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TRADITIONAL IRRIGATION IN THE ANDES OF ECUADOR (1) RESEARCH AND PLANNING*

by P. LE GOULVEN[1] , T. RUF[1] , H. RIBADENEIRA[2]

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.

* IRRIGATION TRADITIONNELLE DANS LES ANDES EQUATORIENNES (1) RECHERCHE ET PLANIFICATION

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In Ecuador, the National Water Resources Institute (Instituto Ecuatoriano de Recursos Hidraulicos - 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-Ecuadoran 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 Ecuadoran Irrigation - Recommendations for the National Plan".

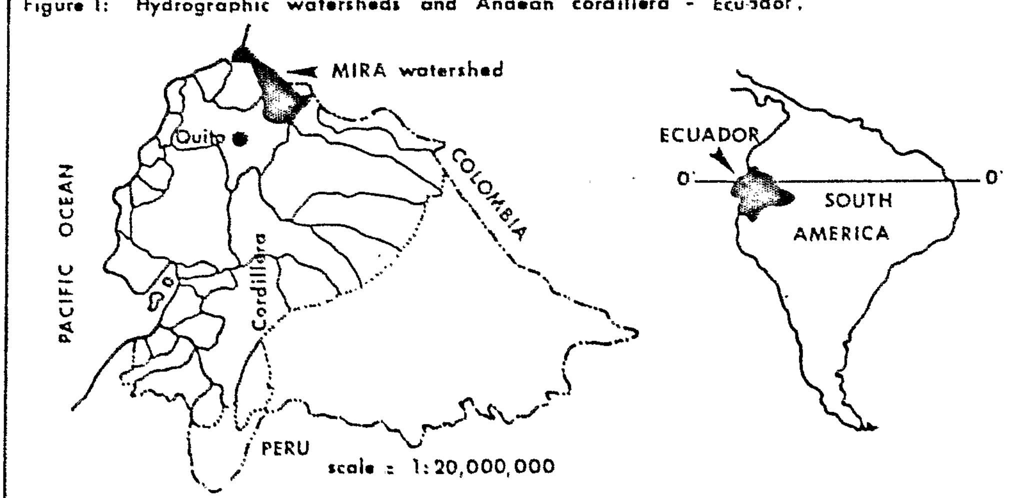
1. PRESENTATION OF STUDY AREAS.

Ecuador extends over 281.000 km2 in the northwestern part of the South American continent, between Colombia and Peru (see Figure 1).

The Andes Cordillera 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: <u>this is the project area.</u>

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 "paramos". Above 4300 meters, because of the frost, there is no vegetation, and permanent snow begins at 5.000 m.

The rainfall is heavy on both sides of the Andes and variable in the inner valleys. It can lower 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 lead 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 erect 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 responsability 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	m3/s
Average intake flow per canal	85	l/s
Total length of canals	1780	km
Average length of canal	6	km
Number of irrigated areas	275	
Total irrigated surface	53923	has
Pure private irrigation surface area and %	46728	has (87%)
Pure public irrigation surface area and %	2210	has (4%)
Mixed irrigation system surface and %	4985	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 Ecuadoran Andes.

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

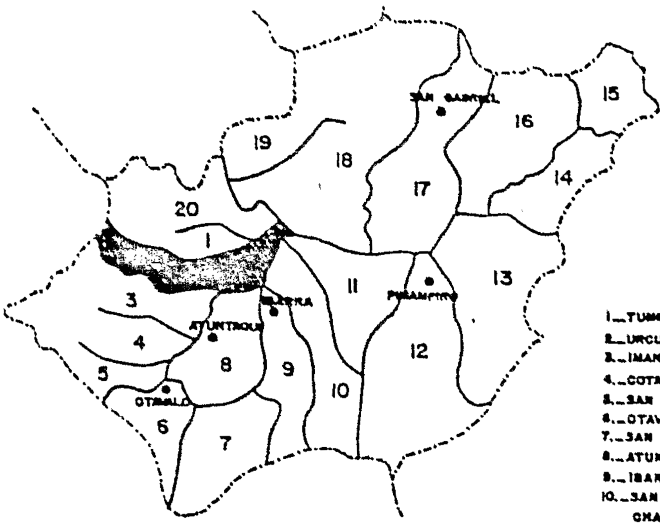
This notion, as appealing as it may be, is unfortunately not adapted to the study of the irrigation networks. The lower parts of the irrigated areas are flat enough to allow the mixing of canals of various origins. Even in the higher parts, the watersheds do not constitute an obstacle to the canals which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

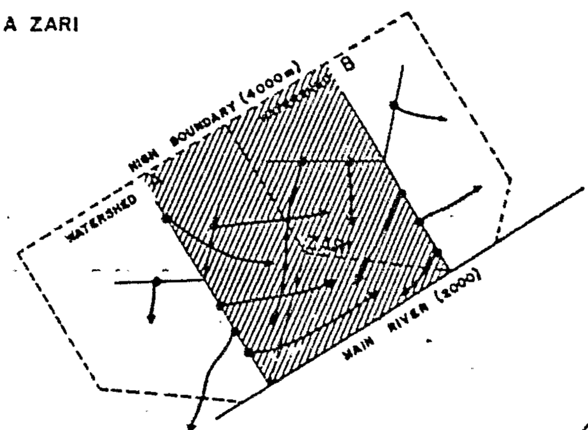


a._ ZARI'S OF THE MIRA WATERSHED

1._TUMBABIRO
2._URCUQUI
3._IMANTAG
4._COTACACHI
5._SAN JOSE DE QUICHINCHE
6._OTAVALO
7._SAN PABLO DEL LAGO
8._ATUNTAQUI
9._IBARRA
10._SAN MIGUEL DE YANUARCO-CHA
11._AMBUQUI
12._PIMAMPIRO
13._MONTE OLIVO
14._RIO MIRAS
15._JULIO ANDRADE
16._SAN GABRIEL
17._EL ANGEL
18._MIRA
19._LA CONCEPCION
20._CAHUASQUI

REFERENCE FOR ZARI	AT MIRA (20 ZARI)	ZARI OF URCUQUI
SPATIAL DIMENSION	80 - 300 Km^2	98 Km^2
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 6000 L/s	4498 L/s
NUMBER OF PERIMETRES	7 - 32	32
CONTINUOUS FLOW RATE IN PERIMETRE	0.1 - 2 L/s/ha	0.08 - 2 L/s/ha

b._ THEORIC SCHEME OF A ZARI



c._ ZARI OF URCUQUI

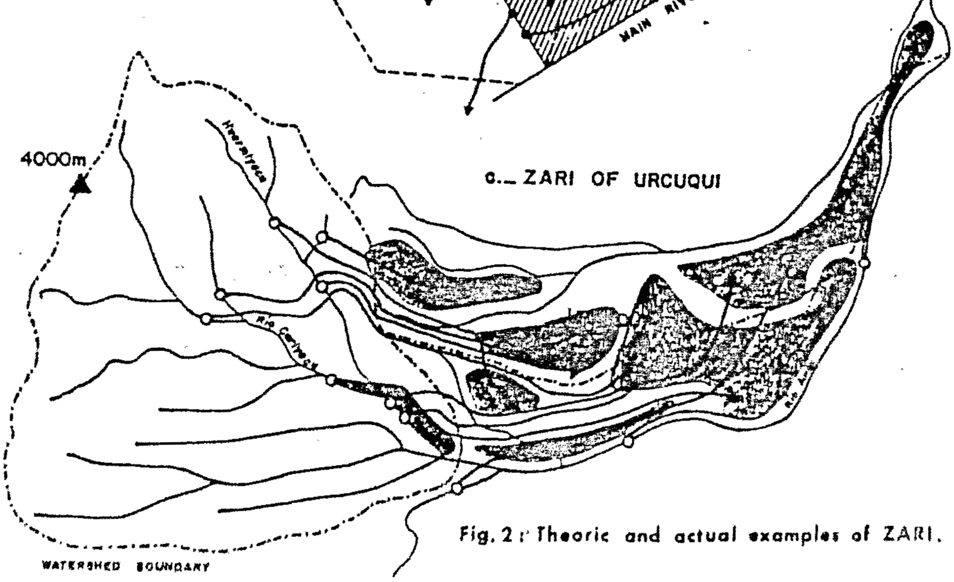


Fig. 2 : Theoric and actual examples of ZARI.

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 km2 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 Fig. 2a), generally created by the union of two half-unit watersheds (see Fig. 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 Ecuadoran 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 URCUQUI 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 resource 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 datas, 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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TRADITIONAL IRRIGATION IN THE ANDES OF ECUADOR (2) DYSFUNCTIONS AND REHABILITATION*

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Abstract

The multidisciplinary team of the franco-ecuadoran ORSTOM-INERHI project presents a synthesis of various dysfunctions which were identified during the surveys on traditional Andean irrigation areas in northern Ecuador.

The features of the diagnosis are formulated at different levels: relations between watersheds and ZARI (Zone of Analysis and Recommendations for Irrigation); between ZARI and irrigated areas; between irrigated areas and farming sistems; between farming sistems and crop plots.

It shows that the water shortage may be the result of many combined dysfunctions that have a negative impact on farmers' decisions: they prefer extensive forms of agriculture and therefore obtain low land productivity.

The authors propose as s preliminary task, in order to prepare the National Irrigation Plan, prospects to structure and organize the traditional networks.

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* IRRIGATION TRADITIONNELLE DANS LES ANDES EQUATORIENNES (2) DYSFONCTIONNEMENTS ET REHABILITATION

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The first report, "Traditional Irrigation in the Andes of Ecuador, (1) Research and Planning", showed how an international and multidisciplinary team had built a research methodology to prepare a Traditional Irrigation Development Plan. We emphasized how much this irrigation did not follow the usual standards. The originality of these systems, especially linked to the mountainous topography and history, justifies the research work on what does not function well along the water mobilization and utilization chain at different levels of the ZARI (Zone of Analysis and Recommendations for Irrigation).

From detailed studies of four ZARI that were selected as most representative, URCUQUI, PIFO, SANTA ROSA, and GUAMOTE, the major features of the diagnosis on the dysfunctions of irrigation in the northern Ecuadoran Andes were formulated and the first channels of improvement of the private networks started to be defined (see Fig. 1. Organization-Type of a ZARI and Location of the Different Problems).

URCUQUI, introduced in the first report, is a ZARI of the dry MIRA watershed in the northern Andes; it is made up of approximately 5,000 hectares irrigated by 17 traditional systems. PIFO is located close to the capital QUITO. Therefore, this ZARI, with its 2,800 hectares irrigated by 12 traditional systems, evolves under the influence of the urban outskirts. SANTA ROSA and GUAMOTE belong to the PASTAZA watershed, located in the middle of the country. These ZARI represent totally opposed situations:

- the first, SANTA ROSA, is exemplary owing to the high degree of artificialness of the Andean environment (very high population density - 300 inhabitants per square kilometer, 8,000 hectares irrigated by large traditional systems from 30 to 50 kilometers long, irrigated continuous crop systems in farming units of less than one hectare);

- the second, GUAMOTE, is a crisis area, abandoned by its inhabitants, and only the sectors that have irrigation networks (of limited scope) remain populated, even though they are deeply affected by seasonal migrations.

1. SUPPLY DYSFUNCTIONS AT THE WATERSHED LEVEL.

1.1 Very poor low-water flows, owing to severe drought even in the high-mountain areas.

Areas that are potentially irrigable do not have any facilities. In the river watershed, only a dam would allow to increase the supply during the dry season. In certain cases, a transfer from a neighboring watershed that has a supply which exceeds the demand could solve the water shortage problem. These cases are rare. They imply prior legal and political agreements and sometimes high investments if the transfer requires special work (tunnels). This problem goes beyond the limited field of rehabilitation.

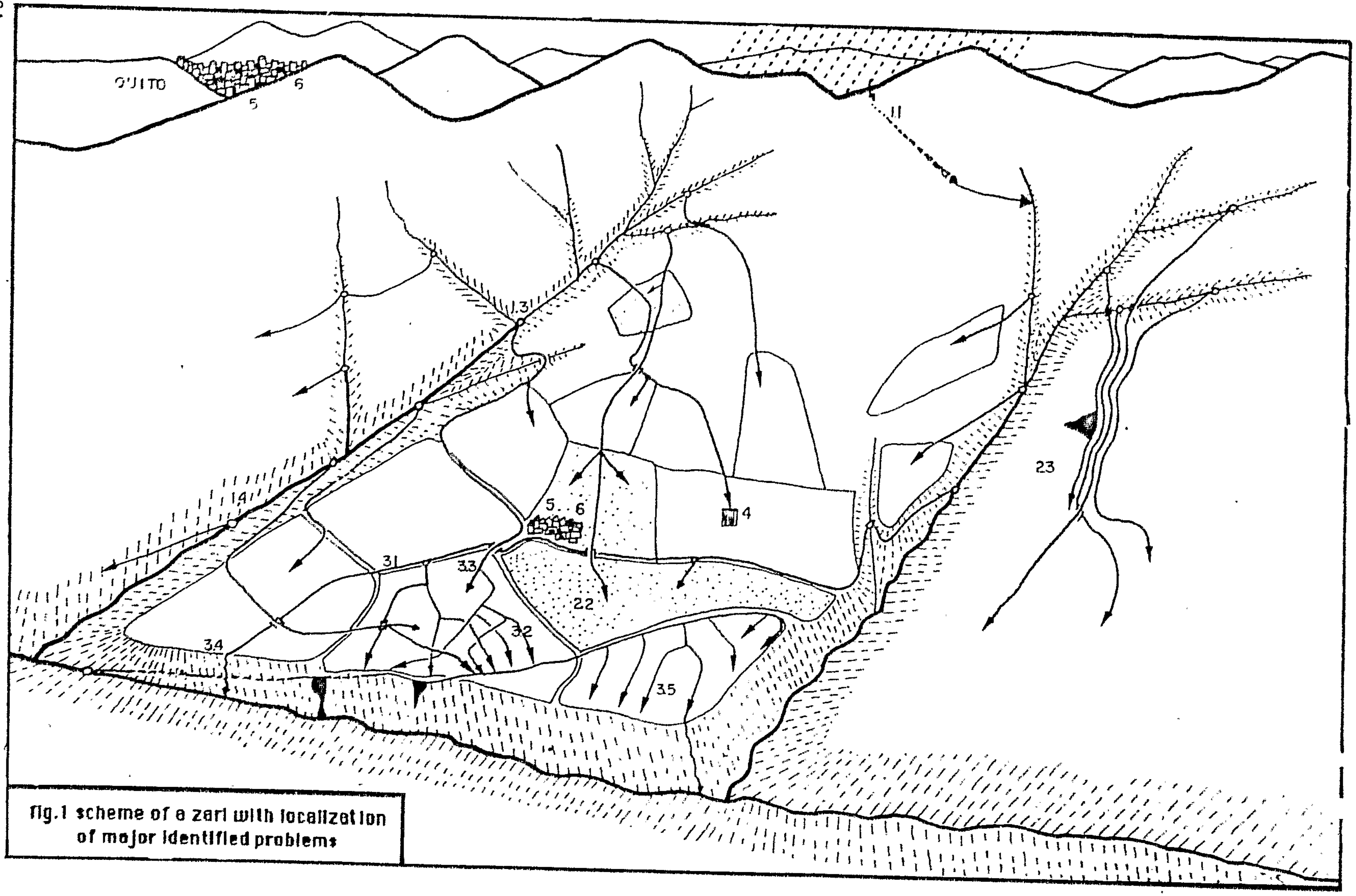

fig.1 scheme of a zari with localization of major identified problems

1.2 Large but inaccessible flows because the gorges are too narrow, the geomorphology is unfavorable, etc.

As before, the areas suffer from a shortage of water, but this time the farmers see the water pass at a few tens or hundreds of meters beneath their land. In certain cases, a dam to raise the water level could facilitate the installation of facilities or the enlargement of those that already exist.

1.3 Highly variable hydrological rhythms with sudden and destructive overflows.

The water intakes are regularly flooded. The irrigated areas are periodically deprived of water. If the damage is considerable, the farmers run the risk of losing part of their crops.

This type of accident (we will see later on that there are many more) becomes even more dramatic if the social organization that manages the system is disorganized.

A modern intake construction program could make the irrigation systems in the aggressive watershed less vulnerable.

1.4 Drying up of the river downstream from a series of outlets.

The areas that are irrigated from downstream intakes systematically run the risk of being short of water. This situation is often the result of a lack of coordination to manage the water resource. It may be accompanied by downstream/upstream conflicts that can go as far as an "intakes war", that is, the alteration and sometimes even the destruction of the facilities.

Solutions to this problem are not easy, because each of the groups involved claims inherited water rights.

In this type of case, it is better to no longer grant any additional concession and to organize a joint effort among the irrigating organizations.

The installation of the intakes and the discharge regulators planned in the concession documents should indeed be carried out with financial and technical support.

2. DEMAND PROBLEMS AT THE INFRASTRUCTURAL LEVEL IN THE ZARI.

2.1 Poor average continuous fictive discharge, owing to lack of available water resources in the watersheds that feed the network.

This case is a translation of the two first kinds of problems already described concerning the watersheds.

When the watersheds do not function in the same way, it may be useful to restructure the networks combining the supplies of the two watersheds towards the crest of the interflow.

Thus a greater regularity and security of the distributed flows would be obtained.

2.2 Considerable disparity in the distribution of the supply, even taking into account the normal variabilities owing to the altitude.

Certain irrigated areas are supplied by a continuous fictive discharge of 2 liters per second per hectare whereas others have only 0.1 or 0.2 liter per second per hectare.

In the landscape this gives a mosaic of highly heterogeneous areas with respect to crop-raising during the dry season.

In the case where the water resource is limited compared to the requirements, it is possible to revise the concessions or, by installing modern intakes, to avoid excessive impoundments of water which would be detrimental to the other systems located downstream.

When the water resource is not limited, an enlargement of the deficient systems could be considered. A poor supply may be due to the deterioration of the canal owing to a lack of maintenance.

For instance, the absence of maintenance to clear the sand from certain parts may, over time, considerably minimize the channel discharge capacity and reduce even more the water supply of such or such a system.

2.3 Too high canal density, which makes it very difficult to maintain all the systems and provides linear or punctual losses, whether of natural or social origins (theft, conflicts).

One solution would consist of simplifying the network especially when the canals run along parallel lines

Moreover, in this type of situation, chain accidents occur when the upper canal breaks following an overflow or a mudslide. The weakest areas should be reinforced by means of special works and protected from streaming if the latter produces dangerous overflows.

Protection against erosion and soil accumulation in the canal can be improved by planting thick hedges above the canal segments in question.

Finally, we have observed that certain sectors are very difficult to reach. Their maintenance would be facilitated if accessways and maintenance roads were built.

3. DYSFUNCTIONS IN THE DISTRIBUTION IN THE ZARI.

3.1 Absence of a rotational working, as a consequence of which there is an unequal distribution among the upstream and downstream users on the distributors.

This lack of rules and regulations to share the water resource occurs in four kinds of cases:

- the number of users is low and water distribution is decided upon from day to day according to the needs of each user: over time and with the parceling of the land, the number of users increases and the first difficulties arise

- the users have just acquired a concession over the canal, for example, when haciendas are divided into lots and sold, and they do not know how or are unable to get organized to set up a rotacional system.

- the users were organized to set up a rotational turn distribution, but because agriculture is no longer a prime activity, the rules have been more or less ignored.

- the users are organized but their number is so large--and their conflicts so intense--that the rotational sistem does not operate well; the planned schedules are not adhered to, the accumulation of delays leads to irrigation cuts.

3.2 Very long transport time in the distributors which sometimes consist of a veritable maze of intermeshed watercourses.

The distribution systems can be explained by the history of transfers of water rights and the sales of user time for the various distributors.

Its efficiency is poor insofar as the water does not always run from one plot of land to the next but rather follows the order established by water rights.

A reorganization of the rotational working would be desirable, although this is generally hard to accept for the users who are accustomed to certain irrigation schedules, especially when this requires that the irrigation take place during night hours.

The distribution could be modernized by installing a permanent module for each sector which would be managed by the respective group of farmers.

To ensure a minimum of fairness in the distribution from a given module, it would seem that the safest method of distribution would be the one that delivers the module first to the last user of the distributor and then the outlets would be open from plot to plot until it reaches the first user (this already exists in certain systems).

Sometimes the distribution works on an alternating basis, so that the last user of the water schedule would become the first for the following irrigation and vice-versa.

3.3 Considerable irregularity of the modules delivered from one irrigation to another, owing at the same time to the above-mentioned dysfunctions in the watersheds and the facilities, but also owing to the fact that the generally rustic dividing junctions do not always distribute the discharge that come to them in the same way.

In reality, the problem is not so much the distribution of water among users but rather the distribution, when it does exist, of the water shortage in the fairest way possible to the users.

Providing the networks that suffer from a considerable flow disparity with proportional outlets seems quite attractive.

3.4 Considerable losses during the night when the farmers do not use night irrigation or put it into practice carelessly and when there are no tanks.

Night irrigation on steep slopes is always difficult to manage. During the night water theft is most frequent, and it is at this time that it is most difficult to reestablish the normal discharge.

The installation of a tank with a capacity that corresponds to the night stock would be an invaluable aid for managing the traditional systems. Such programs already exist , but without a systematic modernization of equipment in an entire ZARI.

In the absence of a tank, there are several solutions available to distribute the night hours to all the users.

The night hours can be assigned on an alternating basis each year. This solution, which seems equitable, hardly modifies the night losses; it only obliges everyone to share the unfavorable conditions every other year.

The frequency of the water shift can also be modified, adopting a period based on an incomplete number of days. For example, instead of seven days, the period could be six days and a half, with one day of service interruption after two periods or two days every four periods for carrying out network maintenance. Thus, each farmer irrigates on an alternating basis during the day and at night during the whole year.

This arrangement can be refined even further by using a period of six days and three fourths, which would lead the users to set back their irrigation schedule six hours from one shift to another and to limit the service interruption for maintenance purposes to only one day every four weeks.

Such changes are hard to effect for they upset habits and interests that have been well established over a long time. But if these changes are thoroughly explained and if they are able to convince the users as a whole, it is possible to considerably improve irrigation conditions both fairly and safely.

3.5 Frequency of irrigation that is poorly suited or inappropriate for intensifying agricultural production systems.

There are areas where the rotational turn takes place over a period of 15, 16, 17, or even 21 days, which virtually prohibits the farmers from choosing crops that demand a great deal of water, during dry seasons when requirements are very high.

It must be emphasized that the usable soil reserves are often poor; the Andean soils contain a high proportion of sand, to such an extent that certain irrigated soils are deemed unsuitable for irrigation in the international manuals. One frequently finds easily usable reserves on the order of 30 mm, which requires an irrigation frequency of about 7 days and not 14 or 21 days.

It is not an easy task to manage this problem for it is generally linked to a considerable disequilibrium between supply and demand.

So that each user can enjoy the privilege of a decent dosage of irrigation, taking into account the time consumed in transfers, the rotational turn should have to be prolonged, but the longer it is the less useful is the irrigation.

Moreover, the risk of having the irrigation withheld is undesirable, as it would mean that the crop under cultivation would have to wait one month or more without any artificial supply. The peasants can only then rely on a redeeming storm, which is paradoxical when one knows that an irrigation infrastructure does exist.

Shortening the frequency would imply significantly increasing the supply.

4. APPLICATION DYSFUNCTIONS AT THE SMALL PLOT LEVEL

4.1 Unsuitable module.

- A module that is sometimes too weak (lower than 5 liters per second), which implies, on the one hand, very long irrigation times by hectare (up to 24 hours or more) and, on the other hand, application difficulties with respect to the arrangement of the furrows: the former sectors end up by being over-irrigated whereas the latter are under-irrigated.

- A module that is sometimes too strong (more than 20 liters per second), which produces erosion because there is no way to control the volume of water that keeps coming into the plot of land. Only by creating buffer tanks would it be possible for the irrigators to select a module that is suitable for their soil, work, and rotational system limitations.

4.2 A poorly performing irrigation arrangement.

- In certain cases, the irrigator merely "throws" water over the upper part of the plot without ever directing it. The water follows the micro-thalwegs and ends up generally by going out of the plot until the irrigator returns.

- In other cases, the irrigator does not optimize the distribution of water: in accordance with the module he has at his disposal and his soil characteristics, he can take advantage of the length of the furrows and work time to correctly distribute the amount of water that reaches the totality of the plot.

It is obvious that the users do generally lack appropriate technical advice and the necessary technical know-how to improve the application.

To explain the water shortage that the irrigators complain about, there is also the fact that they all waste water in their fields.

The promotion of small experimental stations managed by the irrigator associations with the technical support would allow for a better rationalization of the applications.

5. PRODUCTION SYSTEM FUNCTIONING PROBLEMS AT THE AGRICULTURAL DEVELOPMENT LEVEL.

In addition to the eventual limitations linked to the shortage of water, there are a series of socio-economic and technical problems that the farmers take into account when they choose their productions and implement agricultural techniques: lack of capital, credit, equipment, labor force; uncertain marketing outlets; lack of organization and market controls.

Other factors lead to various difficulties: extreme parcelling of the plots in certain irrigated areas, which makes the distribution all the more complex.

In such conditions, water usage proves to be extensive and is sometimes limited to irrigating natural prairies in order to maintain cattle whose main function will be economic: it will allow the farmer to rely on saving in an uncertain economic environment.

With this respect, it is quite curious to note that in Ecuador there is virtually no stocking of fodder neither among the peasants nor in the haciendas..

These aspects of farm management lie outside INERHI's traditional field of intervention.

Nevertheless, they must be taken into account as a part of the planning.

For example, it would be meaningless to rehabilitate the network in a ZARI which has been abandoned by its inhabitants who have gone to work in the city.

6. DIFFICULTIES EXPERIENCED BY THE IRRIGATING ORGANIZATIONS IN THEIR INNER AND EXTERNAL RELATIONSHIPS.

We are at present witnessing a multiplication and atomization of the irrigators' associations which have very severe repercussions on the management of the irrigation systems as a whole: the functions of "water police" and works maintenance are endangered by recurrent conflicts.

External interventions, whether they are public or private, affect only limited groups and do not take into account all the users and systems as a whole.

These phenomena are quite serious, for the maintenance of traditional networks largely rests on a very strong social cohesiveness among the users.

If some of the groups find themselves affected by thefts of water, without any specific improvements, they will tend to refuse to participate in the collective works that aim at maintaining the canals. The conflicts could go so far as sabotaging the work then proceed to direct confrontations

On the short and medium term, such an evolution could only culminate in an agricultural recession, the risk of running short of water leading the involved farmers to choose even more extensive production systems.

On the medium and long term, the major risk lies in the disappearance of certain systems because of a lack of regular maintenance.

In order to prevent such an evolution, it would seem appropriate to propose from outside some global rehabilitation projects on a ZARI as a whole and probably to reinforce the role played by the irrigator associations by organizing them in a federation , so that they will become partners in the rehabilitation projects.

CONCLUSION

The franco-ecuadoran team started first by identifying the many problems that are involved in, and explain to a large extent, the poor performances of traditionnal irrigation systems and then will carry out an in-depth survey of each problem area and attempt to provide data on the impact of the various dysfunctions that have been identified.

In a second phase, the team will set up a network improvement plan adapted to each type of ZARI, which should give maximum efficiency to the public financial assistance that is being provided for modernizing the Andean irrigation systems.

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