

**Com :**  
**VIIIth Afro-Asian Regional Conference**  
**International Commission on Irrigation and**  
**Drainage**  
**ICID, Tokyo, 15-25/10/89, pp 351-361.**

# **TRADITIONAL IRRIGATION IN THE ANDES OF ECUADOR**

## **RESEARCH AND PLANNING**

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### **Abstract**

*After a presentation of their area of study, the authors describe the historical evolution of irrigation in the Andes of Ecuador. The function of the state is emphasized and then the two kinds of irrigation are precisely defined. Next, the paper deals with the present problems of private irrigation systems and presents various possible strategies in terms of planning and development.*

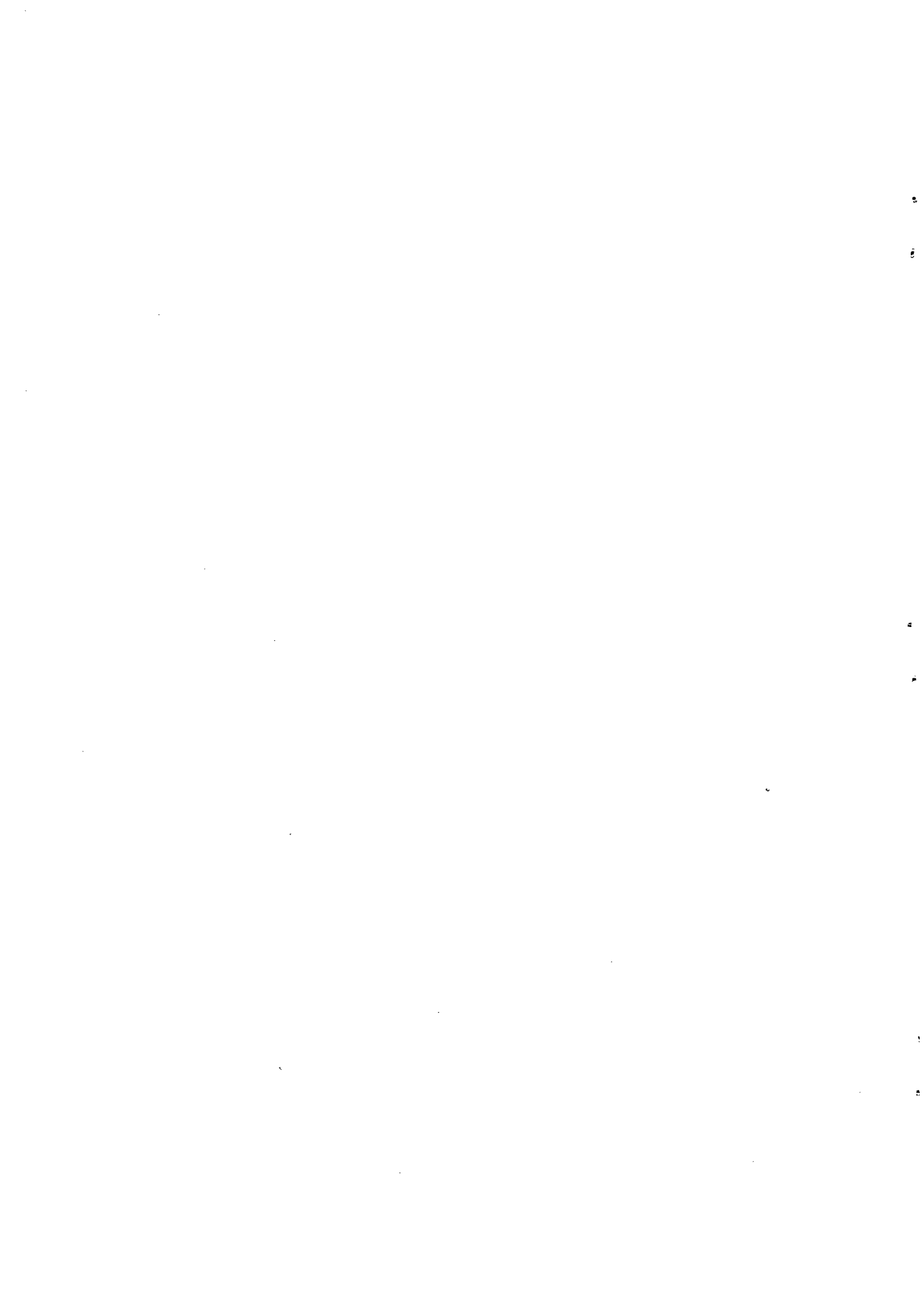
*The selected strategy relies on an elementary space unit (the ZARI) and the authors explain its definition, its conception, and its meaning. Finally, they present the selected methodological outline and the various operations.*

*This paper, above all methodological, precedes a second one entitled "Dysfunctions and Rehabilitation" in which the preliminary results are presented and commented.*

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In Ecuador, the National Water Resources Institute (Instituto Ecuatoriano de Recursos Hidráulicos- INERHI), whose function is to manage water resources and to promote irrigation projects, has to develop a National Irrigation Plan for the next decade.

In a difficult economic context due to very high public debt, it is almost impossible to carry out the policy of realizing new, modern –but very expensive– irrigation projects with still low benefits.

As far as the franco-Ecuadorean team under the leadership of the authors of this paper is concerned, the main point for the elaboration of the future Irrigation Plan consists in considering what still exists, sometimes for ages, i.e., the so-called private or traditional networks as opposed to the recent state projects.

Moreover, this focus agrees with the one advocated by the international organizations. To manage the future rehabilitation activities, it is first necessary to understand the as yet unknown organization of the traditional networks, in order to analyze with precision their various operational problems.

That is the purpose of the international, multidisciplinary team of French Scientific Investigation Institute for Development and Cooperation (ORSTOM) and INERHI, dedicated to the project "Operation, Analysis of Ecuadorean Irrigation - Recommendations for the National Plan".

## 1. PRESENTATION OF STUDY AREAS

Ecuador extends over 281.000 km<sup>2</sup> in the northwestern part of the South American continent, between Colombia and Peru (see Figure 1).

The Andes mountain range divides the country in three areas. In the north, it consists of two distinct chains crowned by high volcanos of over 5000 meters, on each side of the inter-Andean corridor which is about 40 kilometers wide. In the south, the two mountain ranges meet and the peaks are lower.

These Andes mountains, called "sierra", constitute a specific, very early inhabited entity: *this is the project area*.

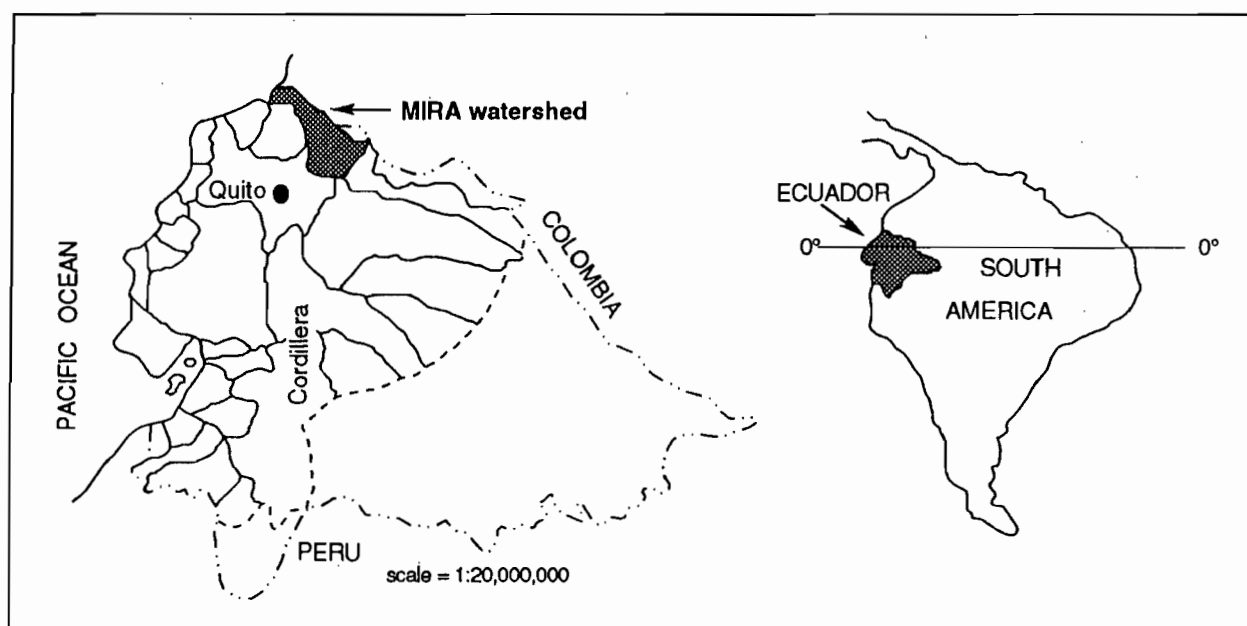


Figure 1 - Hydrographic watersheds and Andean cordillera - Ecuador

The Andean population lives mainly in the inter-Andean valley and has adapted the agriculture to its different ecological levels (1800-3500 m). Above the cultivated stages, sometimes with high slopes, are found wide meadows (3500-3800 m) called "páramos". Above 4300 meters, because of the frost, there is no vegetation, and permanent snow begins at 5000 m.

The rainfall is heavy on both sides of the Andes and variable in the inner valleys. It can go down to 400 mm in some sheltered areas where irrigation is essential. Generally, there are two rainy seasons (from February to May and from October to December), but there may be modifications:

- in some areas, i.e., valleys under the influence of the Amazon river basin climate;
- some years due to the Niño Current.

There is a high probability of drought (even short ones). That is why traditional irrigation networks can be found in almost all the valleys.

## 2. ANDEAN IRRIGATION: AN OLD STORY BUT RECENT STATE INTERVENTION

Irrigation was known long before the arrival of the Spaniards (1530) in the Andean areas and perhaps before the arrival of the Incas from Peru (about 1470). In the XVIth century, the native communities had a kind of water law which was gradually replaced by the law laid down by the Spanish colonizers.

Documents from the National Archives in Quito indicate that most existing networks were built between the XVIIth and XVIIIth centuries when the big landowners were able to make the native labor force dig and maintain canals that were regularly destroyed by bad weather, overflows, and earthquakes.

In the XIXth and XXth centuries, owing to social and economic progress, the land was gradually partitioned, thus producing changes in the use of water.

On the one hand, the biggest haciendas were divided among the heirs, which created conflicts in water partition; these conflicts were settled by the construction of new nearby canals.

On the other hand, the peasant groups (Mestizo or Indian) claimed their water rights which were justified by their crucial participation in the construction and maintenance of the water system. Finally, some individuals or groups acquired water rights by different ways (fraction of the canal flow or the complete discharge during a definite period, etc.).

During the XXth century, the rise in population led to a demand for agricultural land (this justified the Agrarian Reform of 1960-70). The demand for water resources increased at the same time. The latter is not well known but it is the origin of numerous conflicts, even violent ones.

The state intervened for the first time in 1936 and tried to establish the first legal basis for a better distribution of water resources. Then the state created the "National Irrigation Fund" (1944) to carry out works of general interest.

As conflicts between the network owners and the users continued, the military government created the National Water Resources Institute (INERHI) in 1966. The authority of this institute was strengthened when the water resources were nationalized in 1972.

INERHI holds a monopoly on water and intervenes on two levels:

- **It studies, builds and manages directly** a group of networks comprising irrigated areas from 500 to 10,000 hectares where farmers have to pay a tax. It is not involved in agricultural development, crop-raising advice, or production trade.
- **It checks and grants the water concessions.** Therefore, the primitive water rights are legalized because they have to be declared.

In this set, known as private irrigation, the building, maintenance and management of networks and irrigated areas are under the responsibility of the users and their organizations: *Juntas de Aguas*.

These two groups are not always independent and can be combined to form groups of irrigated areas that comprise thousands of hectares.

### 3. CURRENT PLANNING PROBLEMS

Taking the country as a whole, INERHI estimates the irrigated surface for agricultural use at about 550,000 hectares. More than 75% is private irrigation. Analysis of the preliminary results in the Mira watershed (See Fig. 1) seems to indicate a higher percentage in the sierra (See Table 1).

**Table 1 - Description of the private irrigation network in the Mira Watershed**

Number of canals .....	295	
Total intake flow .....	25	m <sup>3</sup> /s
Average intake flow per canal .....	85	l/s
Total length of canals .....	1,780	km
Average length of canal .....	6	km
Number of irrigated areas .....	275	
Total irrigated surface .....	53,923	has
Pure private irrigation surface area and % .....	46,728	has (87%)
Pure public irrigation surface area and % .....	2,210	has (4%)
Mixed irrigation system surface and % .....	4,985	has (9%)
Specific irrigation discharge rate in the private irrigation areas .....	0.5	l/s

Private facilities consist of very winding earth canals, dug on the mountain slope, which can often disappear into long unpropped tunnels and can carry flows of about 500 l/sec.

The water intakes are rustic (overflow with stones), and therefore shaky. All along the flow, the canals cut across each other and become entangled, delivering water according to the needs by means of rudimentary dividers. It is not unusual for a canal to feed several distant areas or for an area to receive water from several canals.

Generally, gravity irrigation techniques are applied as they are well adapted to the area's topography. That means that a precise analysis of the irrigation system is necessary to develop specific standards adapted to the local situation, i.e., gravity irrigation can be noted on slopes of 100%. In this case the usual standards are not applicable.

Up to now, INERHI was mainly interested in irrigating new areas to increase the irrigated surfaces. The example of Mira (like in other andean watersheds) shows that its intervention ignored the existing facilities.

These public projects appear to be the last historical intervention of superimposed equipments.

The lack of planned improvement of the private networks is mainly due to the original separation of INERHI assignments (projects on the one hand, management on the other hand) but also due to the very complexity of the traditional existing civil works, the inventory of which was not always complete or precise. Moreover, the access to the water intakes is often difficult and their control sometimes impossible.

Without method or a well-guided, determined policy, the intervention of the government was punctual and specific: to build here a modern intake, there a storage tank...

Today irrigation in the Andes is being designed differently thanks to several new elements. Most of the ideal sites for irrigation are used and every new project will cost more and more. The country is affected by a serious economic crisis and had to be more careful in its investments, owing to a still high external debt.

Now is the time to guide state intervention (and therefore INERHI) towards a better management of the existing systems, especially the intensification of traditional irrigation for the following reasons:

- **It supplies the main part of the usual consumer goods.**
- **As it is not very technological, its development potential is higher.**
- **It exists throughout the country and involves many people who already have a basic knowledge of irrigation.**

To prepare this new sphere of activities, INERHI and ORSTOM have decided to collaborate in order to establish (first at the Andean level and then at the national one) a methodology based on scientific standards which would result in practical recommendations for the elaboration of a development plan.

Because the operation of the private system is relatively unknown, it is necessary to study the use of water in its entirety in order to detect its weaknesses and to enhance its strengths.

This means that a multidisciplinary study will have to be carried out that can analyze the problem at various levels and provide the necessary data to implement the recommendations.

#### **4. A RESEARCH AND PLANNING SPACE UNIT: THE ZARI**

The country contains about thirty big watersheds of various importance; in the sierra they are very well defined.

They are obviously too wide and too heterogeneous to constitute the basic unit of analysis, but they represent a preliminary classification for the total water resources. They usually belong to a region and often include a big town, a trade and exchange centre.

**It means that this space division has to be considered in the Ecuadorean Andes.**

The hydrologists have refined this partition and divided it into unitary watersheds (or micro-basins) where they estimate the water resource.

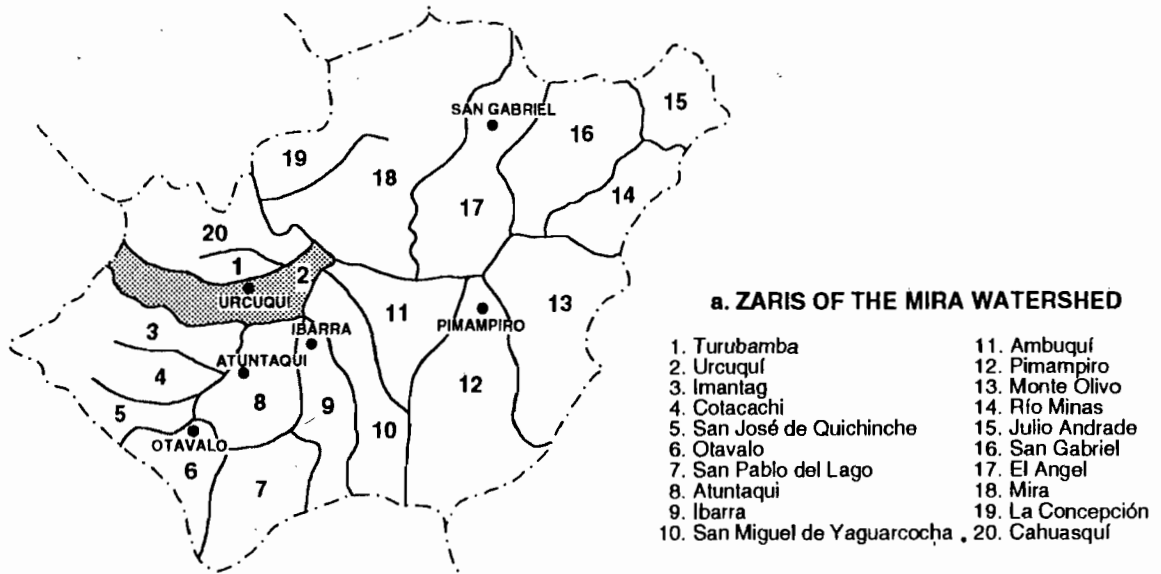
This notion, as appealing as it may be, is unfortunately not adapted to the study of the irrigation networks. The lower parts of the irrigated areas are flat enough to allow the mixing of canals of various origins. Even in the higher parts, the watersheds do not constitute an obstacle to the canals which skirt round them or cross under them in tunnels.

That is why it was necessary to think up and delimit space units that deal with reality: the ZARI (Zone of Analysis and Recommendations for Irrigation).

**The ZARI is a space organization unit of the taking, transport, and use of irrigation water.**

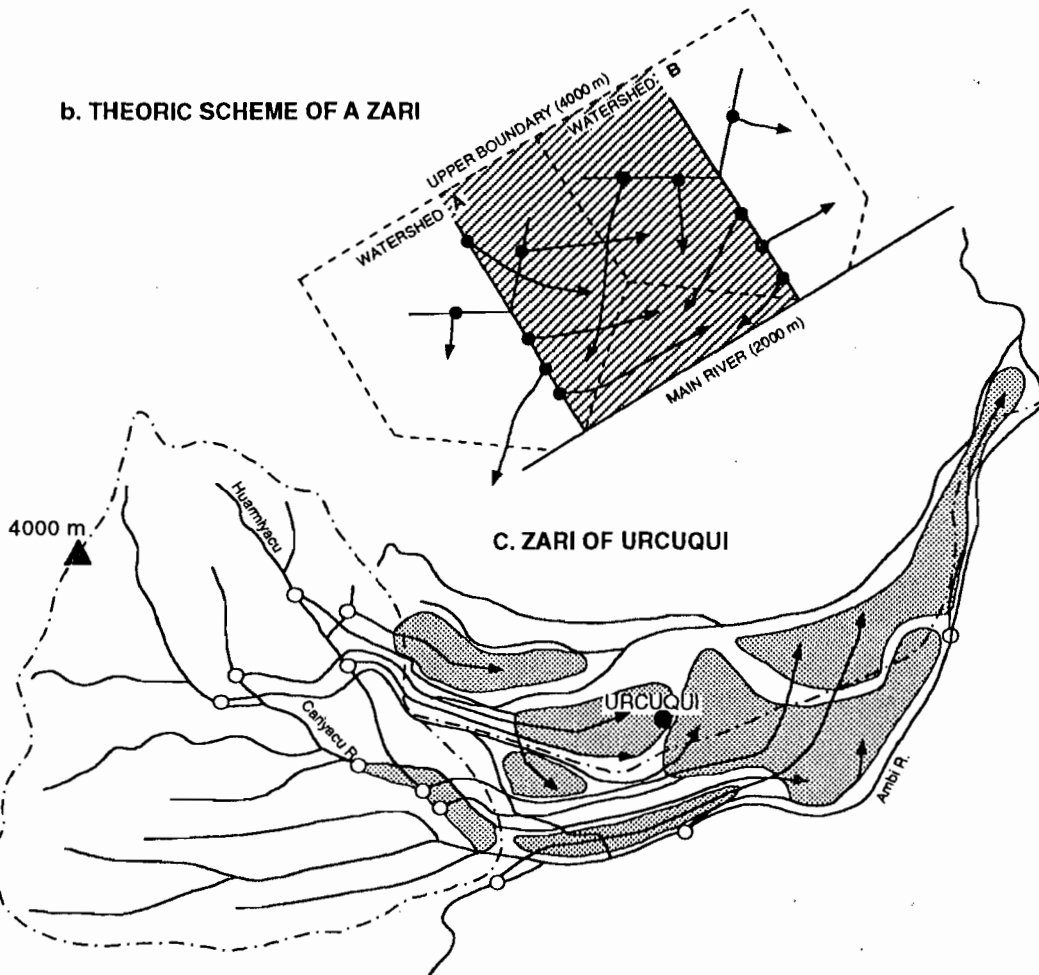
Its boundaries are formed by the important natural obstacles that the network cannot cross. Owing to its very pragmatic definition, the ZARI is the ideal unit of analysis, and it is also a consistent geographical unit on the social and economic level.

Naturally well limited, it has been inhabited for a long time by human groups who share a common history, sometimes in harmony, often with conflicts. Within each ZARI, the infrastructure has been laid down by the local labor force, with limited investments.



Reference for ZARI	AT MIRA (20 ZARI)	ZARI OF URCUQUI
Spatial dimension	50 - 300 km <sup>2</sup>	98 km <sup>2</sup>
Number of systems	10 - 20	17
Number of trenches	20 - 40	40
Length of transport	30 - 250 km	192 km
Diversion discharge of ZARI	300 - 5,000 L/s	4,496 L/s
Number of perimeters	7 - 32	32
Continuous flow rate in Perimeter	0.1 - 2 L/s/ha	0.05 - 2 L/s/ha

**b. THEORIC SCHEME OF A ZARI**



**Figure 2 - Theoric and actual examples of ZARI**

Any water transfer between ZARI costs more, requires a higher level of technology, and has regional repercussions. All the same, any transfer between watersheds in the sierra implies a big project which should be decided upon at a national level.

Thus the planning process can rely on these two space divisions which have a true geographical value, contain the production units, and can help establish the cost and impact of a development policy.

The size of the ZARI varies between 50 and 200 km<sup>2</sup> and its boundaries are established in two stages. Provisional boundaries are drawn up according to the topography and hydrographic network; then they are modified when the infrastructure and the irrigated areas are taken into account.

The Mira hydrographic watershed is subdivided into 20 ZARI (see figure 2a), generally created by the union of two half-unit watersheds (see figure 2b).

Normally no canal should cross over from one ZARI to another (see definition). Actually there are some interconnecting canals but they are rather unimportant channels that feed industrial crops (sugar cane, for example) or public networks.

So the definition of the ZARI is essentially adhered to and permits to lay down a preliminary classification of facilities according to their importance and impact.

**The ZARI forms the basic space unit**, on which the analysis and diagnosis are carried out according to the various concomitant operations which are being studied.

## 5. PHASES OF STUDY

The study is divided into six operations that fulfill precise purposes.

### a. Description of the system

The first operation (LOCIE) locates the irrigation systems and describes their functioning by ZARI and wide basin. The irrigated areas are delimited by photo interpretation and then by the analysis of the SPOT satellite pictures.

The system's condition and functioning are described in detail according to a logical code that divides the networks into unitary segments characterized by a function (supply, transport, distribution) and connected by operation junctions (combination-division). This coding is adapted to the complex systems and is easily computerized.

### b. System understanding

Two operations are designed to explain the organization and functioning of the irrigation systems. THANIE is the first and deals with the historical analysis of the irrigation in the Ecuadorean Andes since the colonial period.

The archive documents explain in large part the inadequacies of the infrastructure (redundancy of canals).

The second operation called TAPATRIE is carried out in one representative ZARI in each big watershed.

In the Mira watershed, the ZARI of Urcuquí was chosen (see Fig. 2c). It contains a very dry ecological environment (1800-2000 m) and includes the three major types of production systems: sugar cane haciendas, cattle-raising haciendas, and very small mixed farming.



Measurements and inquiries are carried out at three levels: ZARI and irrigated areas, farms, and plots of land.

The measurements aim at evaluating the water consumption at different levels and the efficiency of transport, distribution, and in the plot of land.

The inquiries give an idea of the water distribution and of farming productivities.

### **c. Characterization of the system**

A hydrological analysis (EGRADIE) calculates, on the one hand, the water demands at the level of the irrigated areas and the ZARI and, on the other hand, evaluates the available resources at the level of the unitary watersheds.

The water requirements are calculated after a very complete climatological analysis. It has been carried out using the regional vector method. The inventory data, completed by field measurements, provide the system's characteristics.

The water resources are evaluated using a hydro-pluviometrical model at a monthly time step. The intakes situated on the hydrographical network provide relation between the supply unit (unitary watershed) and the water requirements unit (ZARI).

Finally, a detailed study of the farming statistic (OCASEZIE) attempts to determine the realistic margin of productivity evolution in an irrigated area or ZARI by comparing the well-supplied areas with the ones where the water shortage becomes a restrictive factor.

### **d. Elaboration of diagnosis**

Each operation has to contribute to the formulation of the diagnosis. The results are gathered in several computerized data banks.

It is necessary to connect them to obtain a detailed panorama of private irrigation performances at the level of each ZARI, of its weaknesses and potential improvements.

That is the aim of the last operation (BIDRIE).

## **CONCLUSION**

Faced with an unknown and complex reality, the INERHI-ORSTOM project has elaborated a research methodology to support future decisions on irrigation development.

In the last two years a great number of partial results have been obtained in each operation. It is not possible to present all of them in this paper.

But, in contrast, the total results obtained at the level of some of the ZARI of the MIRA watershed have permitted to furnish various recommendations, which are presented in the paper entitled "Dysfunctions and Rehabilitation".

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