

PROMAS: AN EXAMPLE OF SYSTEMS APPROACH FOR THE SUSTAINABLE MANAGEMENT OF LAND AND WATER RESOURCES

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Abstract - Given the challenges of the 21st Century, perhaps the most important consideration in the planning and management of land and water resources will be the need for a much greater focus on the sustainability of the use of these resources by the society. With respect to the previous, this paper gives a brief outline of the pressures on land and water resources worldwide and locally in Ecuador. The paper comments also briefly on the constraints in many engineering designs, and the need to consider solutions in a systems approach as a basis for sustainability. The latter has led to the establishment of PROMAS, a program within the University of Cuenca of Ecuador, with the ultimate goal to bring engineering solutions, in the field of land and water resources, in a system approach. The paper concludes with a description of PROMAS approach, mode of operation and realizations in the field of training, research and consulting/extension activities.

1 - INTRODUCTION

The need for a systems approach for most problems is that sustainable solutions to engineering problems require more than a comprehensive technical and financial analysis, as it has been the tradition for many decades. To be sustainable, it is important that solutions be designed in harmony with the social and cultural behavior of the society for which the solutions are designed, and the environment. The pressure of the society to find adequate and sustainable solutions is very high, as explained in the following from a world perspective and at a more regional scale for Ecuador. If not already, the world will be soon confronted with the situation whereby the demand for food and economic goods exceeds the natural carrying capacity, with the ultimate consequence that non-renewable resources will be over drafted, and not longer be available for future generations. In addition to new approaches, among which systems approach, the society will need people of vision and political leaders not restricted to narrow considerations of traditional foreign policy.

1.1 - A worldwide perspective

In the coming decades, the driving forces of the society can be summarized as: population pressure, the human desire for equity, sustainability, and the overall concern for the environment.

Population pressure and food security

A recent World Watch Institute report (Bonte-Friedman and Sheridan, 1997) compared food and population projections for the next 40 years with the trends of the last 40 years. Between 1950 and 1990, the world added 2.8 billion people, an average of 70 million a year. But between 1990 and 2030, the projected global increase is 3.6 billion, or 90 million a year. The world added 1.15 billion metric tons of food grains between 1950 and 1990, but with the present trends, the next four decades will see an addition of only 369 million metric tons. Furthermore, it is expected that the demand for food will rise more, than what can be derived from the expected growth in population. Given the economic growth in the developing countries, people will consume more food of animal origin, leading to the plant-animal-human food chain that has already become standard practice in the developed countries.

Equity

It is to be expected that in the next century, locally and even internationally, military conflicts will rather increase than decrease, because the poor people will not take it any longer that they remain deprived from food and other economic goods. At present, less than one fourth of the world population, mainly living in the industrialized countries, control and consume most of the earth's resources. There is not only the growing gap of inequity between the countries, but also within the countries. A well-known phenomenon in many of the developing countries is the continuous ongoing migration of the rural people, mostly poor, to the cities, and in the cities there is a growing gap between those having access and those having no access to prosperity. To call a halt to the growing social unrest and to prevent that

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unacceptable levels of poverty leads to civil wars, many developing countries are currently grappling with the process of economic reforms and structural adjustment.

Sustainability

Unless a new major breakthrough in the production of food grains is achieved, it is very likely that the area being cultivated to feed the world population will expand. Parallel to previous, the pressure on the water resources by agriculture will increase, rather than decrease. The direct consequence of such a scenario will be that the pressure on the earth's two basic resources land and water will escalate to an extent that it is no longer sustainable. In addition, industrialization has led to a highly manipulated environment dominated by the use of chemicals of various kinds, derived in many cases from fossil fuels.

1.2 - The situation in Ecuador

The same forces that drive the world are present in Ecuador. Although the average population density is at the low side, due to the low population in the Oriente, occupying a vast part of Ecuador, most people are living in the highlands and the coastal area. As such the population pressure on land, particularly in the highlands is very high, exceeding often the natural carrying capacity. Due to the population increase in those regions, the Indian farming communities are forced to move to higher altitudes in the mountain range, cultivating too steep, mostly shallow, slopes. The productivity of these soils is not only low, also these soils are very susceptible to erosion, and erosion is rather increasing than decreasing. Further, due to the low input of fertilizers soil fertility is gradually decreasing. At the long run, large areas fall out of production, or the productivity is so low that it is not longer attractive for the farming community to cultivate those soils. A direct consequence of the previous is the ongoing migration of the male population to the coastal area, where they are employed as cheap labor in the more industrial oriented agricultural enterprises and the industrial sector. Many of the rural people even migrate illegally to the United States and are employed for the lowest paid jobs.

Whereas land, particularly on the slopes of the mountains is subject to erosion, water is also a scarce element, leading often to conflicting situations between the different sectors of the society. Most water used in Ecuador is surface water. The groundwater reserves, which are not well known, are tapped only sporadically. The largest consumer of water in Ecuador is agriculture, followed by the electricity companies for the generation of hydro-electricity, and the drinking water companies. Not only is the quantity a limiting factor, but also the quality of the surface waters is in danger as a consequence of the increasing impact of humans.

Ecuador's society is also characterized by a large inequity in wealth. About 20% of the population own most land and other economic goods. The middle class, which is not negligible in size, has an average income that is already much lower. The largest fraction of the population is poor, having an income below the country's average level of income, often not reaching the minimum level required to live decently. Taking into consideration that the country's economy is not doing well, resulting into an annual average inflation rate of around 35%, and that the country recently suffered major losses due to El Niño, it is not surprisingly that the political situation is unstable, and that social unrest is quite high. Proof of it is the recent devaluation and the need for a reformulation of the constitutional law.

One of the challenges for Ecuador in the coming years will be the generation of enough jobs, to reduce at one hand the relative high unemployment rates and to meet at the other hand the increasing demand for jobs. The demand for jobs might be even accelerated by the continuing migration of the rural people to the cities. One of the remedies that can help solve the problem is by improving the living situations in the countryside through increasing productivity. Increased productivity in the rural areas must become part of a larger setting of sustainable life systems, where environmentally sound, socially attractive, and the generation of acceptable long-term employment is seen as the centerpiece.

2 - SHORTCOMINGS IN ENGINEERING DESIGNS

To meet food demand humans made the resources therefore required available. Humans have been manipulating the land for centuries. Similarly, for the development of the different economic activities, we developed the resources that were needed for this goal, often over drafting without any restriction non- and renewable resources. By far the humans are the only species that makes unreasonable demands on nature and natural resources. We build roads and waterways, fertilize and drained the land, cleared vegetation, harvest and cut trees, and so forth. However, through the intricate interactions among different components of the ecosystem, secondary, unintended effects are produced. Unfortunately, the failure and/or the inappropriate design of engineering works often accelerated or enlarged the negative side effects.

Common shortcomings in engineering designs, in the field of land and water resources, can be summarized as:

- the design is based on insufficient data and/or the data are of poor quality;
- the design is made using old-dated design methods, or methods that are not appropriate for the given problem;
- current design methods are insufficiently developed, not able to account for the complexity of the problem and the possible interactions with the environment;
- the design is made with a specific, narrow objective, e.g., the generation of hydro-electricity or the irrigation of an agricultural area, without considering the possible impacts of the design on other aspects; and
- the selection of the design is in most cases only based on a cost analysis, rather than on a cost/benefit analysis, including also the costs for the re-mediation of the environmental damage.

Engineering designs in future would be more sound and result in sustainable and environmental acceptable projects if they were designed in a broader, integrated context. With respect to engineering works in the field of land and water, it is suggested to study problems at the level of the catchment and to assess before implementation of the engineering projects, the possible impacts on the society and the environment. In more general terms it is proclaimed that technical and other problems, for which solutions exists, should be studied within a systems approach.

It would be incorrect to attribute all the wrong going of an engineering project to miscalculations and errors made in the design phase. In addition to those constraints, many things can go wrong during the construction, the operation and maintenance of the solution. It is often a combination of factors that makes that projected engineering works do not meet the projected goals, formulated in the design phase. In the following section of this manuscript, the authors elaborate what they understand under systems approach, and how this concept is applied in the field of land and water resources management.

3 - SYSTEMS APPROACH FOR THE SUSTAINABLE MANAGEMENT OF LAND AND WATER RESOURCES

The concept of systems approach dates back as early as 1971. It was for the first time introduced by Chorley and Kennedy (1973). The paradigm was developed by geographers, who are studying processes at different scales, ranging from the micro (process scale, e.g., the slope), over the meso (e.g., the drainage basin) to the macro (e.g., the earth's atmosphere) scale. The objective of the geographer is thereby more than studying only natural systems. Their ultimate goal is, independent from the scale of analysis, a holistic analysis, including study of the interface of people and their environment (Hutchinson, 1986).

For studying land and water resources in a systems approach it is most logic to analyze both resources at the meso-scale, it is the scale of a catchment, being a natural hydrological unit. Knowledge of the hydrological processes in relation to the spatial variability of the basin properties helps to predict what the impact will be on the basin if in a given location changes in the catchment will be introduced, e.g., the clearance of a forest, the construction of a new urban center or the construction of a dam. Since water is considered as the main carrier of effects from one side of a basin to another side, catchments form the natural basis for studies of alluvial geomorphology, soils, vegetation and the impact of people. Catchments are also most suitable units for studying land resources related problems, e.g., for resolving conflicts between competing uses of land (Gomez A.N., 1996).

The concept of systems approach at catchment scale is also better adapted for the inter-professional, inter-sectoral, and inter-disciplinary dialogues needed to integrate land and water management (Castensson et al., 1990). In this conceptualization, humans live in, and are part of the catchment, which is sustained in part because of the water provided from the atmosphere. According to Falkenmark and Lindh (1993) is sustainable development of a catchment equivalent to a careful management of our interaction with it so as to meet three basic criteria for ecological security:

- groundwater must remain drinkable, land productive, and fish edible;
- biological diversity should be conserved; and
- long-term over draft of renewable resources should be avoided.

PROMAS of the Faculty of Engineering, the University of Cuenca, adopted over the years the concept of systems approach, applied to a parcel, a project and a catchment, respectively. It did so, because it was found in an empirical way that it offered the most efficient way of identifying and designing sustainable solutions for the land and water resources problems in the Andean region of the provinces Azuay, Cañar and El Oro (Austro Ecuatoriano).

4 - PROMAS: an example of systems approach for the sustainable management of land and water resources

PROMAS, Programa para el Manejo del Agua y del Suelo, emerged in 1992 from the School of Civil Engineering of the Faculty of Engineering, the University of Cuenca, Cuenca, Ecuador. As many universities in Ecuador and other developing countries, the main and often only activity developed within the university is the organization of undergraduate programs. Conditions, however, are changing, and the positive reaction to those changes in the School of Civil Engineering lead to the establishment of PROMAS. In the following paragraphs, a brief description is given of PROMAS' philosophy, mode of operation and realizations.

4.1 - PROMAS' philosophy

PROMAS did not apply the concept of systems approach, applied to the scale of a catchment, to study land and water resources problems from its early beginning. PROMAS, being originally an experiment within the School of Engineering, started small. The projects of the earlier days were mainly consulting jobs, water related and varied from the design of small hydraulic structures to drainage and irrigation projects. The founders of PROMAS applied strongly from the early beginning the concept of working together, in putting a fraction of the revenues of each project aside, money which was used for investment in infrastructure (office, computer and field equipment, including vehicles for transport) and hiring of last year undergraduate students. The latter contributed considerably to the development of PROMAS, and still today, a large fraction of the staff are last year students of the School of Civil Engineering and other School/Faculties of the University. Through the hiring of students from different schools, PROMAS succeeded in creating a multi-disciplinary team. Furthermore, where the projects in the beginning were mainly studying problems at the micro-scale (at the scale of a field and slope), gradually the size of the projects handled by PROMAS increased to the meso-scale (e.g., an irrigation project, micro-, medium to large catchments).

Within the consulting jobs, PROMAS gradually adopted the concept of studying the technical problems, in a holistic context, i.e., studying the problems within its system boundaries taking into consideration all possible interactions in and outside the system under study, including the interactions with the people. This evolution was strongly pushed by the clients for whom PROMAS was working. The move towards analyzing problems in a system approach was further underpinned by the evolution from pure consulting/extension type of activities to research oriented projects.

4.2 - PROMAS' mode of operation

The operation of PROMAS is based on the revenue of consulting/extension type of projects, being still the main contributor in terms of revenue. The second most important source of income is coming from the currently three research projects, funded by international donors, as the Flemish Inter-university Council, through the Belgian Agency for Development Cooperation, and FUNDACYT through the Inter-American Development Bank. The third avenue of income is revenue coming from the organization of paid short- and long-term training courses. PROMAS operates under the administrative umbrella of the Research Institute of the University. The latter Institute operates independently of the faculties and schools, and coordinates administratively all consulting and research projects run through the University.

Through an optimal use of its financial resources, PROMAS has today a total staff of 40, of which 15 are full-time academic and project staff. The remaining 25 staff are undergraduate students. Of the full-time staff, 3 are international with expertise in the field of civil engineering, soil science and geographic information systems engineering, respectively. Many of the local staff is last year student, and participate in PROMAS within the frame of their thesis research project. PROMAS not only recruits students from the School of Civil Engineering, from which PROMAS emerged and has still strong links, but also from other schools and faculties. As such the local staff covers the following disciplines: civil engineering, agricultural engineering, agronomy, computer sciences, economic and social sciences, contributing to the multi-disciplinary approach of the team and the surveys, engineering studies and research activities pursued.

4.3 - PROMAS realizations

PROMAS realizations can be ranked under the headings education, research and consulting/extension type of activities. Training activities are so far limited to the organization of a postgraduate course in Soil and Water Management in Irrigated Agriculture. For the teaching of the

different modules an appeal is made on international staff. The fees paid by the participants cover completely the investment in the courses. In addition, to this postgraduate course, PROMAS often organizes seminars on specific subjects, for example when international staff is visiting PROMAS, within the frame of one of the current research projects. It is the intention of PROMAS to organize similar postgraduate programs in the field of land evaluation and soil erosion.

PROMAS runs three research projects. Through those projects PROMAS aims at increasing its expertise and research capacity in the field of land and water resources management. The current projects are seen as a step in obtaining other research contracts. The foregoing is in line with PROMAS long-term objective of becoming a research center of excellence in the field of land and water resources. In addition, efforts are currently undertaken to establish research associations with other institutes in the United States, Europe and other countries in Latin America. The funding obtained through the three research projects offers PROMAS considerable possibilities for strengthening its human and physical resources. Furthermore, the research contributes in further integrating the concept of systems approach in all PROMAS activities, such as training, research and consulting, respectively.

Whereas the start of PROMAS has been the execution of small to medium sized consulting jobs, still today PROMAS pursues the execution of consulting jobs, mainly because it helps bridge gaps in funding and it helps the team to stay in contact with the real world. PROMAS not only want to become a research center of excellence in the field of land and water resources management. At the same time, PROMAS hopes to contribute in the elevation of the standard of living of the local communities in the provinces of Azuay, Cañar and El Oro (Austro Ecuatoriano).

Also in its consulting and extension type of projects, PROMAS tries to implement the concept of systems approach. It is making the designs in harmony with the capacity of the people that have to operate and/or manage the implemented designs, as well as to take care that the implemented designs have a minimum impact on the environment. Particularly in its extension activities, PROMAS pays quite some attention to the societal and environmental aspects.

Given the many beneficial effects in conducting consulting/extension type of projects, it is for sure that PROMAS will continue on this avenue. Of course the challenge of PROMAS will be to maintain a good equilibrium and going together between its three basic activities, it is the organization of short- and long-term graduate training courses, the execution of research, consulting and extension type of activities.

5 - CONCLUSIONS

The population pressure, the pressure of the poorer class of the society for equity, the need of evolving to systems that are sustainable and systems that have a minimum impact on the environment, as to make sure that the earth remains livable for the future generations, have without any doubt lead to the introduction of the concept of systems approach in many disciplines

The concept of systems approach was adopted by PROMAS, a program that emerged in 1992 from the School of Civil Engineering of the University of Cuenca, Ecuador, because its founders realized that it was the only way to achieve sustainability and social peace in planning and design projects. The concept gradually developed over the years, mainly through the execution of many consulting jobs in the domain of land and water resources management. Through the attraction of research projects, the concept has been reinforced, and is reflected today also in its recent short- and long-term training programs.

PROMAS philosophy, operation and realizations can stand as an example for similar initiatives in other developing countries. Given the similarity in most countries, in the technical, societal and environmental problems in the field of land and water management, it is hoped that if similar projects as PROMAS in those countries get from the ground, that they seek cooperation as to strengthen the global capacity in science and technology in this field. The foregoing will be needed as to come in the next 25 years to solutions of a much greater sustainability and larger societal achievement.

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