Diagnostic Analysis of an Irrigation System in the Andes Region

Bruscoli[1], P.; Bresci[2], E.; Preti[3], F.

[1] Univ. di Firenze (Italy), Dip. Ingegneria Civile e Ambientale,
[2] Univ. di Firenze (Italy), Dip. Ingegneria Agraria e Forestale,
[3] Univ. della Tuscia (Italy), *corresponding author: preti@unitus.it*
Ist. di Genio Rurale, via s. Camillo de Lellis, 01100, Viterbo, Itally

ABSTRACT

The recognized inefficiency of many irrigation systems, set up in developing countries in the past years, forced the attention to be focused on the investigation of the causes of such a failure. The diagnostic analysis, an investigation process which aims at revealing problems, causes and effects related to the relevant actors involved in the system, has been applied to the Chambo irrigation system, located in an area of the Andes of Ecuador, 200 km south of Quito.

Since the focal point of such a methodology is the user participation, through an information survey collected directly on the field, the «problems» were singled out, and were classified according to cause-effect relations and structured into a problem tree. This process allowed to defining the objectives and the proposals for solutions which were worked out by considering transferability and sustainability by system users.

Solutions to one of the main reason of interruption in the water supply service, slope landslides, have been proposed using bioengineering interventions on the sides facing on the adduction channel. Bioengineering interventions are proposed based on the success they got in other parts of the world, mainly for the abundance of materials that can be found in the zone. The transferring of such technologies was also taken into account based on a bibliographic research.

The analysis showed that the success of an irrigation scheme relies on the expectation of its future use.

Keywords: Irrigation, Rehabilitation, User Participation, Bioengineering Slope Stabilization

INTRODUCTION

The rapid wide-spread growth of irrigation over the past forty years has increased the production and the safety of crops, boosting hopes to reduce the problems of hunger and malnutrition in developing countries.

The global rate of irrigation growth was about 1% per year in the early 60's, it reached a peak of 2.3% from 1972 to 1975 and, afterwards, it began to decrease to the present 1% (Neri, 1996). The first reason of such a decrease can be seen in the fact that the most suitable lands for irrigation have already been exploited. The second reason can be the scarcity of water for irrigation: examples of conflicts between civil and industrial use of water arose in the Middle East and in North Africa due to a drawing of more than 70% of the available water resources.

To face up to the water scarcity problem and to the necessity of water conservation, an increment in more efficient use could be an appropriate solution to the problem. In a situation where the 80% of the available water is used in agriculture, a 10% increase in irrigation efficiency would guarantee 50% more water for civil and industrial uses. The third reason for the irrigation expansion slowing down relies on the result of many irrigation projects which have uncovered many disappointing aspects: higher than expected costs, poor managing capability, failures of planned objectives, negative effects on the environment and public health and the sometimes worsening of conflicts among farmers.

During the 70's, it was realized that there was an enormous gap between the effective performance and the potential efficiency of many irrigation systems. Therefore, the attention was focused on the improving of existing systems rather than set up new ones, developing a pattern in order to understand the real workings of the systems, underlining strong points, limits and, when necessary, evaluating new solutions suitable to different environments. According to Clyma et al. (1977), a thorough knowledge of the whole farming system was required instead of focusing on single factors or restricted components of the farming system.

Irrigation system diagnostic analysis is useful in evaluating the irrigation systems' effective functioning through field studies with farmer participation. In the present work, the methodology is applied to an irrigation system in South America to evaluate the possibility of its sustainable rehabilitation and management.

DIAGNOSTIC ANALYSIS PROCEDURE

The diagnosis of a situation or a system can be viewed as the process for solving a problem by identifying its cause or causes and qualifying and quantifying its effects. Analysis can be understood by examining the methods of ordering, presenting and using information.

Diagnostic analysis is defined by Podmore (1983) as an ordered method/structured investigation of examining an irrigation system to identify its values and constraints (Falciai, 1996). Although problem solving, and therefore diagnostic analysis, is as old as mankind (and probably older), it is only recently that it is being applied in a structural manner in the domain of irrigated agriculture. During the 70's, it was realized that the context of the future users play an important role in the introduction, adoption and use of a given technology. The agricultural research began to take into consideration the complex reality of the farmer.

In 1974, the Colorado State University together with the Pakistan government started the On-Farm Water Management Research project dealing with the irrigation water management in Pakistan. They developed and applied, for the first time, the so-called development model (Clyma et al., 1977), distinguished in three phases: diagnostic analysis (examining both the values and the constraints of an irrigation system), development and assessment of solutions (selecting and testing the potential improvements to the system in which constraints are removed and effectiveness improved is done), program implementation (choosing and developing an improvement program based on selected solutions). Some limitations of such a model are the limiting approach to farm level and the implication of organizational changes. The original idea of the rapid transfer of appropriate technology to feed deficient nations has been replaced by a transfer of technology idea in which the need was stressed to understand the farming conditions.

In diagnostic analysis, «system-oriented» and «problem-oriented» approaches can be distinguished. The first one assumes that the best way to identify the problems and constraints of a system is through the analysis of the whole system; the latter one starts from the assumption that it is possible to identify and define the problems of any system without having complete knowledge of it. Upon the identification of the problems - by system users as well as by the management staff - only the data and information which lead to the adequate definition of these problems should be collected. The solutions to these problems should lead to the improvement of the overall situation.

In the present work, the problem-oriented approach is used, according to a recently developed problem-solving method, the Objectives Oriented Project Planning (OOPP), created by the United States Agency for International Development (USAID) and further developed by the Deutsche Gesellschaft fur Zusammenarbeit in 1986. The underlying idea of the method is that objectives can only be formulated after the essential cause-effect relationships of the problem have been analyzed. Causes of a problem are visualized in a so-called problem tree, which arranges the identified problems according to their direct cause-effect relationships. By transforming the problem tree into an objective tree, causal mean-end relationships result and these can be considered as an indication of potential objectives to be pursued by the project.

To increase acceptance of project planning and to ensure including the hypothetical needs and interests of the system users in the planning, the OOPP uses a participatory approach to the analysis, through a so-called OOPP session or meeting. The procedure of the OOPP meeting is as follows:

1. the objectives and scope of the OOPP session are determined;
2. the problems related to the topic are identified and discussed. All participants are free to identify problems and possible causes for identified problems;
3. a problem tree is constructed by organizing the problems into cause-effect relationships. The principle of the problem tree is that a cause of a problem itself constitutes a problem at a lower level and again has its cause or causes, which in their turn may constitute problems. The problem tree is completed at the level where problems become basic, i.e., their causes can no longer be defined as problems themselves;
4. the objective tree is compiled by reformulating problems into objectives. Mean-end relationships are checked to determine required inputs and effects of the defined solutions;
5. the project focus is determined;
6. project planning is prepared, inclusive of staffing, responsibilities and time schedules.

Aside from some limitations, the OOPP greatest merit is that it involves the different actors in the discussion of the project planning. Most participants in the OOPP share their perception of the problems with people of different backgrounds for the first time. OOPP sessions should be chaired by a competent moderator, who should facilitate open communication by encouraging the participants to explain their points of view.

The following two approaches can be used in combination with or in support to diagnostic analysis, the Rapid Rural Appraisal (RRA) and the Participatory Rural Appraisal (PRA). RRA is a systematic semi-structured activity carried out in the field by a multi-disciplinary team designed to quickly acquire new information and new hypotheses for rural development (Chambers, 1992). Its goal is socially acceptable, economically viable, and ecologically. PRA, derived from RRA, is a thorough and rapid investigation involving the active participation of the community of the local users. It helps communities to mobilize their human and natural resources in the definition of the problems, by considering previous successes, evaluating local institutional capabilities, prioritizing opportunities, creating a setting for intensive collaboration among farmers, specialists and institutions and integrating traditional knowledge and skills with external technical knowledge during the process of development.

CASE STUDY: THE CHAMBO IRRIGATION SYSTEM

Diagnostic analysis approach is applied to the Chambo Irrigation System (Proyecto Chambo, 1995), situated in the Ecuador Chimborazo province, near the town of Riobamba, about 200 km south of Quito (fig. 1). The irrigation perimeter, surrounded by step slopes, covers an area of 90 km^2 and climbs up the Andes mountains, 2.800 m a.s.l.. The current configuration of the system is characterized by the presence of a main adduction channel, with a 5 m^3/s flow, which diverts the Chambo River, a tributary of the Amazon basin, and channels it into the secondary derivations along a course of 51 km.

The gravity irrigation system is divided into eight zones where water distribution is through open and pressure channels. The two main pressure derivation works are a 11 km pipeline which provides water to seven reservoirs limiting irrigation to daytime, and a second pipeline, the Guano Siphon (near Guano city), which links the irrigation system to a faraway area, morphologically cut off by a deep valley.

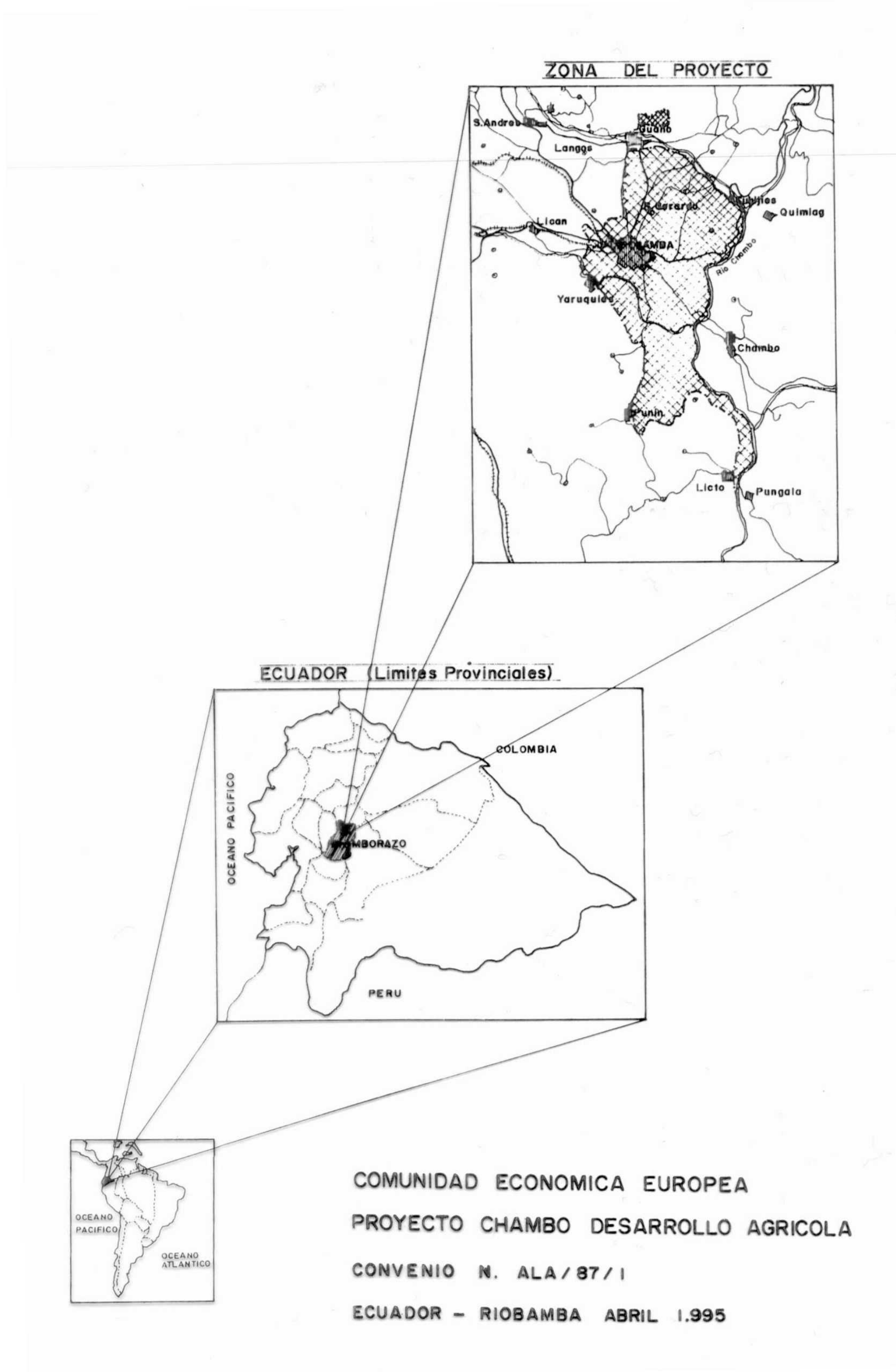


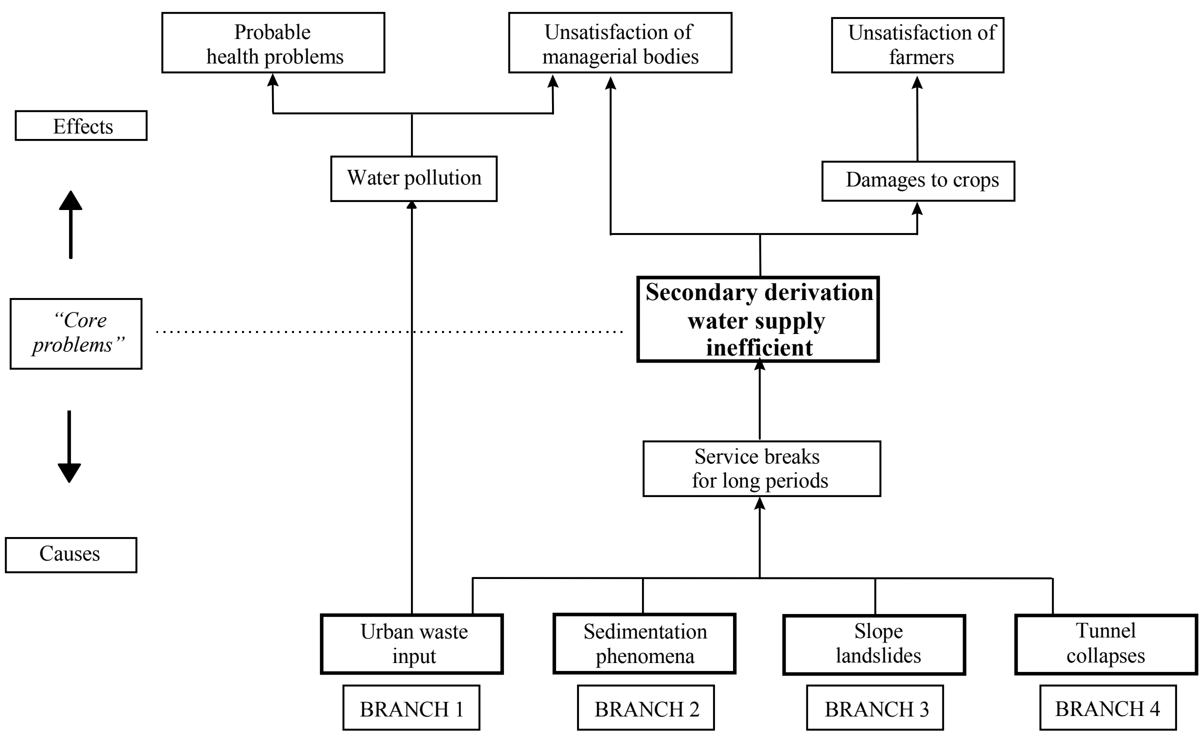
Figure 1 - The Chambo Irrigation System in Chimborazo (Ecuador)

An historical background on the phases which have characterized the system life, (INERHI et al., 1982; Linoli et al., 1993) is given in order to better understand the actual situation and to better develop the analysis and fully understand which actors are now working in it. The system was set up in the 40's, planned and realized by a government agency which, after many failures of the system in the 80's, sought European Community technical and financial help. In the following decade, up to today, the government agency has progressively reduced its presence in the system, in terms of financial resources, as the user organizations have improved their managing skills. Today, the European Community is involved in the *Proyecto*

Consolidación del Chambo, Convenio Ala 87/01, which has a managing and technical-financial aid role. The user organizations are composed of 82 communities, defined *Juntas de Regantes*, and their representative body is called *Corporación de las Juntas de Regantes.*

DIAGNOSTIC ANALYSIS APPLICATION TO THE CHAMBO IRRIGATION SYSTEM

Diagnostic analysis is applied to the sub-system "adduction system", referring to the functioning of the main adduction channel. The work is carried out in three different phases; the preliminary objectives are defined, and the survey phase follows. Using a PRA methodology, with the participation of the different actors, data are collected about the channel conditions through interviewing, and tables are prepared summarizing the characteristics of the open channel and tunnel tracts. The third phase of problem analysis is developed with an OOPP methodology, structuring the problem tree. During meetings with the government agency, the system users and the managers of the project, problems are analyzed and structured, itemizing the relative causes and effects. A core problem is identified: water supply service to secondary derivations results inefficient, causing dissatisfaction of the users and of managerial bodies and the slowing down of rural development. Subsequently causes are structured. The long service interruption, up to three months, was due to different reasons: problems of conflict with urbanized areas, problems of high sedimentation in some open channel and tunnel tracts, problems of instability of the slopes and the sides of the channel and



problems of instability of the tunnels. From the main problem tree, four branches are developed (fig. 2).

Figure 2 - Problem tree

The problems of interaction with urban areas (solid waste input, fig. 3) were due to a lack of good protection structures at the sides of the channel and to unchecked urban expansion. The immediate effect was a possible obstruction of the channel section, with an interruption of the flow and damages to people living near the channel, because of the consequent overflowing, as had frequently happened in the past.

For sedimentation phenomena, the causal chain was more complex. The first cause was the instability of the slopes and of the channel sides, which could cause input of solid materials in the channel without the possibility of efficient clearing because of the lack of settling basins. Poor maintenance caused the growth of vegetation in the channel with increased flood resistance. The effects of the problem are high costs for the annual channel cleaning currently carried out using tools supplied by the Project.

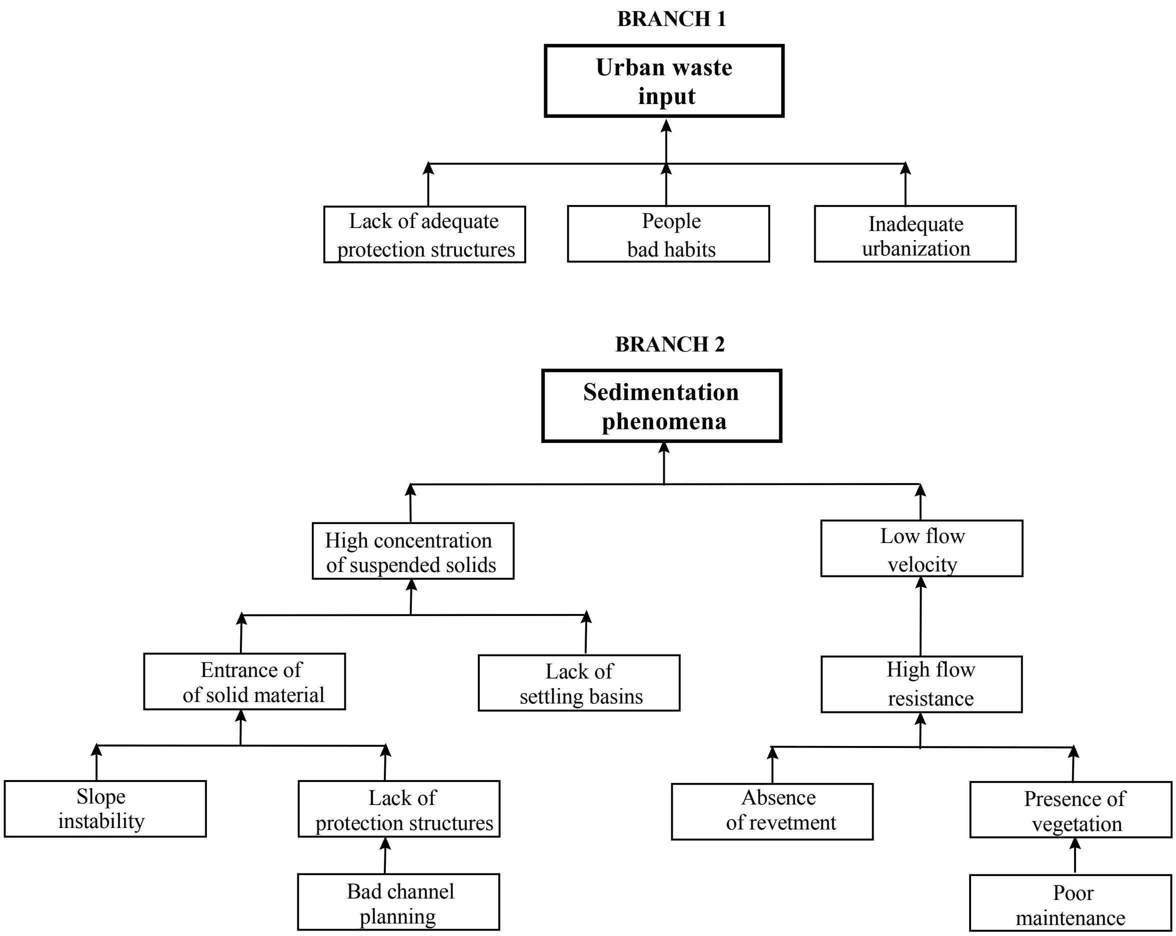


Figure 3 - Branches 1 and 2 of the problem tree

The lack of stabilization works and forest covering, following negative exploitation by local communities, has caused the instability of the slopes (fig. 4). The effects are obvious: major landslides cause continuous and ongoing breaks in the service, especially during the night. If the flow is not promptly stopped by closing the floodgates, it floods outside critical points of the channel and the slope erosion and collapse determine damage to crops and villages downhill.

Tunnel instability (Marchetti, 1994) is due to an incorrect construction: rocky materials with scarce mechanic resistance are crossed and reinforced; concrete covering is lacking. In the case of collapses, service interruption is lengthy because of the difficulty to reach the collapsed tunnels.

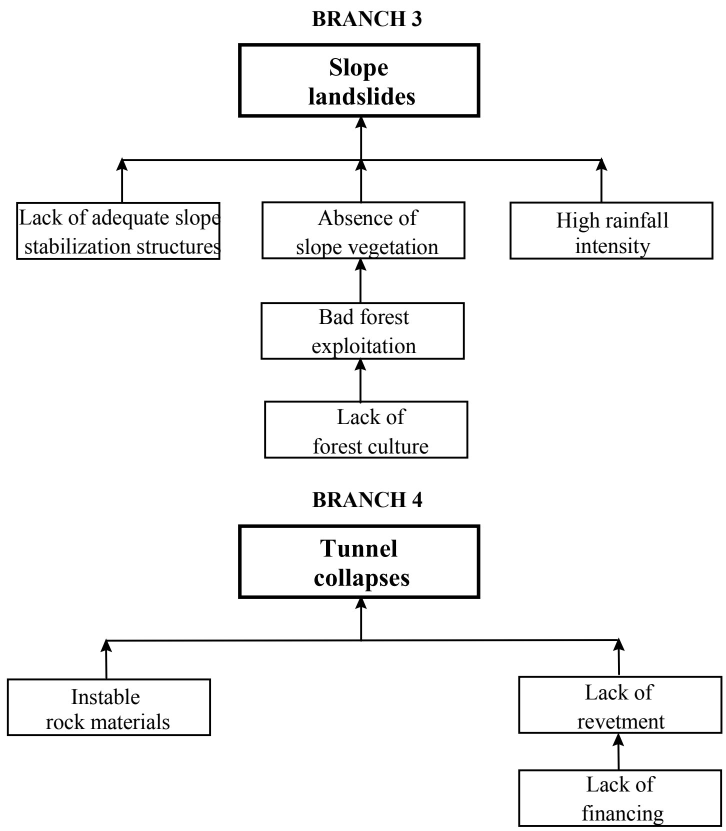
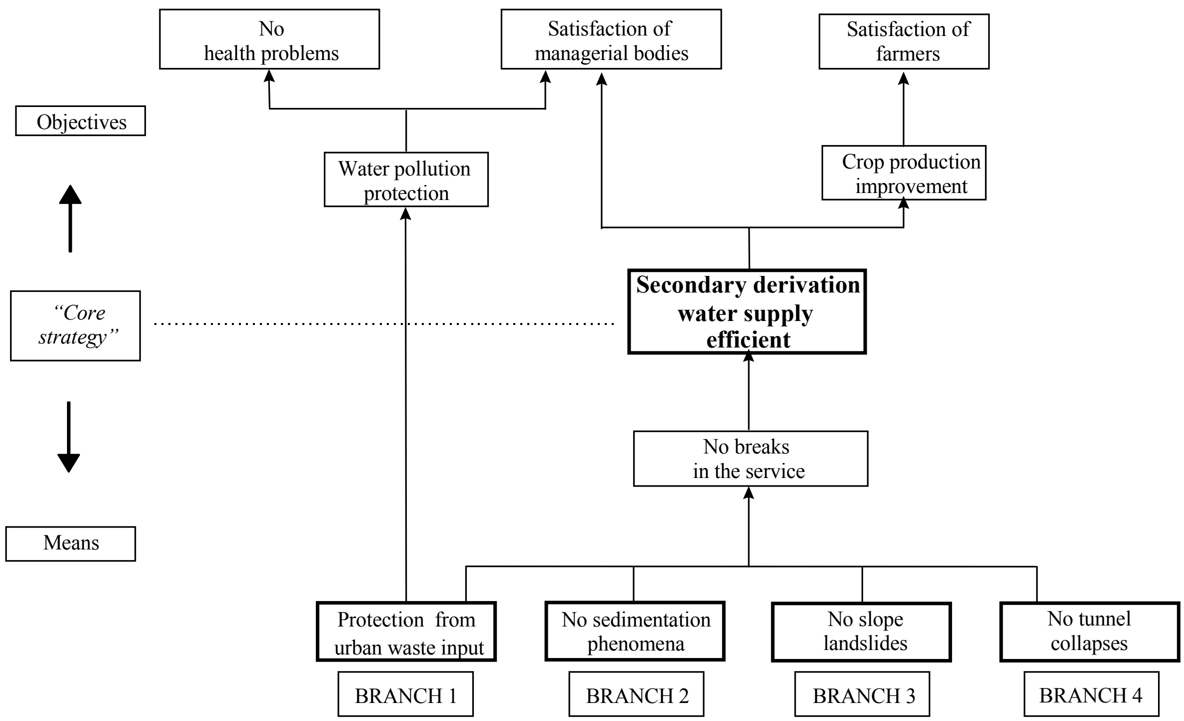


Figure 4 - Branches 3 and 4 of the problem tree

The problem tree is then transformed into an objective tree (fig. 5, 6), where effects become goals and causes become means. The results of such an investigation point out the necessity of avoiding the input of waste materials in the urban areas, of cancelling sedimentation phenomena and of stabilizing slopes and tunnels. The actual possibility of achieving these objectives is evaluated in the following phases, developing more branches of the objective tree and identifying intervention strategies:

- *the realization of appropriate protection structures of the channel;*
- *the realization of a settling basin;*
- *a section covering;*
- *covering of the tunnels;*
- *bioengineering interventions;*
- *adequate forest exploitation;*
- *increased awareness of a forest culture;*



- *awareness of management aspects.*

The last two strategies are introduced to generate favorable conditions for the following phase of user management and maintenance of the interventions.

Figure 5 - Objective tree

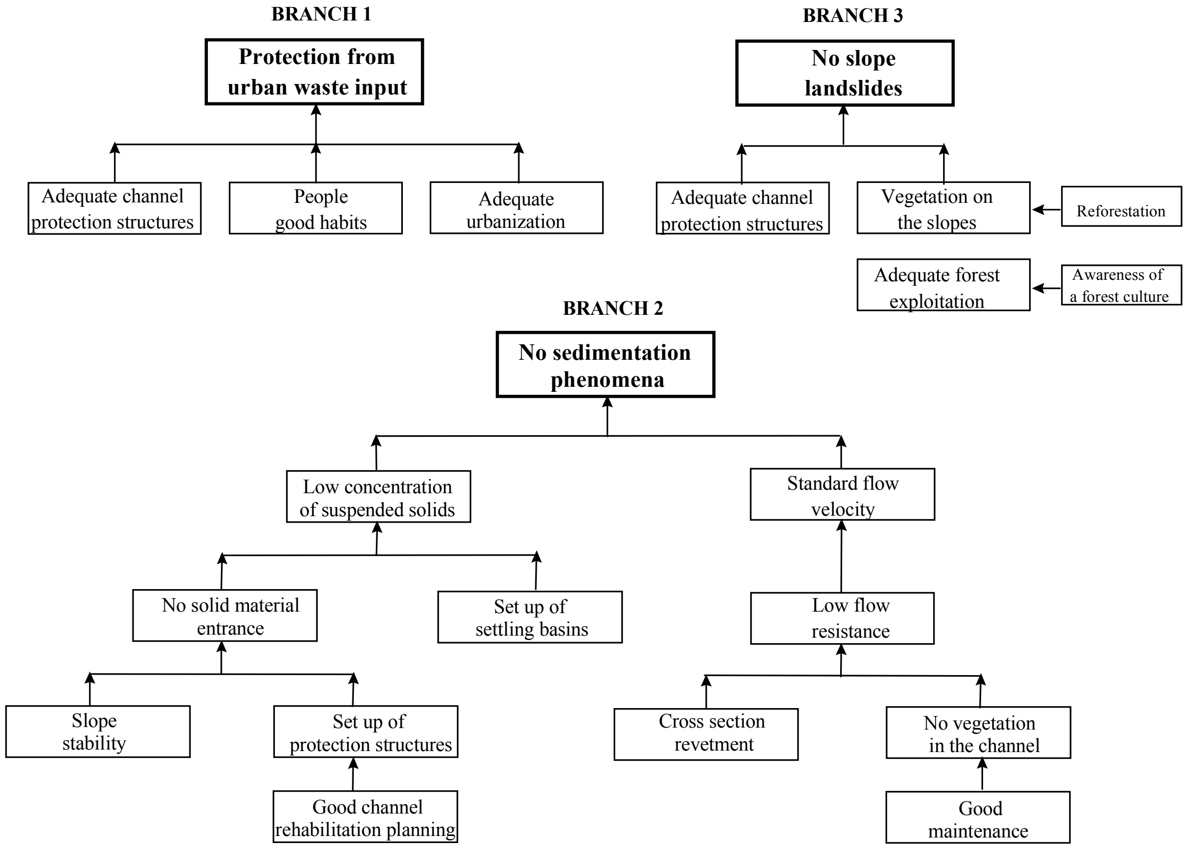


Figure 6 - Branches 1, 2, 3 of the objective tree

ANALYSIS OF BIOENGINEERING INTERVENTION SUSTAINABILITY

The attention is now focused on one of the interventions above mentioned, bioengineering slope stabilization which entails the use of live materials, specifically plant parts (roots and stems), that serve as the main structural and mechanical elements in a slope protection system. It is analyzed if, when faced with slope instability situations, it is possible to intervene with methods adaptable by user communities, taking precautions for the disappearing of the government agency in the system.

In order to evaluate the transferability of bioengineering techniques, the situation in developing countries is analyzed, evaluating the indications given by major international cooperation agencies. For example, in FAO publications, such a technology is underlined as the most appropriate for watershed management, landslide prevention measures, vegetative and soil treatment measures and, generally, in land reclamation (Costantinesco, 1976; Sheng, 1977a, 1977b, 1979, 1990; Bostanoglou, 1980; Marui, 1988; Schiess, 1994). The adopted methodology scheme includes two general fields of analysis: the first one is related with technical aspects, and the second one relative to potential involving by the single farmer or the farming community.

Live plants and other natural materials have been used for centuries to control erosion problems on slopes in different parts of the world. These natural remedies became less popular with the arrival of the Industrial Revolution (Gray and Sotir, 1996). The stabilization of slopes through vegetation and soil treatment measures may be particularly appropriate in situations where an abundance of vegetative materials is present, and where labor, rather than machinery for installation, can be easily found (Schiechtl, 1985, 1990). Currently, bioengineering is largely applied in mountain areas of Europe and North America, giving much data which enables safe planning for similar interventions. In developing countries, since only a few examples can be found, it is important to stress their future use according to the concepts of technology transferring and sustainable development.

As far as the effectiveness of the proposed technology is concerned, it can be stated that it would contribute to slope stabilization with the immediate objective of channel protection, and with the long-term objective represented by integrated development (with the possibility of forest exploitation by the communities owning the slopes outside the irrigation perimeter). It is important to evaluate the risk factors which might cause the failure of the technology. First of all, it seems quite difficult to define the most appropriate typology of intervention because it strongly depends on the conditions of the site (climatological, morphological, etc.). Due to the fact that in some cases professional experience is required, it will be necessary to increase efforts in training technical personnel (CESA et al., 1996; CICDA et al., 1996).

As regards manageability, this depends on its power of convincing in a set social context, and so it is linked to subjective factors outside a technical analysis. But there are other important aspects. These are the conditions in which all potential users will operate and the instruments that they will use in relation to the necessity imposed by the new technology. In our case, manageability seems to be the main characteristic of bioengineering, and it is the first step of our transferability proposal. After defining the most suitable intervention typology, the realization phase presents no problems since the availability of materials and labor to be used for the construction. It results that manageability is quite effective for limited interventions, while for the larger ones it is fundamental to ensure technical consulting in the first period.

The link between the technology and the system must be evaluated, in fact the former must offer the conditions for the diffusion of the latter, multiplying its effects. In the Chambo irrigation system, the information diffusion system seems to be quite good, because of the presence of the farming communities represented by the *Corporacion de las Juntas*.

Since bioengineering transfer provides users with an instrument which assures a continuous water supply service and a better exploitation of the lands surrounding the irrigation areas, it is strictly required to clearly show the objectives, the risks and the reproducibility of the technology to the farmers. In this phase, the information process exchange should go from the users to the technicians and vice versa: data collection by farmers to enable technicians to choose the best configuration, and public demonstrations and technical courses to show users the new technology. In the information gathering phase, users must be informed of all the elements connected with the technology, including the risks, among which it is remembered the lack of a database relative to the application of bioengineering in developing countries, with the consequent difficulty of foreseeing definite results.

CONCLUSIONS

The application of diagnostic analysis to the Chambo irrigation system has permitted the identification of the problems, the structuring of their causes and effects, and the consideration of the user as a major actor in an irrigation system. The recognition of the user role, even in the planning phase, with the obvious difficulty of coordinating professionally and socially different actors, represents the further step to the success of the irrigation system. Among the proposed strategies, bioengineering stabilization interventions seem to be the most appropriate because in agreement with the main concept of sustainable development, thanks to the use of local labor, local materials and the reproducibility of the intervention typologies.

A final aspect is represented by the importance that valid results of the proposed technology in the Chambo area could represent the starting point for the application in other irrigation systems in the Ecuador Andes mountains characterized by similar problems.

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