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Ecological Diversity and Human Settlements in the Tropical Northern Andes

Los Pueblos del Sur: A Pilot Project of Integral Analysis in the Cordillera de Mérida

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With 10 Figures

1. Ecological Diversity in the Venezuelan Andes

Starting at the Colombian border, the main Andean belt in Venezuela extends for 450 km to northwest direction (Fig. 1). All along its length the cordillera has an average width of nearly 100 km. This huge continuous massif appears deeply dissected by large structural valleys that give rise to systems of parallel chains. Most of the population is concentrated along these valleys, particularly in the middle and upper parts. Here, a rich and diversified agriculture occupies the terraces and alluvial fans. Thus along the Bocono, Motatan, Chama and Mocoties rivers, stand Bocono, Valera, Timotes, Mucuchies, Merida, Tovar, Bailadores and other minor urban centres. Beyond these main valleys, most slopes and secondary valleys remain sparsely populated.

In the central part of the Venezuelan Andes, in Merida, the Chama-Mocoties valleys separate the Cordillera de la Culata, to the north, from the Sierra Nevada de Merida to the south. Our study area, Los Pueblos del Sur, occupies both slopes of the Sierra Nevada (Figures 1 and 2) to the northwest, that drains into the Chama river towards the Lake of Maracaibo, and to the southeast that is draind by several rivers descending to the Llanos, which is then collected by the Apure, one of the major tributaries of the Orinoco.

Los Pueblos del Sur are thus bordered on the northwest by the Chama and Mocoties valleys; the highest peaks of the Sierra Nevada: Humbolt, Bonpland and Bolivar, reaching 5000 m, close the region to the north; while a large transversal range, el Batallon, acts as its natural southern frontier. Towards the llanos, the only natural limit that imposes itself is one of human occupation, since settlements are restricted to the slopes above 1000 m. The whole lower slopes remain almost completely unoccupied. The area thus defined has a total surface of about 300 000 ha (Fig. 2).

Due to the wide altitudinal range in this section of the Andes (500 to 5000 m), together with the diversity of rainfall regimes, almost every type of tropical mountain environment can be encountered (Fig. 3). Under each major climatic type a particular altitudinal zonation of vegetation and land-use belts may be found (SARMIENTO et al., 1971; MONASTERIO, 1980) (Figures 4 and 5). The constitutive elements of this zonation, as well as the precise altitudinal limits between them, vary in function of rainfall amount and its annual distribution. Thus, in the driest slopes facing the Chama valley, the vegetation sequence begins with a cactus shrub and ends with a dry type of paramo that already appears at 2500 m. In the moister areas of this same inner slope, most of the mountain side is covered by cloud forests (Fig. 6) that rise to 3300 or more meters, and that still remain mostly untouched because this area belong to the Sierra Nevada National Park. Above the cloud forest a wet type of paramo occurs, that is replaced higher on the slope by the Desert Paramo (Fig. 7), then by the periglacial desert and finally, above 4700 m, by the nival zone.

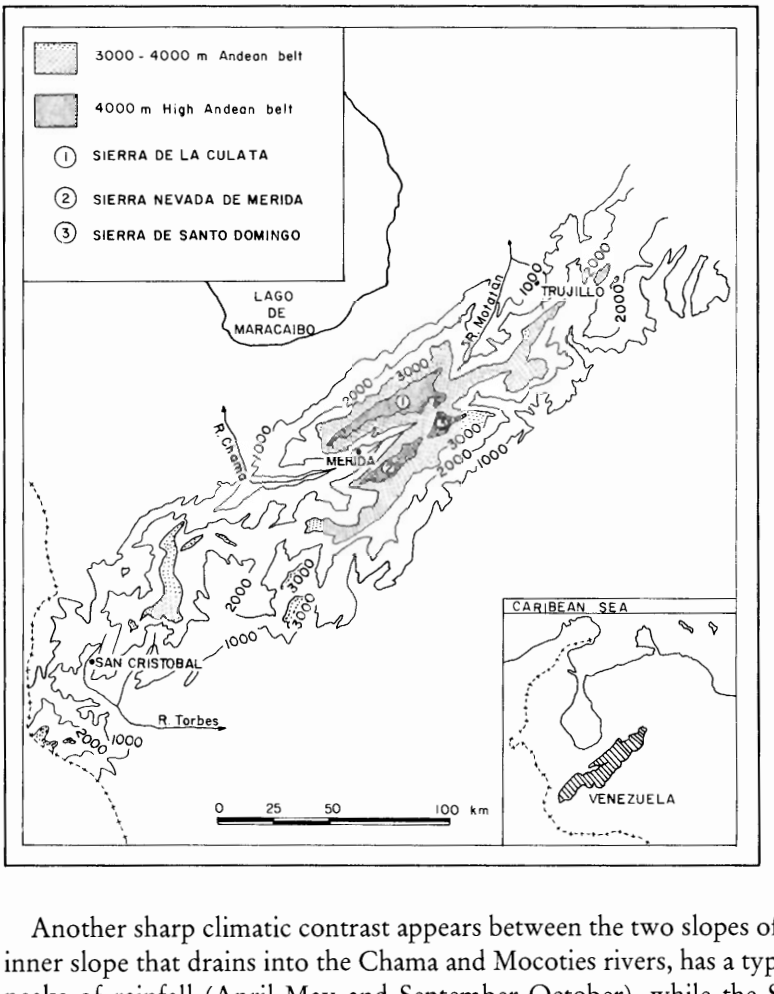

Fig. 1. Surface corresponding to different altitudinal levels in the Cordillera de Mérida, Venezuela.

Another sharp climatic contrast appears between the two slopes of this Andean chain (Fig. 8). The NW inner slope that drains into the Chama and Mocoties rivers, has a typical bimodal rainfall regime with two peaks of rainfall (April-May and September-October), while the SE outer slope, looking towards the llanos, shows an unimodal distribution, with a single annual peak in the midyear months and an accentuated drought from December to March (MONASTERIO and REYES, 1980).

Geology is another important factor which plays a major role in environmental diversity. Several geologic formations outcrop in this area, characterized as most mountain regions by a moving geological history (SCHUBERT, 1980). The main contrast in habitat condition for vegetation and cultures arise from

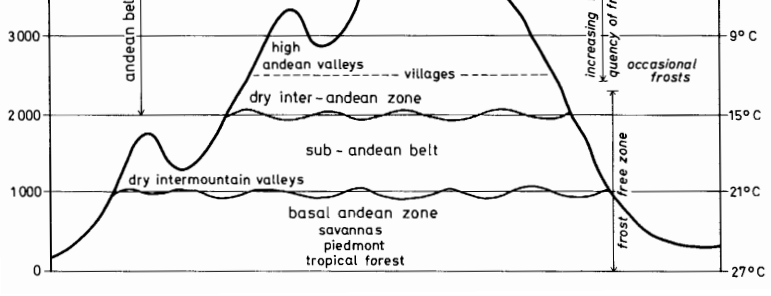

Fig. 3. Idealized profile of altitudinal zonation in the Cordillera de Mérida. The human population, distributed in "islands", is primarily in the two valley zones of Andean and sub-Andean belts (after MONASTERIO, 1980).

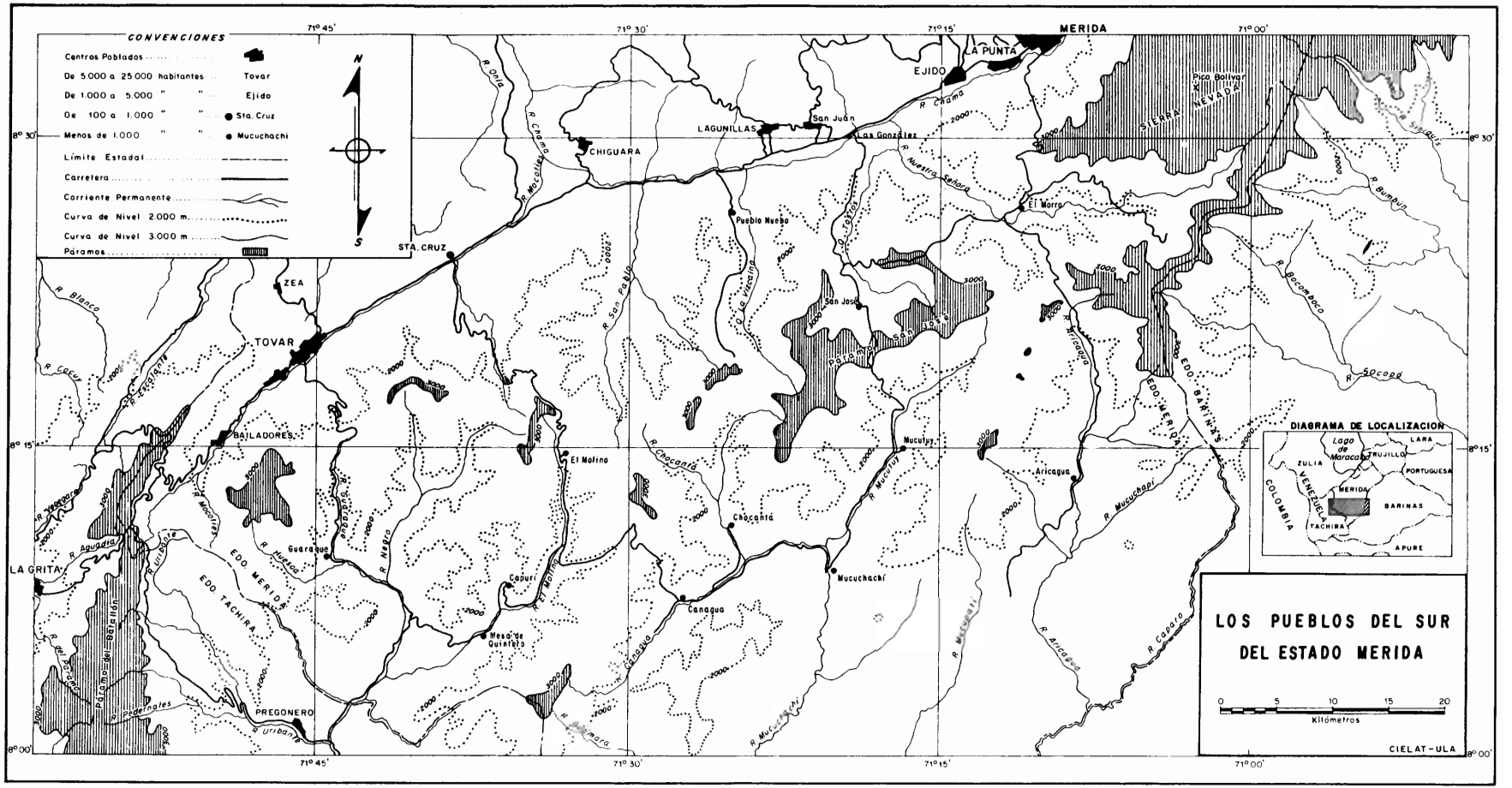

Fig. 2. Area of Los Pueblos des Sur de Mérida.

the occurence of three quite different rock types: metamorphic rocks, mostly gneisses and schists, giving rise to a massive relief; hard sedimentary rocks, like conglomerates and sandstones, that produce a contrasted faulted relief of crests and monoclines; while softer sedimentary rocks, such as shales and limestones, produce a gentler topography where deeper soils may develop. In this way, lithological influences through its effect on structure and differential erosion, the kind of surface modelling, the degree of soil development and hence the possibilities of land utilization (MESSER, MONASTERIO and SARMIENTO, 1982).

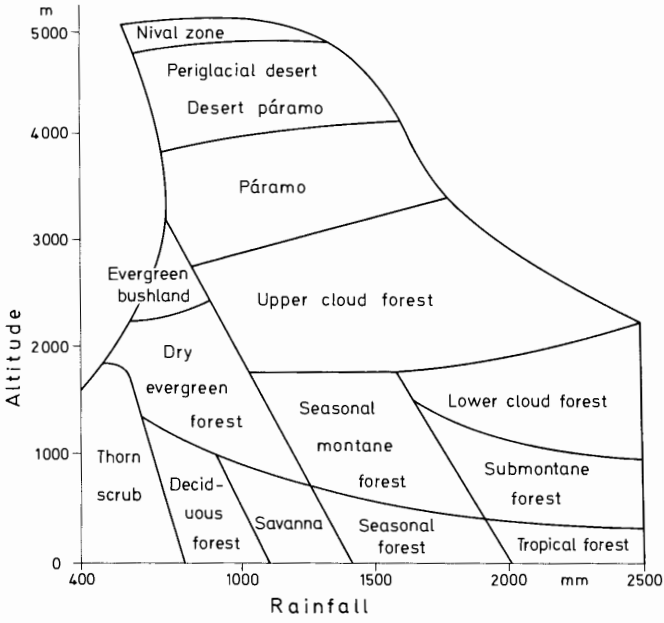

Fig. 4. Wide diversity of primary ecosystems existing in the northern tropical Andes (Cordillera de Mérida), according to altitudinal and rainfall gradients.

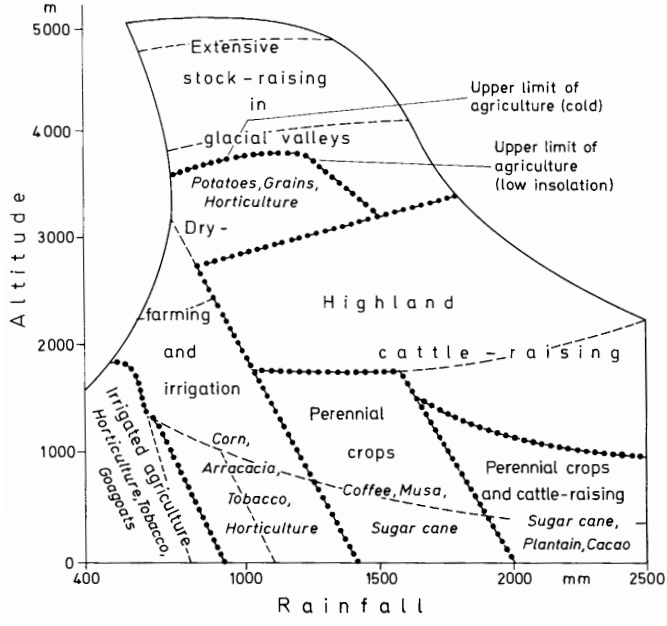

Fig. 5. Main land-use patterns in correlation with primary ecosystems existing in the Cordillera de Mérida (compared with Fig. 4). Thus, in the cloud-forest area, we have cattle raising for milk and meat production, the seasonal montane forest corresponds to perennial crops, mainly coffee, etc.

2. General Outlook and Some Key Methodological Premises

The primordial aim of this project, already in progress, is an ecological and socioeconomic study of the Pueblos del Sur in the Cordillera de Merida (see Fig. 2). This should provide a basic contribution to the establishment of developmental policies in harmony with the natural environment having their main focus on the stabilization of the local population and the improvement of their living conditions.

The Pueblos del Sur constitutes an area of striking regional individuality resulting from both eco-geographic factors and the historical development of its economy. Until very recently this area was relatively isolated from the macroregional context, even considering the isolation patterns characteristic of the high Andean valleys. Modernization is just beginning and most of the area remains as a marginal zone of traditional agriculture. However, public works are already in progress: roads, electricity, irrigation, etc. They will certainly lead to a dramatic change in all aspects of rural life. For this reason it becomes still more urgent to undertake an integral study that might lead to further knowledge of the overall regional picture of its agricultural systems, the local technologies and their ecological rationality. It is also important to study the possible alternatives created by better access to regional and national markets, the intensification of land use, and new pressures upon natural resources.

Furthermore, this region shows a diversity of temperature and other agroclimatic conditions given by the extension of its altitudinal belts. These range from the tropical lowlands in the Andean piedmont to the coldest paramos bordering the snowcovered peaks. The diversification of agroeconomic activities

Fig. 6. A view of the cloud-forest at 3000 m, in the Pueblos del Sur.

Fig. 7. A view of the Desert Páramo ecosystem with *Espeletia timotensis* at 4200 m in the Cordillera de Mérida. Snowfall is frequent at this altitude.

made possible by this rich variety of natural environments the relative persistance of production and conservation, and of local cultivars, render particularly interesting. It is especially important to analyze and characterize these systems or to define the conditions under replacement by socially more productive forms could be envisaged.

It is also worth emphasizing that, even if the traditional practices of management have allowed a relative equilibrium of the local environments and ecosystems, the strong slopes prevailing everywhere in this high mountain area, together with the climatic stresses to which it is normally subjected, determine the potential fragility of most natural and secondary ecosystems. Every technological innovation and infrastructural work has to be based on a thorough knowledge of the dynamics of the ecological units.

One of the most important elements considered in this project refers to the human resources of the region. Its peasants, heirs of aboriginal and hispanic traditions, remain warmly attached to the land. In spite of their isolation, they were open to trade both during the colonial and the republican periods. Any developmental programme must therefore take into account local traditions and feelings, avoiding the mechanical extrapolation of experiences and results coming from completely different socio-cultural backgrounds. High priority will be given to promote policies whose main objective is the well-being of the local peasantry and the maintenance of a long-term natural and social equilibrium.

To cope with the forementioned premises, it becomes absolutely necessary to implement methodologies ad hoc, adapted to the tropical mountains of Latin America. A multidisciplinary approach is essential, where the various personal and institutional participants can integrate their viewpoints and

abilities in a process of mutual learning and gradual self-correction leading to the improvement of the whole team. Many methodologies are supposed to use an integral approach to regional problems as a basis for agricultural planning and rural development, but apparently none of them are entirely satisfactory nor have they resulted in direct application to all real situations. In our case, the existing agricultural systems, as well as the environmental conditions and the natural ecosystems, suggest the need for a global systemic approach rooted in a solid understanding of the physico-natural and socio-historical factors. From these factors may be derived the most rational alternatives to improve land-use and increase land and human productivity. We will try to set out, and to test in practice, certain methodological principles that could be applied by a small multidisciplinary and interinstitutional team. These principles could be adapted to the previous knowledge and to the working conditions of the tropical Andean environments. The two institutions already engaged in this project are the FONAIAP (National Organization for Agricultural Research), and the CIELAT (Center for Ecological Research of the Los Andes University).

One of the major interests of the project may lie in its possible value for future programmes of regional analysis on a large scale, by demonstrating an integrated approach, focused towards a clearly established practical goal. Quite often the programmes of rural development or regional planning, in Latin America and elsewhere, have neglected the ecological processes and constraints, either by lack of pertinent information or by straightness of vision, thus imposing a heavy handicap to the success of the project. On the other hand, regional analysis undertaken on sounder ecological basis have suffered from a distinctly academic bias. Scale problems are also evident, many studies are designed on such an excessively small scale that makes them useless for regional planning in mountain areas.

3. Patterns of Settlement and Land-Use

According to the figures of the last available National Census (1971) the total population of the Pueblos del Sur was approaching 40 000. In this essentially rural area, a dual pattern of human settlement appears: an archipelago of small villages together with a sparse population of isolated farms. There are about 30 villages, that in the humid areas always lie in valleys between 1200 and 1800 m. In the drier zone, where valley bottoms are excessively dry, most settlements stand on slopes between 1600 and 2800 m. In any case they range from small groups of a few houses to villages of a few hundred inhabitants.

Human occupation in the Pueblos del Sur follows divergent historical patterns according to agricultural possibilities given by the ecological conditions. On dry slopes, wheat (Fig. 9), seconded by other temperate-zone grains, constituted the major market crops. During most of the colonial period, and in spite of the non-existence of carriage roads, this area exported wheat not only to regional markets in the Andes

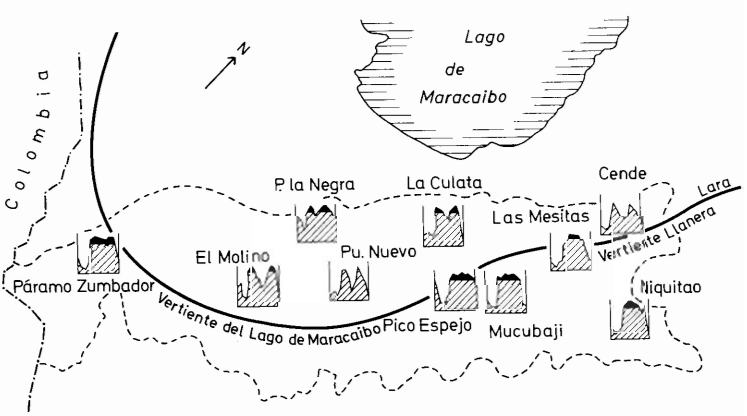

Fig. 8. Diversity of rainfall patterns in the Venezuelan Andes. Northwestern slopes show a bimodal rainfall distribution, while southeastern slopes show the typical unimodal tropical regime, with a dry season from January to March.

Fig. 9. Ancient wheat village at 2700 m in the Cordillera de Mérida. the wheat system is relictual and persists on dry slopes. There is a clear trend towards diversification and market crops beginning in alluvial fans.

Fig. 10. Threshing the wheat, traditionally a community activity. Cordillera de Mérida at 2700 m.

but even to Maracaibo and through this port to other regions. In the last decades of the nineteenth century, this wheat cycle was replaced by the coffee cycle. Coffee is cultivated in the Seasonal Montane Forest. Nowadays, wheat appears as a relictual crop directed mostly to self consumption (Fig. 10). During many periods, smallholders maintained a subsistence agriculture on these dry slopes, but recently modernization has progressed slowly through a diversified agriculture oriented to regional and local markets. Maize, blackbeans, arracacia, garlic, carrots, stand among the principal crops.

The southeastern slopes, as well as the moister inner slopes draining into the Mocoties, were colonized much later than the drier areas that already maintained aboriginal populations before the Spanish conquest. Until coffee cultivation and export came to play a significant role in the last decade of the century, most of these humid slopes remained sparsely populated. The coffee cycle persisted until the world crisis of 1930 that, together with the oil boom, induced dramatic changes in the whole Venezuelan society. Nowadays coffee production, complemented by subsistence crops, is regaining importance, but a new boom in horticulture results from ease of access to the national market and modernization. Most of the fertile alluvial soils are dedicated to a variety of crops like potatoes, onions, garlic, carrots, and many other vegetables, i.e. market gardening.

We have to recall here the fact that the Andes was not only but still remains, a major area of coffee production in Venezuela. However because of its unique agroecological conditions given by its mountain climates within a predominantly tropical warm country, the high andean valleys represent the sole area where many temperate crops become possible. In this way, this mountain areas, in spite of adverse slope conditions, become the necessary complement to the tropical agriculture of the warm lowlands.

Finally, a recent trend clearly apparent in the Pueblos del Sur, as in many other highlands in Venezuela, is the tremendous expansion of cattle raising on lands gained from the mountain forest. This upwards extension of rangelands not only changes the whole economic picture of the region, but also is subjecting the high ranges to new pressures of unpredictable consequences. Thus, the development of large hydroelectric projects points out the incompatibility between stockraising in the catchment areas and large dams and water reservoirs in the middle and low basins.

4. Some Objectives of this Research Project

a) Delimitation, characterization and mapping of the regional ecological units.
b) Identification and evaluation of the physical and biotic factors conditioning or limiting the use of natural resources in each ecological unit.
c) Inventory of the agricultural systems by ecological units.
d) Farm typology definition, characterization and analysis of agricultural systems.
e) Understanding of the regional agrarian systems on the basis of the existing agricultural systems and their interrelationships.
f) Analysis of the interrelationships between ecological factors, and agroeconomic structure and use of natural resources.
g) Identification of socioeconomic factors affecting or promoting the efficient utilization of natural resources in this region.
h) Analysis of the impact of past and present land-use practices on the stability of the ecosystems.
i) Consideration of the local technological traditions and their ecological and economic rationality.
j) Evaluation of possible impacts of new agronomic technologies on the agricultural systems, agroecosystems and natural ecosystems.
k) Analysis of the ecological, economic and social consequences of various infrastructural works undertaken in the last years: roads, irrigation systems, education and health-care centers, etc.
l) Discussion of methodological principles applicable to the agroecological zonification and agroeconomic analysis of tropical mountain regions.

5. Some Final Remarks on Methodology

During the last two or three decades, the problems posed by developmental urgencies in many regions, particularly in the underdeveloped countries, initiated the search for appropriate methodologies that could afford a rapid and efficient gathering of relevant information to sustain governmental or private actions. Though many useful tools were increasingly available, especially in the field of remote sensing, a lot of unsolved problems remained in this multidimensional research area.

The actual knowledge on climates, morphodynamics, soils, ecosystems and many human and social aspects, is so fragmentary that even guiding principles, not to speak of hard facts of scientific laws, are difficult to support or extrapolate. Obviously the underdevelopment also has a scientific dimension. This lack of hard facts and quantitative data is still more dramatic in tropical or in mountainous regions. Probably, the mountain regions of tropical countries accumulate the most handicaps.

It is our intention in this project to start with a quite restricted goal, taking into account the sea of ignorance around us. Our aim is to analyze a few aspects in a particularly restricted area that by its near location to our daily activities could be carried out by a small team having some previous experience both in the area and in the general ecological, agricultural and socioeconomic problems.

Two rather divergent types of approach have been followed in regional land and resources inventories. One is multi-sectorial approach, where specialists analyze each component of the natural and social environment. Once the sectorial aspects have been accomplished more or less independently, all this information is added in some way to produce an a posteriori synthesis. These seems to have been the methodological guiding principles in some ambitious and successful programmes carried on in various countries. Perhaps the best example might be the RADAM BRASIL program of inventory of natural resources in the huge Amazonian region of that country.

The second alternative is to start with a synthetic viewpoint, delimiting units resulting either from physico-natural conditions or from social pressures. That is, to have a first reading of the landscapes to be used later in the analysis and characterization of factors and processes. The leading thread towards a synthesis has been land forms in the CSIRO methodology (CHRISTIAN and STEWART, 1963); natural vegetation in many European mappings; surface dynamics in the ecographic approach of Strasbourg (TRICART and KILIAN, 1979); or the global landscape as a product of environment and people in their actual and past actions in some geographic approaches (BERTRAND, 1970).

This approximation to integral regional analysis through an initial synthetic lecture of the landscape continued by a further analysis leading to a new synthesis, seems more adequate to small projects involving a reduced multidisciplinary team and limited resources. On the other hand, it may be argued that this synthetic approach would be more adequate than the multisectorial one, in mountain regions where all factors physical, biotical and social, are strongly linked with each other.

The system we propose to follow is one of successive approximations through interdisciplinary discussion of the conclusions obtained during each stage of the research work. It may be started with a preliminary delimitation of homogeneous landscape units through both interpretation of remote imagery and field work. Then each unit is sampled in its natural parameters and in its agroeconomic organization. The sampling may lead to some reinterpretation of units and may suggest the consideration of some previously neglected factors or processes. The zonification is thus improved and further data collection is suggested. Within this process, various kinds of information are pooled, from field data to imagery interpretation, from available statistics to questionnaires submitted to rural producers or other qualified informers, from various laboratory data to a collective discussion with landowners in their villages.

In this way, the art of regional ecological analysis, taking the word ecology in its wider and wiser sense, may be developed through a gradual process of learning and giving, what we hope would lead to a deeper understanding of this fascinating world of the Tropical Andes.

Acknowledgements

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Discussion to the Paper Monasterio

Dra. M. L. Salgado-Labouriau:

I find your project very interesting. I would like to ask if the rural settlements in the area have remained fairly stable or if they have expanded in the last 50 years.

Prof. Dra. M. Monasterio:

According to the various populations censuses (the last one in 1981), the total rural population in the Pueblos del Sur remained fairly stable during the last 50 years in spite of the large migration to other regions of the country. Various processes of internal displacement are also apparent, such as the seasonal or permanent migration from the relictual wheat system to the more dynamic coffee system or even to the expanding cattle raising areas in the Cloud Forest belt. These migratory currents were compensated by the high rates of population growth and the improved health conditions.

Prof. Dr. B. Ruthsatz:

Is there some knowledge about symbiosis between species of *Espeletia* and fungi, such as some type of mycorrhiza that could improve the uptake of mineral nutrients?

Prof. Dra. M. Monasterio:

Preliminary observations suggest the occurence of mycorrhiza in several species of *Espeletia*. This may obviously constitute a great selective advantage for species colonizing páramo environments where nutrient supply may be critical.
Specialists interested in a more systematic approach to this relevant problem are certainly needed.

Prof. Dr. W. Eriksen:

In what concerns your first map, why there are no páramos southward from Peru, at least on the eastern, more humid, Andean slopes?

Prof. Dr. M. Monasterio:

In our map (not published), we show the páramos extending from 11 °N, in the Sierra Nevada de Santa Marta (Colombia) to 8 °S in northern Peru. These limits frame the páramos in equatorial or mostly equatorial areas – where they occur as islands conforming a continental archipelago. Southwards from 8 °S, the high tropical moutain appears as a more continuous area, drier and less equatorial. Even if the eastern slopes are wetter, as in the case with the Peruvian Jalca zone, we prefer to relate these systems to the punas. Both types of formations: punas and páramos occur inside wide humidity gradients, therefore we do not emphasize this aspect as a basis for their ecological distribution. There are quite dry páramos, with 600 mm of rainfall, in the Cordillera de Mérida.

Then, to represent the continental extension of punas and páramos, we rely more on the particular features, structural and functional, of both types of ecosystems, as well as on the actual or potential land-use patterns.

Prof. Dr. F. Klötzli:

The parallelisms between Andean and East African Páramo vegetation are well known. But less thought has been given to special adaptations of typical Páramo organisms (e.g. *Espeletia*, *Senecio*, *Lobelia*). There must be a special reproduction or regeneration strategy, because in certain cases (as in Ethiopia with *Lobelia thynchopetralum*) such organisms are more or less growing solely under extreme solifluction conditions. Are details known from Venezuela concerning their regeneration?

Prof. Dra. M. Monasterio:

In the Cordillera de Mérida, all species of *Espeletia* growing in the Desert Páramo (that is above 4000 m), reproduce only sexually. We undertook a detailed analysis of their reproductive cycles and annual phenodynamics using permanent plots along a period of seven years (1976–1983). Some forms of vegetative regeneration by means of basal stems have been observed in species of *Espeletia* that occur at lower elevations (3000–3800 m).

Given that the solid surface maintains the most extreme habitat conditions in the Desert Páramo (daily frost cycles), with the related phenomena of solifluction and cryoreptation, it seems that all species of *Espeletia* have avoided a concentration of their biomass in the lowest, most unfavourable layers, exhibited by the contrary one upright life form and very sparce distribution pattern, in a similar way to that showed by the high-altitude Ethiopian Lobelias. Other characteristic features of the reproductive patterns of these species are presently under analysis and will be the subject of a coming publication.

Prof. Dr. W. Lauer:

Which climatic conditions characterize the individual páramo-types mentioned by you?

Prof. Dr. M. Monasterio:

In the Andes of Mérida it is possible to fix at about 4000 m the lower limit of undoubted periglacial features. This level marks the boundary between two clearcut ecological zones: the Andean belt, downwards, and the High Andean belt, towards the summits. The Desert Páramo corresponds with the periglacial belt of low latitude mountains where frost action and daily cycles of freeze-thaw promote specific geomorphogenetical processes and soil movements of deep ecological consequences. This climatic effects are reinforced by the open nature of the vegetation cover, giant rosettes of *Espeletia*, that leaves large areas of bare ground, favouring thus the rapid cooling and heating of the soil surface that lead to daily cycles of freeze and thaw along most of the years. Below 4000 m, the Desert Páramo is replaced by various páramo formations characterized by a continuous vegetation cover. Frosts in this belt are either mostly seasonal phenomena or they occur sporadically.