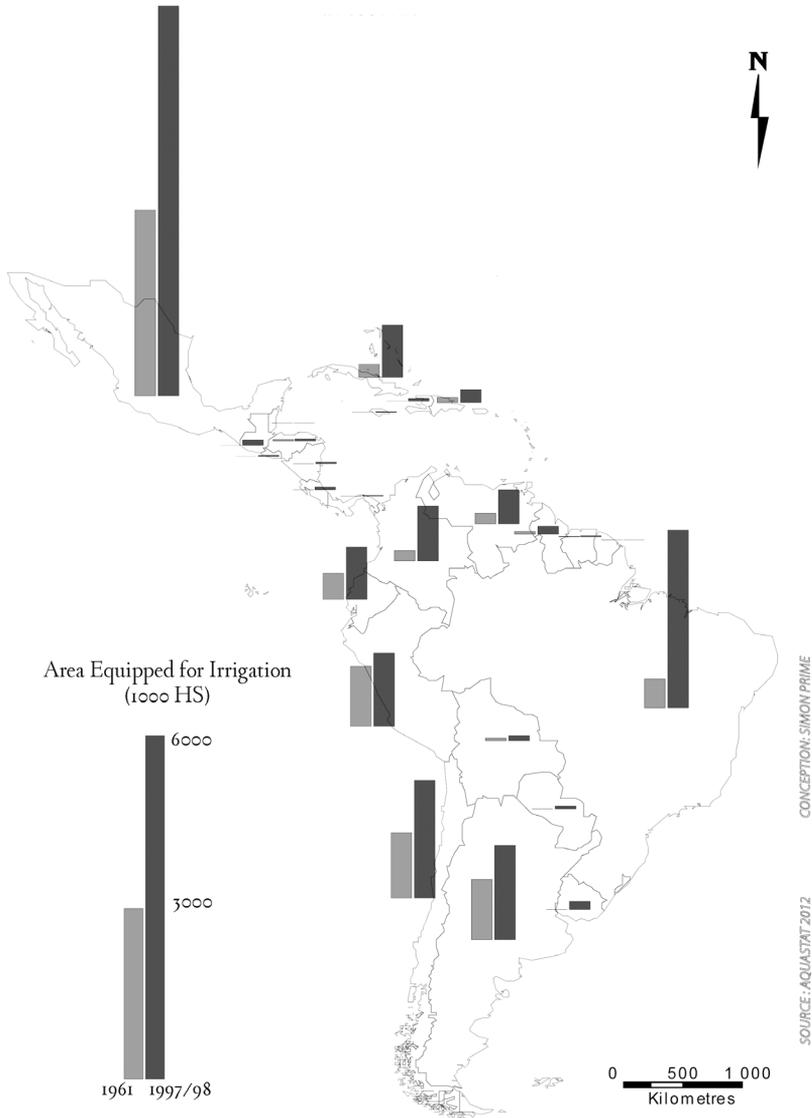


FIGURE 1. Historic variation of areas equipped for irrigation in Latin America (1961-1997; 1998\*).

SOURCE: the authors with data from FAO (2012)

\* Except for Guyana, Haiti and Honduras (1991); Argentina (1995); Chile (1996); Bolivia and Dominican Republic (1999); French Guyana (2007). Definition: Area equipped to provide water (via irrigation) to crops. It includes areas equipped for full/partial control irrigation, equipped lowland areas, and areas equipped for spate irrigation. Calculation criteria: [Area equipped for irrigation: total] = [Area equipped for irrigation: full control - total] + [Area equipped for irrigation: equipped lowland areas] + [Area equipped for irrigation: spate irrigation]. Results appears here: <http://www.fao.org/nr/water/aquastat/data/query/results.html>. This map has been created using *MapInfo 8.5* and *Adobe Illustrator CS3*.

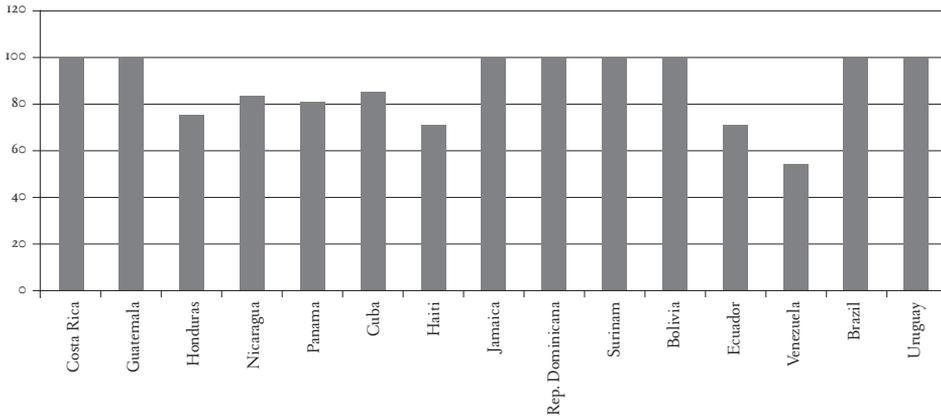


FIGURE 2. Percentage of areas equipped for irrigation which are effectively irrigated in Latin America (1990-1999)

SOURCE: the authors with data from FAO (2012)

## 1.1. Origin and management of irrigated zones

Although a great part of the big irrigation projects has been financed with state resources through irrigation districts, the private sector also plays an important role in irrigation systems development. That role is so important that approximately two thirds of the irrigated surfaces are private (Maldonado Rojas, 2000). This pattern, which is common to almost all Latin American countries, has clear exceptions, such as Peru and Mexico, where the relation is inverted. In these countries about 70 per cent of the irrigated area corresponds to state or public systems. This difference is basically due to land and associated infrastructure redistribution as a result of the Mexican revolution and the Peruvian agrarian reform.

Medium or large irrigation systems are usually co-managed by the state and the communities, and are characterized by some combination of public and common property regimes. Small or communal systems are mainly managed by the communities, which limits the role of the state, in most of the cases, to providing water flow to the community, and, eventually, resolving conflicts.

Within this context, since the 70's, self-management schemes have been encouraged inside the neoliberal policies logic, whose objective is to reduce the state costs and strengthen the appropriation processes by means of transferring the public irrigation systems to the users. In countries like Chile, this process ended several years ago. In other cases, such as Peru or Mexico, this process is advanced. In Ecuador, Colombia and Guatemala, it is in progress. In Venezuela, Brazil and Panama, it has just begun, while it is under study in Costa Rica, El Salvador, Guyana, Jamaica and Dominican Republic (FAO, 2010).

Such processes have been widely discussed since the transfer of irrigation systems to users have not had substantial effects on the operations' performance, maintenance or the irrigated lands' agricultural and economic productivity. This situation affects the sustainability of those "inspired-by-the-state" systems suddenly given to private and communal users. Additionally, not always poor rural communities can finance the investments needed to build or operate the irrigation systems<sup>4</sup> (Smith, 2002)

As a result of such diversity of processes, water for irrigation management systems and the regulations used are extremely different. This great variety results what some authors like (Boelens, 2009a; Cremers, Ooijevaar, & Boelens, 2005; De Vos, Boelens, & Bustamante, 2006; World Water Assessment Programme, 2009; von Benda-Beckmann, von Benda-Beckmann, & Spiertz, 1998) define as *legal pluralism*. About this issue (Boelens, 2009b) says that "*analyzing and untangling the whole in particular contexts show that what seems to be an incomprehensible, unstable and irrational disorder unproper for governing the highly conflictive environment of water control, can be characterized as an organized complexity in the practice.*"<sup>5</sup>

## 1.2. Irrigated family farming in Latin America

The large scale of irrigation systems are generally located in low zones where most of the agro-industrial systems are developed, while the small scale and highland ones mainly serve family farming systems<sup>6</sup>. However, it is possible to observe both types of agriculture in every region.

Such sectorization is described by Linck (2006) for the Mexican case, and it is more evident for the countries located in the central and northern Andes, where most of the highland irrigation systems are found: in Colombia, only 4% of the formally irrigated total area is located in the highlands (data obtained through interviews to officials at INCODER). In Ecuador, it is 14% (Maldonado Rojas, 2000) and 20 per cent in Peru (Palerm-Viqueira, 2010). These data will be re-estimated in this article.

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4 One of these particular cases is seen in Mexico when the water policy (Ley del agua) in 1992 introduced reforms, which had an impact on the country's irrigation districts organization and operation.

5 Translated from Spanish

6 This process is not exclusive of Latin America since worldwide investments in irrigation tend to concentrate in big scale projects (Gender and Water Alliance, 2007).

According to Forero Álvarez et al. (2011), most family farmers in each of these countries are located in the Andean zone. This implies that irrigation has been developed in a geographically unequal way, and its expansion has been marginal in the highland and family farming zones.

Neither the statistics nor the cartography that exists, allows us to distinguish family farming from other types of agriculture with accuracy. For this reason, it is necessary to observe the national dynamics<sup>7</sup>. Available data do not differentiate between highland and lowland irrigated agriculture.

Family farming in Latin America traditionally has had great importance in the production of fresh products and internal supply. It is estimated that by 1990, 85.5 per cent of the Latin-American agricultural units could be considered as family units (Chiriboga, 1999). Nevertheless, according to the same author, these production units corresponded to only 12.2 per cent of the region's agricultural area, which showed a great inequity in land property and, probably, in the kinds of crops those lands were used for<sup>8</sup>.

Although family farming is understood as that which uses mainly family labor, it is almost impossible to establish the boundary which indicates when a system is classified as family or capitalist. Therefore, the family farming characteristics will depend on several factors. A common strategy is to define the family production systems based on the farm size, which is arguable. FAO (2010) establishes that the family agriculture systems median surface varies according to each country: 3 ha in Colombia, 6 ha in Mexico, 23 ha in Chile and 26 ha in Brazil. Carmagnani (2008), who used information from national agricultural censuses, offers another classification to define the family farms size in five Latin-American countries: in Brazil, family farms are those smaller than 50 ha<sup>9</sup>. In Uruguay, these farms size fluctuates between 6.7 and 71.1 ha. In Buenos Aires province in Argentina, the average size for family farms is 149 ha, in Nicaragua, it is between 3.5 and 14 ha, and in Mexico, it is between 5 and 10 ha.

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7 Two regions can be distinguished in Mexico: a Northern Region, where horticulture is industrialized, developed in big extensions of land, and mainly directed to export markets, and a Central Region, where horticulture is developed in small family farms and is mostly destined to local and regional markets.

8 These are general data that must be read carefully as they do not show the great variability given between the different countries and even inside each country.

9 Nevertheless, he showed that even farms of 100 ha could still be classified as family farming, and found that it is the farms between 31 and 67.8 ha the ones that define optimal conditions for family farming in Brazil.

Despite the absence of universal statistics concerning family farming, FAO & BID (2007) claim that family farms in Latin America contribute greatly to the national agricultural GDP (PIB for its acronym in Spanish), as well as make a considerable contribution to generating rural employment (See Figure 3). Unfortunately, no data on agricultural employment in Ecuador and Nicaragua were found.

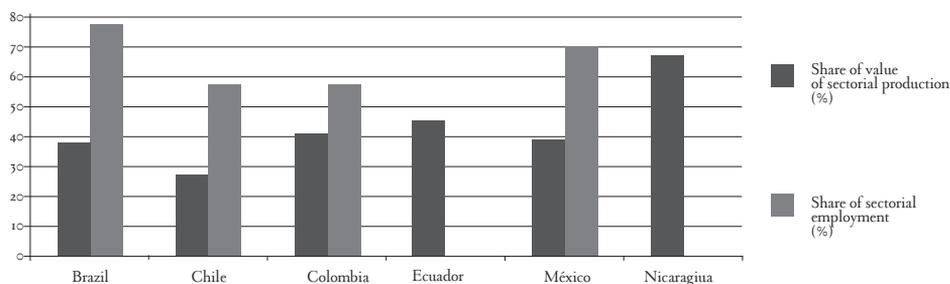


FIGURE 3. Family farming participation in agricultural production and employment value for some Latin American countries

SOURCE: the authors with data from FAO (2010)

The quick expansion of strong added-value product markets, particularly horticulture, a small scale cattle-raising, fish farming and dairy products, offer an opportunity to diversify the agricultural systems and develop a small competitive agriculture with intensive use of hand labor (World Bank, 2007) and water for irrigation. In this sense, permanent access to water for irrigation is a key factor to stabilize and increase family farmers' incomes (Leiva & Skees, 2008). Van Der Zee, Fajardo Reina, & Holtslag (2002) found that, in Nicaragua, safe water access can increase family farming systems' incomes between 35 and 155 per cent, depending on the farm size; Jauregui et al (2005), found that such increase reached 236 per cent in Bolivia.

The environmental contexts of Latin-American family farming vary. National statistics do not differentiate family irrigation from agribusiness farming irrigation, nor do they differentiate lowland zones from highland zones. In Latin America there is highland or mountain irrigated family farming, where the slopes allow transporting water easily by using gravity force, which avoids pumping costs.

According to Zimmerer (2010), in the Andean case, the presence of irrigated family farming is especially visible in lands higher than 1000 m; this can be extrapolated to the rest of the mountainous zones in Latin America. The altitude of 1,000 meters is what we will use as the demarcation of the highlands from the lowlands.

The presence of mountain irrigated family farming, dedicated to strong added-value crops, can depend on multiple factors. These include the presence of transport infrastructure, the closeness to consumption or commercialization centers, and climate favorability provided by the altitudinal variation, providing cooler temperatures than in the lowlands. This climate offers the physical and sanitary conditions which allow vegetables and other “fragile” products to be cultivated all year long.

Mountain family farming is very sensitive to climate changes, as they are located in the hydrographic basins heads. These natural characteristics, joined to high population density and intensive soil use, make water extraction over the sources’ capacity common during the low precipitations periods (Girard, 2005; Ruf & Gasselín, 1999; Vanacker et al., 2003), which aggravates the situation for ecosystems and users waters downstream.

Although the Latin American mountains are vulnerable zones, they exhibit strong and active agricultural production, most of which is family and irrigated. Successful examples of highland irrigated family farming can be observed in almost all the countries with altitudes higher than 1000 m:

1. Merida, Venezuela, where agriculture production has increased and the landscape has changed since 1970 (Angeliaume-Descamps & Oballos, 2009), thanks to the proper climatic conditions given by the mountain, the implementation of irrigation systems, and supported on the economic growth due to petroleum exploitation, immigration and dietary changes.
2. Puebla, Mexico, where horticulture development in high plateaus, located at 2000 m above sea level, has grown since 1980, thanks to the peasants’ mobilization in order to benefit from the irrigation systems in a non-favorable rural context, which resulted from the state liberalization and policies of structural adjustment (Prime, 2010; Ramírez J., 1999).
3. Fomeque, in the Colombian Andes, which has a dynamic agriculture thanks to family farming intensification in small holdings, which would not be viable without the access to water for irrigation (Angeliaume-Descamps & Gutiérrez-Malaxechebarría, 2012; Gutiérrez-Malaxechebarría, 2011).
4. The mesothermal valleys in Cochabamba, Bolivia, where there is wide use of irrigation by family farmers, strongly integrated to the country’s urban dynamics. (Godoy, Morduch, & Bravo, 1998; Zimmerer, 2000).

5. The Colca Valley, in Peru, where there are intricate local agreements to access water for irrigation and where the irrigation systems are community-identified elements (Robles Mendoza, 2010).
6. The Ecuadorian Andes, where there are many examples of successfully peasant and indigenous irrigation systems (Boelens, 2009b; Le Goulven & Ruf, 1993, 1994; Ruf & Gasselín, 1999; Ruf & Mathieu, 2001; von Benda-Beckmann et al., 1998).
7. Other interesting examples, although not the only ones, can be found in the highlands of Dominican Republic, Guatemala and El Salvador.

The wide use of irrigation systems as well as their variability provides examples of family farming production systems' capacity of market adaptation and technology appropriation, inside the green revolution modernization processes. In other words, the spread of irrigation in family farming production systems has allowed family farms to survive and have a wide spatial presence.

## 2. Methodology

To find reliable spatial resolution data<sup>10</sup> for this study was difficult because of the size of the region to be analyzed. The first stage consisted in obtaining the necessary data from different sites that had spatial data available (see Chart 1).

CHART 1. Sources where data were obtained from\*

DATA	SOURCE	RESOLUTION (PIXEL SIZE) (IN THE EQUATOR)
International borders	"Global Administrative Areas"	near to 5m
Population density	FAO, 2007	near to 915m
Relief (elevation)	CGIAR-SCI, 2008	250m
Irrigated areas	Siebert et al., 2005	81km2

SOURCE : "Global Administrative Areas" (<http://www.gadm.org/>) ; SRTM 90m Digital Elevation Data (<http://srtm.csi.cgiar.org/>)

<sup>10</sup> The data that has the least reliable resolution is taken as the main data. The use of further data which have better resolution allow us not to degrade the data that matter most to our purpose.

The collected data was vectorized<sup>11</sup> by using the ArcGis program. This stage allowed us to use the entire program's potentials concerning vector data manipulation and analysis; it was also necessary to determine each country's final statistics.

The three layers are georeferenced in the same geographical coordinates system (WGS 84). As a result, the data are perfectly superposed in latitude and longitude. Then, identical deformation data are projected over an identical referential (here, Mollweide equivalent projection<sup>12</sup>). Thus, it is possible to combine data and to calculate surfaces with a precision that only depends on source data.

After that, we chose the data that met the three previously defined criteria for each country. Concretely, the calculation algorithm indicated the zones whose information was overlapped. This allowed us to finally determine the spatial distribution of those zones that: have an altitude above 1000 m (which, according to Zimmerer (2010), is the lowest limit for irrigated agriculture in the Andes), have rural density of more than 50 inhabitants per Km<sup>2</sup> (data defined by the authors using the expert's criterion<sup>13</sup>), and where irrigation takes place. This last data about irrigation took the information in Siebert et al. (2007) as a basis, according to the irrigated area reported per pixel. Thus, for example, if the zone comprehended in a pixel shows that 20 per cent of it is irrigated, this represents 16.2 Km<sup>2</sup> of irrigated area out of a total of 81 Km<sup>2</sup> (20% of 81 Km<sup>2</sup>). The whole process is schematized in figure 5. In order to compare the obtained data, the total irrigated areas located at higher altitude than 1000 m were calculated for each country by using the same methodology and sources, but varying the selection criteria.

The cartographic manipulations done did not affect the resolution or the exactness of the data used as basis. Therefore, the reliability degree obtained is the same as the one in Siebert et al. (2007). To obtain more detailed results, the international organisms would have to provide a better resolution source maps.

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11 Vectorizing an image consists in transforming it into a group of geometrical forms (dots, lines and polygons).

12 An equivalent projection allows conserving surfaces.

13 This information corresponds to saying that a family composed of five members manage an area of or smaller than 10 ha (not all of them irrigated or cultivated). This size, although defined arbitrarily by the authors and which does not meet the criteria given by the authors taken as reference, is within acceptable ranges, and allows us to establish that, because of the land size, working labor is mainly familial; additionally, it allows us to include activities in which the territory is not used, since the rural zones comprehend non-cultivable or conservation zones. Family farming zones that have lower population density are not taken into consideration in this study.

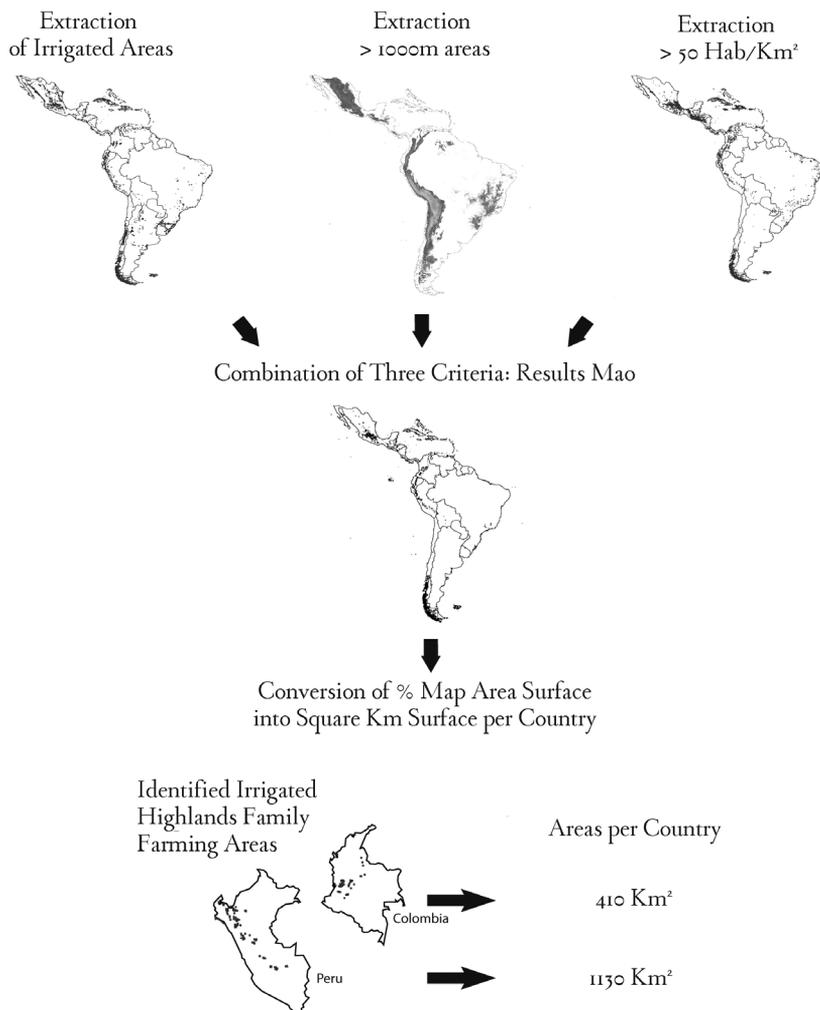


FIGURE 4. A descriptive scheme of data handling (methodology)

SOURCE: the authors.

In some cases, it would be possible to obtain data separately from each country. However, this would multiply the information sources, and, therefore, the difficulties in the data treatment and comparison.

### 3. Results

The data management allowed us to identify, following a cartographic method, the family farming irrigated areas in the Latin-American highlands. Figure 5 shows the representative areas of family farming in the region.



FIGURE 5. Family farming irrigated areas in Latin-American highlands (this study)

SOURCE: the authors.

Spatial information was quantified and it is shown in Chart 2. It presents totals of agricultural areas in highlands irrigated areas by family farmers, the totals of irrigated areas per country according to FAO (2102), and suggests the importance of the former, over the national totals. Some countries are not reported in the table, because no areas that met the defined criteria were found.

CHART 2. Irrigation in Latin-America summary table

COUNTRY	TOTAL IRRIGATED AREA (KM2)	OVER 1000M IRRIGATED AREA (KM2)	OVER 1000M AND OVER 50 HAB/ KM2 IRRIGATED AREA (KM2) (AFIM)	AFIM/ TOTAL IRRIGATED AREA (%)	AFIM/ OVER 1000M IRRIGATED AREA (%)	OVER 1000M IRRIGATED AREA/ TOTAL IRRIGATED AREA (%)
Mexico	65704	28920	8901	13,55%	30,78%	44,02%
Peru	17458	9957	1130	6,46%	11,33%	57,03%
Ecuador	8746	3593	773	8,83%	21,50%	41,08%
Colombia	9069	3502	410	4,56%	11,81%	38,62%
Guatemala	1427	382	239	16,76%	62,59%	26,78%
Dominican Republic	2718	387	59	2,16%	15,17%	14,24%
Bolivia	1304	1204	48	3,69%	4,00%	92,36%
Costa Rica	1034	153	42	4,01%	27,12%	14,79%
El Salvador	474	51	38	8,09%	74,96%	10,80%
Honduras	755	178	35	4,64%	19,73%	23,52%
Brazil	31657	1392	29	0,09%	2,09%	4,40%
Haiti	986	22	16	1,58%	71,11%	2,22%
Nicaragua	627	35	14	2,22%	39,46%	5,63%
Panama	372	63	7	1,84%	10,93%	16,85%
Chile	19064	3823	7	0,03%	0,17%	20,06%
Venezuela	5727	1192	0	0,00%	0,01%	20,81%
Argentina	18425	1967	0	0,00%	0,00%	10,67%
Cuba	8716	8	0	0,00%	0,00%	0,09%

DATA belong to the period 1997-1998, except for Honduras and Haiti (1991), and Dominican Republic and Bolivia (1999). The countries which are not included in the figure do not have data of this kind. Definition:

Percent of area equipped for irrigation that is actually irrigated in any given year, expressed in percentage. Irrigated land that is cultivated more than once a year is counted only once. Calculation Criteria: [Area actually irrigated as % of area equipped for irrigation] = 100 \* [Area equipped for irrigation: actually irrigated] / [Area equipped for irrigation: total]. Results appear here: <http://www.fao.org/nr/water/aquastat/data/query/results.html>.

The data obtained allow relativizing the family farming irrigated area within the national context, as well as on the irrigated area above 1000 m.

The countries with the highest proportion of family farming in highlands – Mexico, Peru, Ecuador, Guatemala and El Salvador– have a strong presence of

indigenous communities and a long history of highland irrigation. The weight that this type of agriculture has over the total irrigated area is an indicator of the historical continuity of these agricultural techniques, or of defined and distinctive cultural characters<sup>14</sup>.

It will be necessary to revise the data reported for Bolivia, as it was expected to have a similar behavior<sup>15</sup>. This is because Forero Álvarez et al. (2011) reported that 99 per cent of the Andean agriculture in Bolivia corresponds to family farming. On the other hand, the data concerning the irrigated zones located at an altitude higher than 1000 m obtained from FAO (2102) and Siebert et al (2007) are not consistent with what Forero Álvarez et al. (2011) and Paz Ballivián (2009) said, since they affirm that the agriculture in low zones is capitalist, which would be characterized by the use of irrigation systems. Therefore, it was not expected that the higher-than-1000 m irrigated areas represented the largest proportion. In consequence, the information obtained for this country is not conclusive and the basis data must be revised<sup>16</sup>.

A lower relative presence of highland family farm irrigation in the national context, but still representative, is observed in Colombia, Dominican Republic, Costa Rica and Honduras. These countries are located in different surroundings: the Andes, Caribbean islands and Central America, respectively, which shows wide distribution and importance of irrigated family farming in the mountains.

Brazil's relative scarcity of land over 1000 m explains why agriculture and irrigation in the highlands makes a very low percentage of the total Brazilian irrigation.

With respect to total areas, Mexico stands out among the countries with bigger family farming irrigated areas in the highlands, with 8901 km<sup>2</sup>. It is followed by Peru, with 1128 km<sup>2</sup>, Ecuador, with 773 km<sup>2</sup>, and Colombia, with 414 km<sup>2</sup>. Mexico, Peru and Ecuador are also included in the group that has a major relative weight over the irrigated totals in mountain family farming, which suggests the need to develop further research in those countries. Regarding the highest representativity of irrigated family farming in zones higher than 1000 m, in their national context,

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14 Additionally, family farming has the highest participation out of the national total in Mexico and Peru, thanks to the revolution in Mexico and the agrarian reform in Peru.

15 This is mainly explained by the minimum rural population density defined.

16 We suppose Bolivia's data report only public irrigation systems and do not include private irrigation systems which are located basically in the east low lands.

the countries that stand out are: El Salvador (74,96), Haiti<sup>17</sup> (71,11%), Guatemala (62,59%) and Nicaragua (59,46%). They are followed by the group composed by Mexico (30,78%), Costa Rica (27,12%), Ecuador (21,50%), Honduras (19,73%), Dominican Republic (15,17%), Colombia (11,81) and Peru (11,33%).

The low presence of mountain irrigated family farming systems in Chile and Argentina, where the highland irrigated areas represent 20.06 and 10.67 percent of the national totals, respectively, can be explained by the chosen density selection criteria. An analysis in those countries needs to put in consideration the geographic land tenancy patterns, as well as the rural population density.

Although the obtained data correspond to information offered by international entities, it is surprising that Venezuela is absent. This can be due to the quality of data corresponding to the country, the dispersion of the irrigated zones in the Venezuelan Andes and, overall, because of the chosen criteria on altitude and the population impact on this country. Additionally, despite the fact that in Venezuela the mountain irrigated agriculture represents a 9 per cent out of the total (52458 ha, according to Angeliaume-Descamps, Blot, Leroy, Maire, & Molina (2011)), it is distributed in different narrow valleys whose highlands are neither irrigated nor populated. This is why the spatial resolution used, could not register such rapid spatial variations. Similar phenomena might have occurred in other countries where bigger areas were expected, just like the already discussed case in Bolivia. For this reason, it would be necessary to revise these cases particularly, which implies using data with higher resolution and trying specific limits, which must be adapted regionally.

## Conclusions

Although the results presented here differ to the ones by other sources, they are derived in a transparent manner that seeks to deep into and improve the comprehension of the Latin American rural world.

For every case, mountain irrigated family farming is a minority system within the nation, as well as the highlands as a percentage of the national land mass. The highland irrigations' minor presence confirms what was said in the conceptual section of the present article. However, it contributes greatly to the national agricultural production, it is located in environmentally sensitive zones, it is

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<sup>17</sup> Although the higher than 1000 m irrigated area in Haiti represents only 2,22% of the national total.

part of the Latin-American rural world complex realities, and its presence can be observed in all the Latin-American regions.

The resolution we worked with, excludes agricultural mosaic zones where there is a strong presence of irrigated agriculture and where there are also conservation or non-use zones, simultaneously. Therefore, the data can undervalue the presence of such areas, just like what happened in the case of Venezuela. For this reason, we suggest deepening in the research with a better resolution of information and analysis conducted country by country or, if possible, for different regions in each country. However, the use of diverse sources will make comparison between countries problematic.

Another restriction to obtain accurate data is the dispersion of the mountain irrigated agriculture and its combination with dry crops or other land uses, which makes it difficult to visualize the irrigated areas. On the other hand, the information that includes secondary data, based on official statistics is not updated. It includes the zones that are equipped for irrigation and excludes informal (not accounted for) irrigation zones. This explains the differences in the areas reported by different authors.

The results of our cartographic analyses of irrigation, allow us to have a closer vision to this reality, particularly, its spatial distribution. However, a slight modification in the defined criteria (for example, choosing altitudes higher than 800 m, or rural densities higher than 40 inhabitants per km<sup>2</sup>) could widely change the results obtained for each country, in terms of surface. It would be pertinent to test those limits and reflect on those that would be the most representative ones. To come closer to reality, it would be doubtlessly optimal to define different limits according to each country, depending on its national characteristics. Thus, for example, it would be interesting to adjust those data treatments for the countries with the biggest relative and total areas object of study. Those countries would be, for instance, Mexico, Peru, Colombia, Ecuador, Haiti, Guatemala, Dominican Republic, Costa Rica or El Salvador.

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