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The Ecological Factor in Regional Development: A Venezuelan Case Study

This paper seeks to distill lessons learned in the process of testing environmental assessment and management methodologies. Generalizing of methodologies from the Venezuelan experience is possible despite the distortions induced by petroleum income. The glossy film of non-renewable wealth contrasts sharply with the ecological, cultural, and institutional problems that combine to sustain rural underdevelopment throughout the tropical world.

In the following sections are described the development problems faced in the case study, the formal methodology and its theoretical basis, and the interdisciplinary study process and results. These provide the reader with a concrete framework for comparing similar experiences and for evaluating the conclusions presented.

Project Background

Influenced strongly by the world environmental movement, Venezuela established a Ministry of Environment and Renewable Natural Resources (MARNR) in 1977. The new ministry centralizes an unprecedented mandate in regional planning and in the development and management of natural resources. Effective implementation of this mandate awaits the creation and adaptation of sound concepts and methodologies for environmental management.

MARNR has requested assistance from the Organization of American States (OAS) in application of recent advances in applied ecology to regional development planning. The project involves the evaluation of a pre-MARNR regional development scheme in the western *llanos* as a point of departure for demonstrating new concepts and methodologies in environmental management.[1]

The OAS-MARNR-CIDIAT study has three related objectives:

1) Provide MARNR with a series of specific alternatives for regional development in the Guanare-Masparro area, taking into consideration ecological factors and principles;
2) Based on the Guanare-Masparro experience, design criteria and methodologies

applicable to regional development in similar environments;
3) Develop environmental management curricula of in-service short courses and a graduate program to meet both the Inter American and Venezuelan responsibilities of CIDIAT.

The Guanare-Masparro Program

The western *llanos* were a focus of agricultural development during the colonial era that in turn was superimposed upon an extensive pattern of precolumbian settlement (Zucchi, 1975). Following independence, the area suffered a decline in importance and population due to the combined effects of political unrest and a particularly virulent strain of malaria. Only with the control of malaria following World War II did the repopulation of the area begin (Crist, 1932; Veillon, 1976).

Representative of 18 million hectares along the Andean front is the Guanare-Masparro area which comprises 960,000 hectares of adjacent watersheds. The upper watershed protective zone in the piedmont and eastern Andes occupies more that half the area. The 460,000 hectare *llanos* portion (Figure 1) contains 170,000 hectares of soils of good structure and moderate to high fertility derived from recent sediments from the Andes (Quintero, 1974). These soils comprise an estimated ten percent of the soils of high agricultural potential in Venezuela. Development of the llano soils for conventional agriculture is impeded by contrasting problems of drought and excess water. The latter is caused by river overflow and slow runoff of rainfall in the wet season, during which 85 percent of the annual rainfall is concentrated between May and October (Quintero, 1974). The *llanos* part of the project area (1400-1500 mm of rainfall) is classified as tropical dry forest according to the Holdridge system (Ewel, 1968). The depositional patterns create an array of hydric and edaphic associations typical of wetter lifezones or savannas resultant from seasonal innundation.

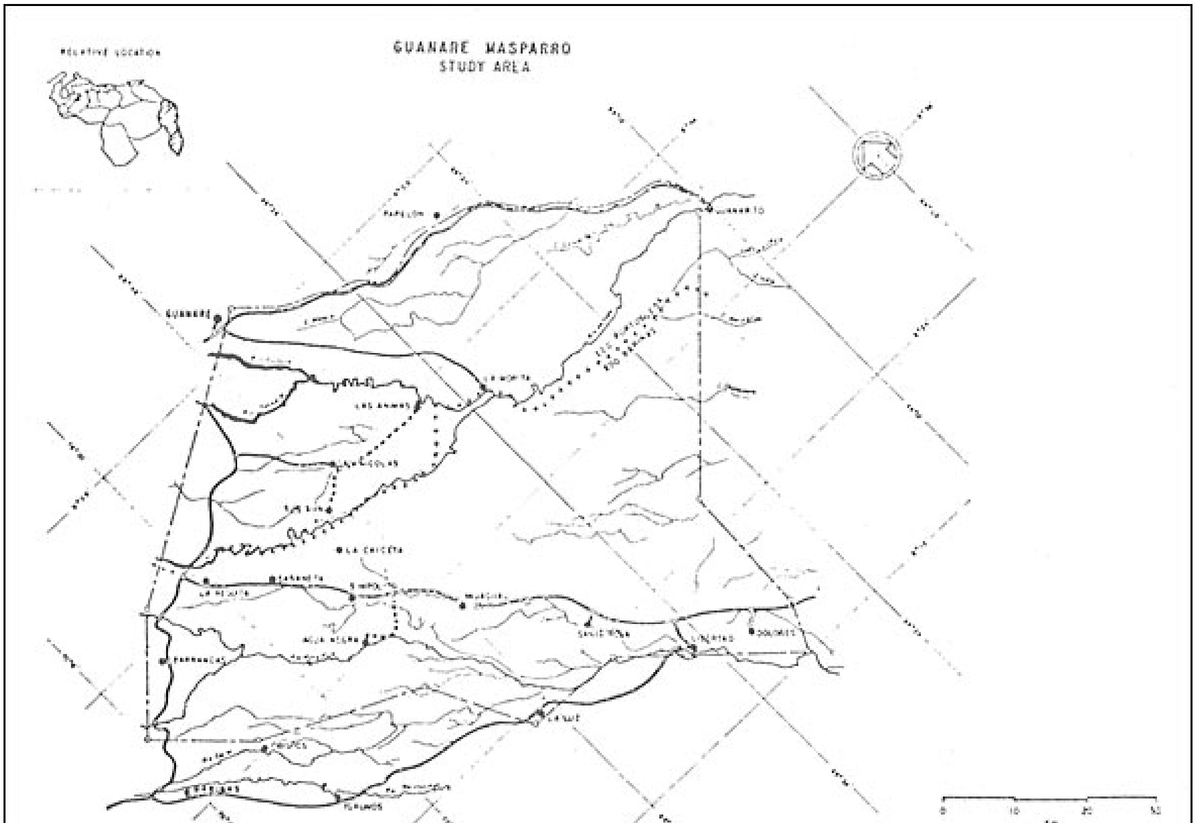


Figure 1.

The Guanare-Masparro Program was created by presidential decree in 1974 with the twin goals of increasing agricultural production and improving the well-being of the campesino population of the region (Obras Públicas, 1974). the data base for the program was built upon a series of overlapping surveys and development studies dating back to the 1940s (CORPOANDES, 1974). The four dams projected for the area are part of a nationwide network of petroleum financed infrastructure construction which includes ten dams intercepting streams entering the Orinoco Basin from the Andes. In addition to the dams, the program projects a canal irrigation for a large portion of the area, and a complex infrastructure of social services, towns, and industries.

The Guanare-Masparro Program as originally conceived has fallen upon hard times. Profligate spending elsewhere, rising costs, and changed political priorities have combined to bring infrastructure development to a virtual halt. Dams are in various stages of construction or planning. The primary road and drainage network covering ten percent of the development area is partially completed. The Ministry of Public Works as the lead agency began construction in its areas of competence: dams and canals. These works have continued since 1977, albeit at a reduced pace, by the hydraulic works division of MARNR, successor to the now defunct Ministry of Public Works. The elaborate 35 year plan for peasant resettlement, large scale farm enterprises, detailed production schemes, and new cities was never initiated nor was the regional authority created to implement the plan.

Extrinsic political factors unrelated to the merits of the program have been largely responsible for the delay. The current evaluation of the program elements has substantiated the serious doubts about its technical and economic viability raised by Venezuelan professionals over the past years. The potential for environmental disruption is high. The following problems are representative.

When the earliest studies on possible dam sites were made in the area in the 1940s and 1950s, the population was small. The 1960 aerial photographs show much of the area to be virtually undisturbed. Subsequent population growth and land clearing have affected extensive portions (Veillon, 1976). In the piedmont, widespread deforestation has resulted in erosion of the unstable soils and changes in the hydroperiod of streams originating in the area. This cultural augmentation of sediment loads, combined with that occurring naturally in a 500,000 hectare watershed ranging from 200 to over 3,000 meters in elevation, poses an unassessed threat to the useful life of the reservoirs. Although the upper watershed is designated as a water management reserve by law, no program has been implemented to manage the process of settlement and land disturbance in the area. The 14,000 hectare reservoir will cover deposits of deep course sediments raising an interesting infiltration problem and a question about the maintenance of the designed storage volume of the reservoir. The rivers where dams are proposed do not have an adequate network of upstream gauging stations for flow comparison.

In the *llanos* area designated for intensive development, other potential problems are manifest. More than a thousand kilometers of canals and roads are projected, creating a uniform grid pattern superimposed upon a landscape that is far from uniform. Government approaches to development are symptomatic of sectorial planning in a complex environment. The single-minded approach to dam and canal building by a public works ministry is not unique. As in the case of Egypt's Aswan Dam project, the Guanare-Masparro project as originally planned will be a monument to competent engineering while the functioning of the overall project will likely be far less successful than anticipated. The chaotic state of man's relation to the land is analagous to the earliest stages of ecological succession (Odum, 1969). In a rush to modernize, traditional dooryard gardens, shifting agriculture inherited from the Indian, and the extensive ranching systems dating from the Colonial period have been rejected. Complex irrigation schemes are being applied to lands plagued by excess water. Agricultural extension is in the hands of pesticide and farm equipment salesmen.

Environmental Management

Environmental management is the term and concept chosen for the holistic planning method applied to the problems described in the preceding section. The approach brings the practice of systems ecology to bear on the problems of regional development. The government's goals in the Guanare-Masparro area are indisputable: augment agricultural production to reduce dependency on imports and improve the well-being of the area's inhabitants. It is clear that these goals cannot be fulfilled simply by turning planning over to the ecologist. It is equally clear that plans and actions lacking the ecological input do not and cannot achieve optimum sustained development. The study of environmental management is based on the assumption that a broader, more systematic approach to regional planning and project design will better serve society. The management method involves two related principles:[2]

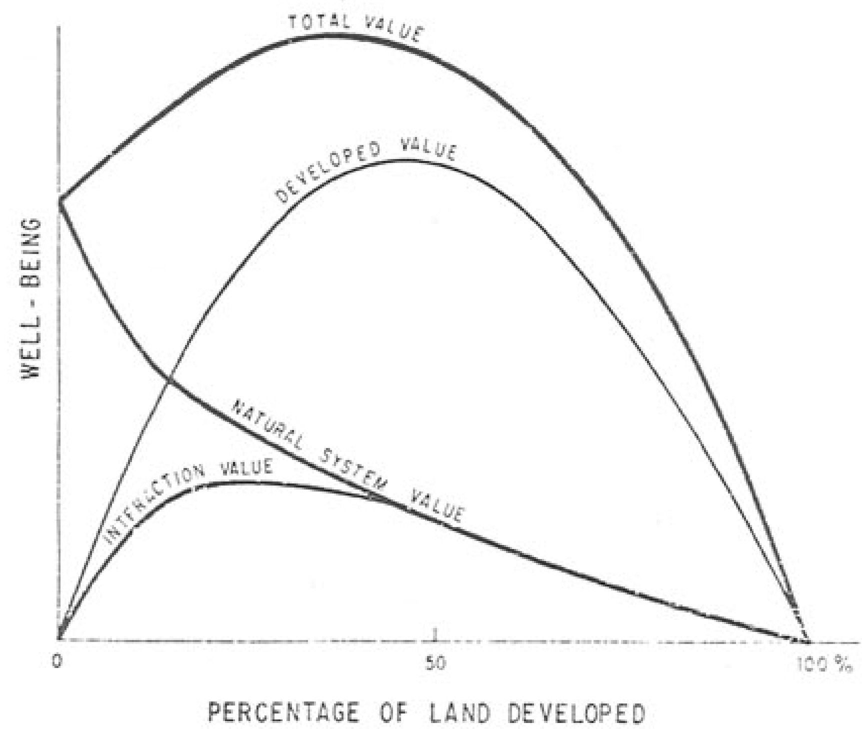
1) Lotka's maximum power principle – Successful systems are those which maximize their sustained energy flow for useful purposes. Some energies are limited in total quantity, like petroleum, and others, such as the productivity of a forest or buffering capacity of a wetland, are limited in sustainable flow by rates of insolation and mineral cycling. A developed system assures its survival by evolving intricate mechanisms for sustaining its vital inputs. In the Guanare-Masparro area, energies derive from diverse sources, agriculture, forests, aquatic systems, processing and maintenance industries, and so forth. Competitive success depends on sustained inputs from all sources; management that underutilizes or over-stresses an input source is inherently suboptimum. The optimization principle is discussed below.

2) Optimization principle – We assume that attaining an optimum sustained net yield from an area is a viable planning objective in a region. This involves understanding first the structure, function, and productive potential of the natural, managed interactive (agricultural), and developed or urban-industrial subsystems of the region. Second, interactions among the subsystems are ascertained, both complementary and negative. At the extremes, logic indicates that optimum well-being occurs neither in a totally natural environment (cave dwelling) nor in a

totally developed (asphalted) one. Figure 2 illustrates the general case (Odum, 1975, 223). In the Guanare-Masparro study, we are searching for the specific management options for optimum development.

FIGURE 2

RELATION BETWEEN WELL-BEING AND AMOUNT OF LAND DEVELOPED



The application of the above principles in practice requires an integrated, interdisciplinary effort. To accomplish this we have adopted the energy circuit modeling approach developed by H.T. Odum (Odum, 1971). The procedure has been applied in a wide variety of research and planning problems involving the complex interaction between man and his environment (Hall and Day, 1978). Model development involves the following steps:

1) Identification of system boundaries. Boundaries chosen may be along physiographic, political, or watershed limits as determined by the convenience of analysis. Given the great importance of water management in the Guanare-Masparro study, watershed limits were used wherever possible in establishing system boundaries.

2) Identification of components or subsystems. Major subsystems may be

identified according to the degree of intervention by man, natural, managed (agriculture), and urban-industrial. Distinct outputs or management requirements resulted in further subdivision in the Guanare-Masparro area, for example, crop and livestock components, terrestrial subsystems determined by relationship to hydroperiod, the aquatic component, and the water management infrastructure.

3) Identification of external forces affecting the system. When the system boundary is established, external flows of energy, materials, and information can be identified. Important external forces affecting the project area are sunlight, rainfall, fuels, agricultural chemicals, capital investment in infrastructure, and management and policy decisions.

4) Identification of interactions and outputs. External forces drive internal processes such as photosynthesis or canal building, which in turn involve interactions and feedbacks among components and eventual outputs from the system. Interactions may have positive or negative effects on component functions and system outputs.

The model serves a series of functions as an environmental management project develops. The initial conceptual model aids in visualizing the structure and dynamics of the system. Identification of interactions involving a specific subsystem provides the basis for organizing disciplinary research in agriculture, civil engineering, aquatic ecology, and so on. Research models may be quantified and aggregated to the scale of the whole system for analysis of interactions, impacts, and management alternatives.

The Drainage Case Study

The first test of the methodology in the Guanare-Masparro project came in the summer of 1979. It was determined by the project leadership that the thousand kilometer drainage and road network would prejudice future options for development. An environmental impact assessment was initiated to ascertain the potential effects of the project.

An arbitrary six months limit was imposed on the study for the following reasons: 1) the period during which an impact study might result in change in project design is very short and is most likely to occur during the conceptual stage; 2) pressures on a new government to take action on long delayed projects in the area were very real. Such a time frame limited the project largely to the use of available information.

Consultation with individuals having considerable professional experience in the area resulted in conceptual models of the system with and without the drainage project and the identification of the potential problem areas listed below:

1) The technical feasibility of linking the secondary and tertiary on-farm drains to the primary drainage network as currently designed.

2) The costs and benefits of establishing a drainage network on all soils, including those of marginal productivity, relative to the alternative of draining only those soils with a high crop production capability.

3) The effect of drainage on the traditional livestock systems with special reference to the quality of forage in the periodically flooded *esteros* (seasonally flooded savannas), should they be drained.

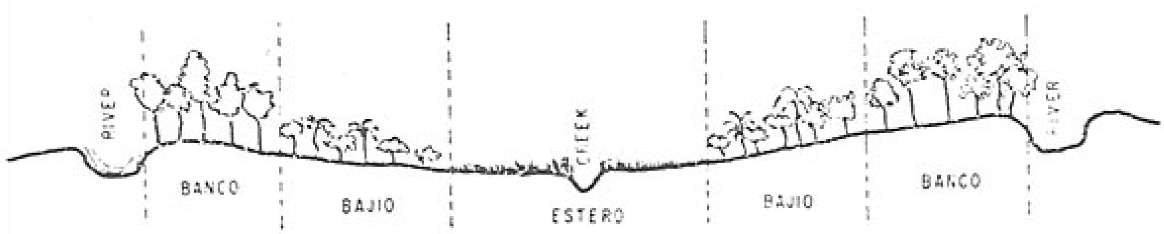
4) The effect of drainage on natural system values with special reference to fisheries in the streams of the area. The evaluation of the problems listed above was carried out by an interdisciplinary team representing various institutions. Among the fields involved were agronomy, geomophology, agricultural economics, soil science, animal science, geography, and icthyology.

The impact study on the drainage and road network was seen as an interim step in a broader evaluation of development alternatives in the entire Guanare-Masparro area. The project was organized around a series of workshops designed to bring the project team together for discussion of methodology and integration of results. Conclusions and recommendations were presented to the Minister of MARNR and his staff in December, 1979, six months after beginning the study. The findings presented below have been summarized from the workshop documents and consultant reports.

The landscape of the western *llanos* is characterized by a complex pattern of sedimentary deposits. The rivers leaving the piedmont quickly lose their competence in the *llanos* where slopes rarely exceed one per thousand. As the meandering rivers drop their sediment loads, their beds rise above the surrounding floodplain. Eventually the rivers break through their levees and begin the process of levee building anew. A transect of the area normal to the natural drainage reveals a repeating subtle relief pattern of levees (*bancos*), intermediate slopes (*bajios*), and seasonally flooded savannas (*esteros*) (Figure 3). These topographic features are loosely associated with patterns of soils, vegetation, and local drainage. Geomorphological interpretation indicates that the major rivers of the project area, the Socona and Guanare, laid down their sediments along parallel southeasterly axes normal to the Andean front during an antecedent period of higher rainfall. Lower rainfall and reduced competence in sediment transport have resulted in a drainage tendency controlled by a slight easterly dip of the uplifted plain. Only along the contact between the older river depositional systems does the southeasterly pattern control drainage. Location and mapping of these depositional features was made possible by the availability of 1:60,000 aerial photographs taken in 1960 prior to extensive land clearing (Aubert, 1979). Knowledge of the geomorphology and related hydrology has been critical to the prediction of effects of the proposed drainage and the elaboration of alternatives. The study revealed the deficiencies in the drainage system planned and under construction as well as indicating potentially viable alternatives for evaluation. The geomorphologist was able to utilize maps displaying the behavior of excess water that he had helped prepare as part of a land inventory covering several states (PINT, 1979). The interpretation of water movement and sedimentation patterns was based upon analysis of vegetation patterns appearing on 1960 aerial photographs prior to large scale clearing. This approach was adopted after a team of hydrologists indicated that a lack of quantitative data on river volumes and topography precluded the use of computer models for hydrological analysis.

FIGURE 3

TYPICAL SECTION LLANOS OCCIDENTALES



While the proposed canal network generally followed the natural drainage, notable exceptions were found. Levees along relic river channels create diversions of surface flows that would be costly to redirect with canals. Canals draining upstream areas would raise water levels higher during peak flow than bordering land downstream, preventing connection of lateral canals meeting main canals at right angles.

Massive drainage in the Guanare-Masparro area has the objective of rapid removal of water with the unavoidable result of contributing to downstream flooding. At the time of greatest drainage volume the downstream area is generally already partially flooded due to high river stages that dam off streams draining the area. The potential areal extent, depth, and duration of induced flooding has not been quantified. It may be justifiable to sacrifice downstream areas with lower productive potential in order to fully utilize the better soils upstream. This study phase seeks to bring the issue to light for evaluation of relative benefits.

On maps depicting extent and duration of excess water, the area was zoned according to relative difficulty of drainage. This information overlayed upon maps of potential soil productivity provides criteria for designing the most efficient drainage system. Recommendations resulting from the study included: 1) Redesigning the primary drainage network in accordance with geomorphic maps; 2) zoning the area in terms of relative facility of drainage; and 3) establishing a hierarchy of natural drainage to insure efficient connection with the secondary artificial drainage. In one pilot area it was suggested that there be elaborated a complete drainage design down to the parcel level as a test of the management strategy (Aubert, 1979).

In terms of crop production potential, using semi-detailed soil survey data, data from experts on soil-water relationships, and field interviews with farmers, an agronomist was able to establish estimates of crop production potential on different soils with and without drainage (Staver, 1979). It was determined that 5 percent of the 440,000 hectares served by the proposed drainage would not benefit due to location on the upper levees of sandy texture with excessive internal drainage. Another 13 percent in heavy textured clay soils of frequently flooded natural savannas would not justify drainage due to difficulty of water management. The best levee soils, 40 percent of the area, have the highest potential yield, needing drainage mainly to insure trafficability for machines during the wet season. Soils of low to intermediate productive potential due to moderately clayey texture, 42 percent of the area, often suffer losses of 20 to 80 percent of the crops planted because of flooding due to slow runoff of rainfall. The latter soil group poses a strategic problem for optimization if capital is considered to be limiting. Generally poor levels of management resulting in yields averaging 1200 kilos of corn per hectare (United States yields are now on the order of 7000 kilos per hectare) indicate that benefits for drainage in the forseeable future will result from preventing loss of crops planted rather than facilitating theoretically achievable upper yield limits on the best soils.

Recommendations for improving crop production potential included zoning the area in terms of soil aptitude for agriculture, taking into consideration both soil classification and distribution patterns. It is important to know if an association is divided in narrow strips of *banco* interspersed with *bajios* or if the *banco* soil is concentrated in one manageable unit.

In terms of cattle production, it was found that excess and scarcity of water are the dominant factors affecting traditional cattle production in the *llanos*. Management is intimately related to the previously mentioned pattern of *bancos*, *bajios*, and *esteros* (Figure 3). During the wettest months, June-August, cattle are largely restricted to grazing the higher *bancos*. As the water retreats, fresh pasture becomes available in the *bajios*. Finally, with the onset of the dry season, the heavy soils of the *esteros* retain sufficient moisture to support a mixture of native grasses that carry the cattle through until the onset of the following wet season in April. Carrying capacity is limited by the extent and quality of dry season pasture in the *esteros* (Morales, et aI., 1979). The system is transhuminant on a highly localized scale, controlled by drought and flooding.

Drainage of the *esteros* and lower *bajios* would signify the loss of their critical function in water storage and pasture production. Maintenance of cattle production would require capital investment in irrigation and planted pasture, improvements not justified by the quality of actual management. It is doubtful that such intensification would be competitive economically or energetically with a variation on the traditional system involving pasture rotation, basic animal health measures, and the culling of non-productive animals. In addition, the heavy clay soils with poor internal drainage are difficult and expensive to manage for crops even if successfully drained. The soil survey carried out prior to drainage design explicitly recommended against draining the heavy soils (Quintero, 1974, 41).

Recommendations of this study include using the same geomorphic data base to identify sites suitable for mixed crop/cattle production and areas appropriate for cattle only due to difficulty of drainage and heterogeneity of soil distribution. The latter areas should be excluded from the secondary drainage network. It is necessary to determine water storage requirements for most efficient cattle production should natural storage have to be augmented by check dams in *esteros* and *bajios*.

With regard to natural systems, the mosaic of natural ecosystems is intimately related to the landscape morphology and the hydroperiod of the *llanos*. These systems offer a range of natural goods, services, and values that will playa significant role in the optimum sustained development of the region. The need for intensive development of the excellent soils covering more than half the area obligates careful management of natural systems. Among the most important functions is that of riparian vegetation and wetlands (Karr, 1978). The impact of biocides, nutrients, and sediments contained in agricultural runoff upon downstream water quality and fisheries is buffered by these systems. Other functions include a managed output of forest products and fauna, recreational values, and the maintenance of a land reserve.

The proposed system of roads and drainage guarantees the maximum destruction of natural systems at considerable cost without commensurate benefit. Access results in spontaneous colonization and deforestation regardless of soil quality and aptitude for other use. Costs are high for building and maintaining roads and bridges across the natural drainage pattern of *bajios* and *esteros*. At the parcel level in heavy clay soils, seven times the drainage density is required to achieve water removal comparable to that achieved on the better *banco* soils. Fish constitute a major contribution to the regional diet and economy. This protein source costs less than half as much as beef and represents a self maintaining free service of the aquatic systems of the *llanos*. Catches in the study area approach a million kilos of fish per year (Chapman, 1979). It is a concern that the large number of canals emptying directly into the rivers will result in migrating fish entering canals by mistake and becoming stranded. However, the dams constitute the most grave threat to the migrating fish population.

In light of these findings, recommendations include, in areas where natural system values are greater than those resulting from development, minimizing the penetration of drains and roads. Riparian and wetland vegetation adjacent to cultivated areas should be maintained. Developers should analyze and simulate the behavior of aquatic systems and associated fish populations affected by the proposed canals and reservoirs.

Lessons and Conclusions

The environmental factor has achieved official consideration in development projects via the environmental impact assessment process. The assessment process mandated by the United States National Environmental Policy Act of 1970 has been adopted in similar form by international agencies such as the World Bank and by various national governments. In Venezuela, an evaluation of environmental impact is mandated by a basic program of MARNR for development projects and policies (Programas Básicas, 1977, 115).

Impact assessment in Venezuela represents a microcosm of the unfulfilled promise that has marked the environmental movement over the last decade. The problems discussed below are both specific to the Venezuelan case study and universal flaws in the process:

1) The process is by nature negative; an adversary relationship is established between those who would protect the environment and those dedicated to economic development. Rarely is the outcome of the conflict an optimum compromise. In Venezuela, as almost everywhere else, the agency charged with environmental protection has neither a large nor powerful constituency. Presentation of the drainage impact study to MARNR elicited an immediate defensive "them versus us" reaction from the head of infrastructure whose ox was being gored; hardly a way to begin exploring alternatives.

2) The Environmental Impact Assessment is a reactive process, isolated both in time and, within most institutions, from planning and project development. Procedures are triggered when a full blown project plan as presented for evaluation. Unfortunately the flexibility for considering development alternatives for impact mitigation is inversely proportional to the time elapsed since project conceptualization (White, 1972). When sufficient information is finally marshalled to justify a recommendation, blueprints are in hand, reputations on the line, and political commitments made. Though not the fault of the institutions involved, this was precisely the situation encountered in the Guanare-Masparro drainage study. The project was ten percent complete at a cost of over 13 million dollars when our study concluded that it should be redesigned.

3) The process emphasizes the identification and mitigation of harmful effects of projects on elements of the environment such as air pollution or fauna disappearance. Rarely mentioned is whether or not a project effectively utilizes the services of natural systems or if system functions that could have adverse effects

on the operation of a project have been considered. Such factors are generally of considerable economic and technical significance. In the Guanare-Masparro study, natural system services were a primary concern. However, this is not generally the case.

One has serious reservations about a procedure that fails to consider the most persuasive arguments for protecting and managing the natural environment, creates an estrangement from powerful development forces, and is so ill-timed and isolated as to have little effect on development projects. An incomplete and poorly defined perception of environment has permitted the erection of an elaborate rhetorical and legal structure in undisturbed coexistence with institutions totally oblivious to important environmental considerations in their development projects (Fairfax, 1978).

To date the impact assessment process has proved to be a weak vehicle for bringing appropriate consideration to the environmental factor in development. The process can be useful only if we recognize its limitations and assure its full and timely integration within the planning, execution, and monitoring of development.

When a political decision is made to invest in the development of a region, the planner is dependent upon the development guidelines and information at hand. With little money and less time, mindless data gathering and detailed evaluation is indefensible. The method must quickly yield guidelines that help avoid major disasters and assure that future options are maintained. This is difficult in a case such as in the Guanare-Masparro area where an a priori decision was made that dams were the first and best investments in regional development. If rational guidelines are accepted and the time horizon expanded, more detailed quantitative analysis becomes possible. If one is able to participate in the conceptual stage of planning rather than in an impact study of a project design, avoiding the major errors can be relatively simple. In the Guanare-Masparro case the superimposition of soil potential and geomorphic maps on the proposed drainage scheme immediately revealed both the errors in the original conception and the direction to take in alternative evaluation.

If environmental management as a planning concept is to contribute to development, we must define the major considerations. As an example, the sizing of a canal or the choice of core material for a dam are considerations in project design, not planning. In contrast, alternatives in water management, location options, and the relative value of migratory fish compared to flood control benefits are potentially important to the planner.

Planning should focus first on the possible within the context of the desirable and ideal. In the Guanare-Masparro area it would be desirable if people would settle on land with high agricultural potential and if areas with high value in a natural state were preserved. However, settlement and land clearing are spontaneous and uncontrollable once access is constructed, despite rules to the contrary. The planner operating within the realm of the possible would recommend focusing drainage works on the best soils and not bridging canals where facilitating access would lead to undesirable land use.

The approach emphasized in the project is to elevate the "environment," meaning natural systems, to co-equal status with other components such as agriculture and urban-industrial complexes. We document the goods and services such as forest products and waste treatment contributed by the natural systems in a framework of optimization of the input from all components to development. The logic for protecting the source of these goods and services is clear. Not so with anti-pollution measures or culture specific concern about litter or scenic values. We do not deprecate the transcendental value of nature to man, but defense of these values presupposes involvement by a vigorous, enlightened public. Few in Venezuela are able to articulate such values. Fortunately, the strategem of protecting system functions on straight economic grounds is often compatible with more esoteric considerations. The annually flooded prairie or *estero* is preserved in its natural state because of its critical role in the support of juveniles of commercial fish species in the wet season and cattle during the dry. The same *estero* supports flocks of the brilliant scarlet ibis immortalized by the *llanero troubador*.

Notes

1.The study of environmental management in the Guanare-Masparo area is the result of a contract between the Program of Regional Development of the OAS and two Venezuelan institutions, MARNR and the Centro Interamericano de Desarrollo Integral de Aguas y Tierras (CIDIAT). The author is on a two year contract as project director.

2. See Dickinson, 1978, pp. 89-100. This chapter includes a detailed discussion and literature review on ecological principles and methods applicable in planning.

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