Chapter 6

Discussion

Land-use Planning

6. Discussion

The results of the developed model of spatial analysis (SEPRA) proposed as part of the process of the sustainable environmental planning of rural areas, is in this Chapter discussed. This section has been structured in accordance with the different issues tackled in the thesis.

6.1 Theoretical framework

Regarding the last five decades, several approaches, strategies, measures and technical methods about environment and its management, have been developed. Among them the concept of sustainable development (Brundtland, 1987) has become the principal reference framework for the current worldwide environmental management. In this approach the importance of the different management strategies in order to achieve conditions of sustainability for local and global levels is recognized.

The processes of environmental planning, as a fundamental strategy addressed to achieving the sustainable development of countries, regions and local communities, have had progressively significant importance. These processes assess the physic-ecological and socioeconomic limitations and potentialities of the territory, in order to establish the appropriated strategies of environmental management. By means of the environmental planning strategies to maintain the natural resources and improve the quality of life can be formulated.

According to the above several requirements of environmental planning and land use planning have been included into the Venezuelan legal framework. Therefore, at local levels, the process of environmental planning needs to be applied by means of technical tools which, in one sense, guarantee the success of the sustainability and in another sense, can be applied by using friendly methods adapted to the very frequently scarce basic information. Thus, the designed model of spatial analysis constitutes an instrument that can be applied at local levels, in order to generate a territorial analysis as a basic reference for the formulation of a sustainable land-use plan. It is emphasized that the subsequent plan must consider the participation of all social actors.

6.2 Importance of the environmental planning in the study areas

Rural Venezuelan areas require the technical instruments of spatial analysis which could serve as a guideline for its sustainable development. In this sense the selected study areas represent two different zones with not only significant environmental differences but also very different agricultural systems. The successful application of the model on these cases demonstrated the high possibilities of this analysis to be applied in others rural areas.

Rivas Dávila municipality comprises a sub-humid high intermontane catchment dominated by a very steep relief. The narrow Quaternary deposits of the valley bottom represent the most suitable lands for anthropogenic uses, most of which are croplands and cattle breeding. However, in the last few decades, very steep slopes and the high headwater have been occupied by agricultural uses. This threatens the permanency of natural resources, triggers natural hazards and increases the socio-environmental risk.

Quíbor Valley, located in a semiarid region, constitutes a low intermountain depression, characterized by an extended and plain valley bottom surrounded by low hills. Intensive agricultural activities are developed there using intensively the scarce surface water and groundwater. The aquifer, after five decades of intensive use, has been significantly reduced. In order to support the agriculture, in 1983, the National Government declared the valley as an "*Area of agricultural use*". In the area a very important hydraulic project (Sistema Hidráulico Yacambú Quíbor) is currently under construction to supply the water requirements for agriculture that will be increase the current irrigated surface of 3,500 ha to 26,000 ha. Thus, it is expected that the current environmental problems could be increased with the future operation of this project.

The application of the proposed model in these two very different areas allowed the suitability of the designed model to be tested. This, maintaining the principles on which approach was based, could at the same time, incorporate adaptations in accordance with the different conditions of the two areas, e.g., scale of the base information, surface area and different sources and types of information.

With the obtained results it was possible for both areas, Rivas Dávila and Quíbor Valley, to reach appropriated references in order to generate guidelines for the sustainable land use plan.

6.3 Spatial analysis model: Sustainable Environmental Planning of Rural Areas (SEPRA)

Several aspects related to the concept, design, application and results of the proposed spatial analysis model are discussed in the following.

6.3.1 Conceptualization of the model

The model of spatial analysis (SEPRA) was developed into an holistic conception of the environment, which is dominated by dynamic and complex interactions between the factors and processes. Consequently, the conceptual model was constructed by means of the integration of the principal environmental components which determines the conditions of stability–instability of the landscapes. For this conception, basic references of different approaches about environmental assessment were considered. Among these approaches are, for example, landscape sensitivity, geomorphological instability and ecological vulnerability (Buckley, 1982; Thomas, 2001; Villa and McLeod, 2002; Luers, 2005; Schütt, 2006).

As was established in the graphical concept (Figure 4.1, Chapter 4) environmental conditions are defined by the behavior of trigger-processes, i.e. earthquakes, rainfall and land uses, which influence the other environmental factors causing, potentially, environmental instability or damage. The estimation of the possible behavior and the thresholds of the trigger processes as well as the assessment of the capacity of the landscapes to resist to the forces of changes (Schütt, 2006) represent some of the most important objectives of the environmental assessments (Usher, 2001).

Embedded into these premises, it was defined that the objective of the proposed analysis model would have to evaluate the behavior of the environmental components in order to determine the conditions of environmental sensitivity as a basic reference for a sustainable environmental plan of land uses in rural areas.

The model was technically designed to be developed by means of computational Geographic Information Systems. In this case the ESRI ArcGis 9.1 software was utilized, widely applying several extensions and tools of its components ArcMap and ArcCatalog. The development of the model by means computational software allowed a very large quantity of information for the two studied area to be processed. Although some basic data was obtained in digital format, most were only available in analog format, which needed to be scanned and digitalized.

6.3.2 Outputs

Apart from the basic layers generated e.g., geology, geomorphology, DEM and their derivatives, etc.; eight final layers were obtained for every study area (Chapter 5). They were the products of different processes by means of which the basic layers were analyzed. Some discussions about of them are presented in the following.

6.3.2.1 Geo-structural stability

The analysis of the geo-structural stability was originally designed as the combined analysis of the geological aspects, i.e. earthquakes, geological faults and lithology. In the earthquakes analysis it was found that the whole regions in which the study areas are located are dominated by a high seismicity. Taking into account the relatively small surface of the study areas, it was not possible to find deferent levels of seismic risk in the analysed zones. Thus, it seemed appropriated to consider the whole areas as having very high seismicity, such as declared by studies like Schubert and Vivas (1993), Vivas (1994), Escobar and Rengifo (2001), CIDIAT (2004) or Audemard et al. (2008).

Consequently, the combined analysis of the geo-structural stability referred to the generated layers of faulting zones, obtained by buffers around the fault lines (Gokceoglu, 2007), and the fragility of the lithology which was constructed according to the condition of fracturing, weathering or collapse of the rocks.

The resulting layers indicated important spatial differences in the analyzed zones to be considered as a fundamental reference for the desired environmental planning. It is recognized that these layers have an important contribution in the integral analysis included in this model. Additionally, the results contained in this layer can partially be used for other assessments with different objectives in which the geo-structural issues could play an important function. This could be the case, for example, for selecting the zones for allocations of roadways, water reservoirs or even the application of measures of environmental control.

6.3.2.2 Hydro-geomorphlogical stability

The hydrological network and the geomorphological aspects like process (mass movements) and land forms were involved in this partial analysis. The hydrological network was obtained from the base map and processed by means of buffers, in order to determine the potentially more affected area due to the stream dynamics, i.e. overflow, channel erosion, undermining and landslides. The geomorphlogical aspects were analysed in two senses: 1) determining of potential areas of mass-movement risk in accordance with the prepared geomorphological map, and 2) determining of the land forms of the terrain in accordance with the relief, the elaborated Digital Elevation Model and its derivatives, principally slope and curvature.

By means of the results, a fundamental overview of the current and potential hydro-geomorphological risk zones was obtained. The layer indicates that those areas located in the nearness of the streams are subjected to a higher hydro-geomorphological instability level, but also those zones with very steep slopes have high instability. The changing behaviour of the environmental processes and factors involved in this analysis increases the importance of the obtained results. Additionally, the results can be considered partially, especially in the design of measures of environmental control, or as a basic reference for institutions related to environmental hazards management.

6.3.2.3 Erosion susceptibility

Soil erosion susceptibility was analyzed by means of three aspects: relief, soil and rainfall. As analysis parameters of the relief, slope, slope aspect and curvature were utilized. Soil evaluation referred to the physical characteristics of the soils types. The Modified Fournier Index was used as an indicator of rainfall aggressiveness. The results offered a summarized and integral overview of the potential soil erosion susceptibility of the studied areas.

In accordance with the premises that emphasize the overriding influence of the slope on the landscape sensitivity toward erosion (Li et al. 2007; Schütt et al, 2007) it can be concluded that most of Rivas Dávila have a high erosion susceptibility, due to its very steep relief. There, about 55% of the area is characterized by slopes with more than 50% of inclination. Inclinations between 20% and 50% constitute about 32% of the catchment, while only a 13% of this study area presents slopes with less than 20% inclination. Thus, only sectors of the valley bottom, where even predominate rolling relief with slopes between 10 and 20%, were defined as having moderate susceptibility to erosion processes.

Additionally, the results indicate that sectors located on the sunny slope (east-exposed slope) are more susceptible to erosion, because of its higher dairy radiation and, consequently, its dryer and warmer microclimate conditions (Mejia and Vera, 2001; Martínez, 2008) and its scarcer vegetation. In respect to this, Ataroff and Sarmiento (2003), identified the montane dry evergreen forest in the sunny slope while, in the more humid shady slope, the high montane cloud forest predominates.

In the case of the Quíbor Valley, the extended plain relief indicates a reduced incidence of this variable on the erosion processes. 58% of Quíbor Valley has a slope less than 2%, while 22% shows a slope inclination between 2% and 5%. However, the low hills and alluvial fan located around the valley bottom, with slope between 10 and 15%, present more susceptibility to the erosion process as declared by UNDP (2006).

The erosion susceptibility in Quíbor Valley seems to be then very influenced by the low structural stability of the soils because of its clay and clay loam texture with a silt fraction larger than 50% in the most of the valley bottom as considered by Villafañe (1999) and Ecology and Environment (2004).

The Modified Fournier Index showed moderate and low rainfall aggressiveness in the two study cases. Its influence on the soil erosion susceptibility is more significant in the case of Rivas Dávila, whose northeast side presents a very high erosion susceptibility as a consequence of the larger grade of rainfall aggressiveness.

6.3.2.4 Fragility of the vegetation cover

Vegetation cover contributes to maintaining the stability conditions of the landscapes because it configures a protector layer for the soils against the rainfall’s aggressiveness and the soil degradation (FAO, 1995). Soils are reinforced by the roots system (Van Westen et al. 2008) and the organic matter contributes to the control of the erosion process, by means of the percolation and retention of soil water, reducing the runoff and improving the soil structure (Hill and Schütt, 2000).

The fragility of the vegetation units was evaluated considering its characteristics of height, density and grade of intervention. Due to the appreciable level of disturbance of the original vegetation in the valley-bottoms of the analysed areas, the vegetation described in these lands is indicated as a reference of those that could be found in natural conditions. Most of the hillsides of the two areas present pristine vegetation units, although some sectors have been disturbed by anthropogenic uses.

In Rivas Dávila, the most fragile unit corresponds with the Andean Paramo, which covers the upper lands of the area, above 3000 m a.s.l. in the coldest climatic conditions of the area, with an annual average temperature of about 7°C. Between the shrubland and grassland of these units there are some endemic species of high ecologic importance such as the *Espeletia schultzii* or frailejon. Also, the high montane cloud forest, preponderant in the shady slope, was catalogued as highly fragile due to its ecological complexity. Once disturbed its recuperation is only possible over a very long period of time. Other types of vegetation more resistant to alterations were classified as moderately fragile. This is the case of montane semi-deciduous forest.

Because of its high grade of disturbance the analysis of the vegetation in Quíbor Valley was oriented to identifying priorities of conservation. In this sense the typical vegetation of the southeast of the area constituted by very dry tropical forest was defined as having very high priority. In some sections this unit can present relicts of the original vegetation especially where the undulated relief has limited the anthropogenic uses. The dense thorny shrub of the hills around the valley was defined as having moderate priority, while, in the valley bottom the scarce natural vegetation was identified as having moderate priority, especially that which still can be found around the streams, lagoons or abandoned lands. In these lands ecological successions play an important function in the control and of soil degradation processes.

6.3.2.5 Land-use intensity

Intensity of the land uses was employed as an indicator of the human impacts on the environment. In this sense, the land uses of the study areas were analyzed in accordance with their incidence on landscapes. Thus, the following was taken as reference: those land uses that implicate intensive affectations on natural resources would be classified as high intensity, whereas those land uses in which natural resources are maintained unaltered or scarcely altered would be considered as low intensity.

The highest intensity level was assigned, in both cases -Rivas Dávila and Quíbor Valley- to intensive croplands. These agricultural activities cause strong environmental impacts due to factors such as complete disturbance of the natural vegetation of the occupied areas, use of agricultural machinery, intensive irrigation which reduces the stream flow and increases the soil erosion, or even intensive use of pesticides and chemical fertilizers. Others land cover as natural vegetation predominately in vast zones of Rivas Dávila were classified as low intensity because of its unaltered or slight alteration grade.

Quíbor Valley, as a consequence of ancient and intensive human intervention, presents zones with a high level of disturbance. Thus, most of the valley bottom is constituted by agriculture lands. One important part of these agriculture lands is currently occupied by intensive croplands; other parts vary between fallows and abandoned lands. Intensive croplands, due to the intensive use of channel irrigation, agricultural machinery, pesticides and fertilizers, were classified as very high intensity. Abandoned lands and human settlements were classified as high intensity. The areas where natural vegetation can still be found -principally the hills around the valley- were classified as low intensity.

6.3.2.6 Physiographic restrictions

As an integral analysis of the physiographic conditions of the analysed areas, a map of physiographic restrictions was elaborated. It was the product of the three first results of the applied SEPRA model, i.e. geo-structural stability, which refers to geological conditions; hydro-geomorphological stability referred to the combined elements hydrology and geomorphology; and finally, erosion susceptibility, produced as a result of the integral analysis of relief, soil and rainfall.

This analysis in both study cases orients around the conditions of fragility of the geo-physical parameters analysed by means of SEPRA. In the case of Rivas Dávila, for example, the results indicate that the nearest areas to the principal streams present the highest restrictions for the anthropogenic occupations. This is a consequence of the overflows, floods or even landslides potentially produced by the hydro-geomorphological dynamic. Other areas with severe restrictions are constituted of sectors of the left slope dominated by a severe faulting zone. The valley bottom, due to its lower restriction level, was considered as the area with more potentialities for the anthropogenic uses.

In the case of Quíbor Valley, it was found that the highest restriction grades are represented by hills and alluvial fans. This is influenced by their more inclined relief and their high level of erosion susceptibility. There, it is necessary to carry out actions of environmental management in order to guarantee its recuperation and permanency. These areas represent the zones with more natural conditions of the valley. In the valley bottom, in spite of its lower restrictions, anthropogenic interventions must be made considering its moderate physiographic restrictions. These restrictions basically refer to sheet erosion and, potentially, gully erosion processes, as consequence of the fragility of the soils in accordance with Villafañe et al. (1999) and UNDP (2005).

6.3.2.7 Landscape sensitivity

A layer of landscape sensitivity was produced as a result of the combined analysis of physiographic restrictions and fragility of the vegetation. The first, as was explained, concerns the imposed physiographic limitations to the anthropogenic uses; the second summarizes the ecological conditions indicated by the vegetation units.

For Rivas Dávila, the principal results of the physiographic restrictions were maintained: the hydrological network was valued as very sensible, whereas elevated and relatively plain areas of the valley bottom were valued as the lowest sensitivity level. On very steep slopes it was found that some sections, which had been classified as very high physiographic restrictions, were here divided into two classes: very high and severe sensitivity. This was a consequence of the different levels of fragility assigned to the vegetation cover that characterize these terrains.

In the case of Quíbor Valley, very high sensitivity areas were found in the low hills and alluvial fans of the valley, where previous analysis had identified restrictive physiographic conditions as well as high priority of preservation of the natural vegetation. Some sections of the hydrographical network in the valley bottom as well as the lowest zones of the alluvial fans resulted as landscapes with high sensitivity. Most of the valley bottom was classified as landscapes of moderate sensitivity.

6.3.2.8 Land-use suitability

This represented a comparison between landscape sensitivity and the conditions of land-use intensity. This results offer an overview about the current and potentially conflict established in the study areas between anthropogenic uses and landscape sensitivity.

The obtained layer indicates that about 34% of Quíbor Valley, is characterized by forest and natural uses, located in areas with severe and high landscape sensitivity. These areas are located in the hills around the valley, as well as in different sections of the valley bottom, especially in the north of the area. Programs of environmental management aimed at maintaining their natural resources should be implemented in these areas.

In the case of Rivas Dávila about 35% of the area is characterized by the forest and natural uses, located in areas defined as having severe sensitivity. It suggests that these areas of severe landscape sensitivity are occupied by the most indicated land-use type: natural protection. It is obvious that the permanency of these natural zones not only guarantees the conservation of ecosystems of high fragility, but also guarantees the sustainability of the water resource, which is at the same time one of the basic resources needed for carrying out the necessary agricultural uses in valley bottom.

Also, 17% of this study area is covered by forest, located in zones of moderate sensitivity, which seems the most suitable use of these areas in order to preserve the natural resources and guarantee conditions of sustainability.

The most conflictive conditions between anthropogenic uses and landscape sensitivity are represented by about 5% of the area, where intensive uses, such as intensive cropland, are developed on areas classified as severe sensitivity. Most of these sectors are integrated by intensive agriculture carried out on the near to riverbanks and in their flood plains.

About 34% of the Quíbor Valley is characterized by forest and natural uses, located in areas having severe and high sensitivity. These areas are located in the hills around the valley, and in different sections of the valley bottom, especially in the north. Programs of environmental management aimed at maintaining their natural resources should be implemented in these areas. Also 34% of the valley represents land of moderate landscape sensitivity, where the current uses are developed with low intensity. Most of this is agriculture land that is currently in fallow condition. In these areas the future irrigation system, which has been projected for Quíbor Valley, could be carried out embedded into programs of sustainable agriculture.

Larger environmental conflicts were identified in areas of severe and very high landscape sensitivity used by very intensive agriculture. There, also programs of environmental management must be applied that are addressed to recuperation and conservation.

6.4 Proposal of land-use plan

As a fundamental goal of the environmental planning process and, in this case, of the designed spatial analysis model, a proposal of the land-use zonation must be formulated. In this zonation the land uses are defined that could be carried out in the study area, in accordance with the sustainability principles. The zonation must take into consideration the conditions of environmental sensitivity of the areas in order to prevent and mitigate on one hand, the environmental damages caused by the environmental conditions, and on other hand, the environmental impacts due to anthropogenic uses.

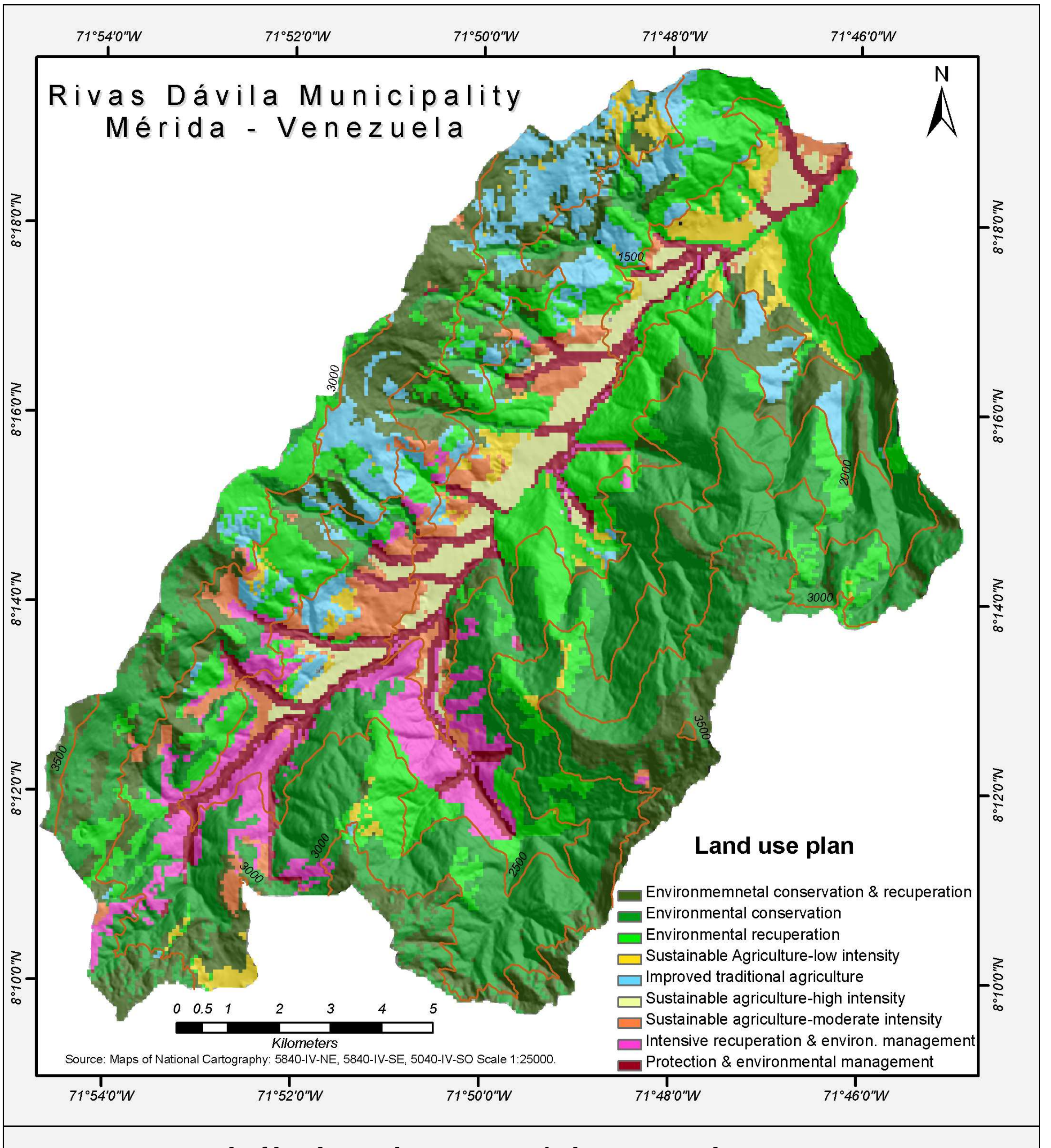
In general terms, degrading land uses should be replaced by environmentally friendly uses, such as natural conservation, organic agriculture, agrotourism or ecological tourism. Suitable uses should be maintained, and perhaps improved, in accordance with sustainable principles.

In this thesis, the formulated plans are the result of the sequential spatial analysis developed by means of the SEPRA model, in which the most important environmental components, factors and processes were partially and integrally analyzed. Basically, the spatial analysis model allowed, by means of a successive and combined analysis and decision-making process, to identify the environmental conditions of stability and instability. The produced plans definitively represent a guideline or a very advanced draft plans which can be the basis for a definitive land-use plan which, as was expressed in Chapter 1, needs to be discussed and agreed with the social actors.

The final zonation proposed as a consequence of the SEPRA model is the result of the analysis of the generated layers *Suitability of the land uses* (Maps 5.20 and 5.40). However, qualitative checks and confirmations of the partial products obtained by the model were carried out at the same time. In accordance with the sensitivity of the landscapes and the intensity of the current land-uses, the proposal of land-use plans for both study cases Rivas Dávila and Quíbor Valley are presented in Maps 6.1 and 6.2.

6.4.1 Proposal of land-use plan. Case Rivas Dávila Municipality

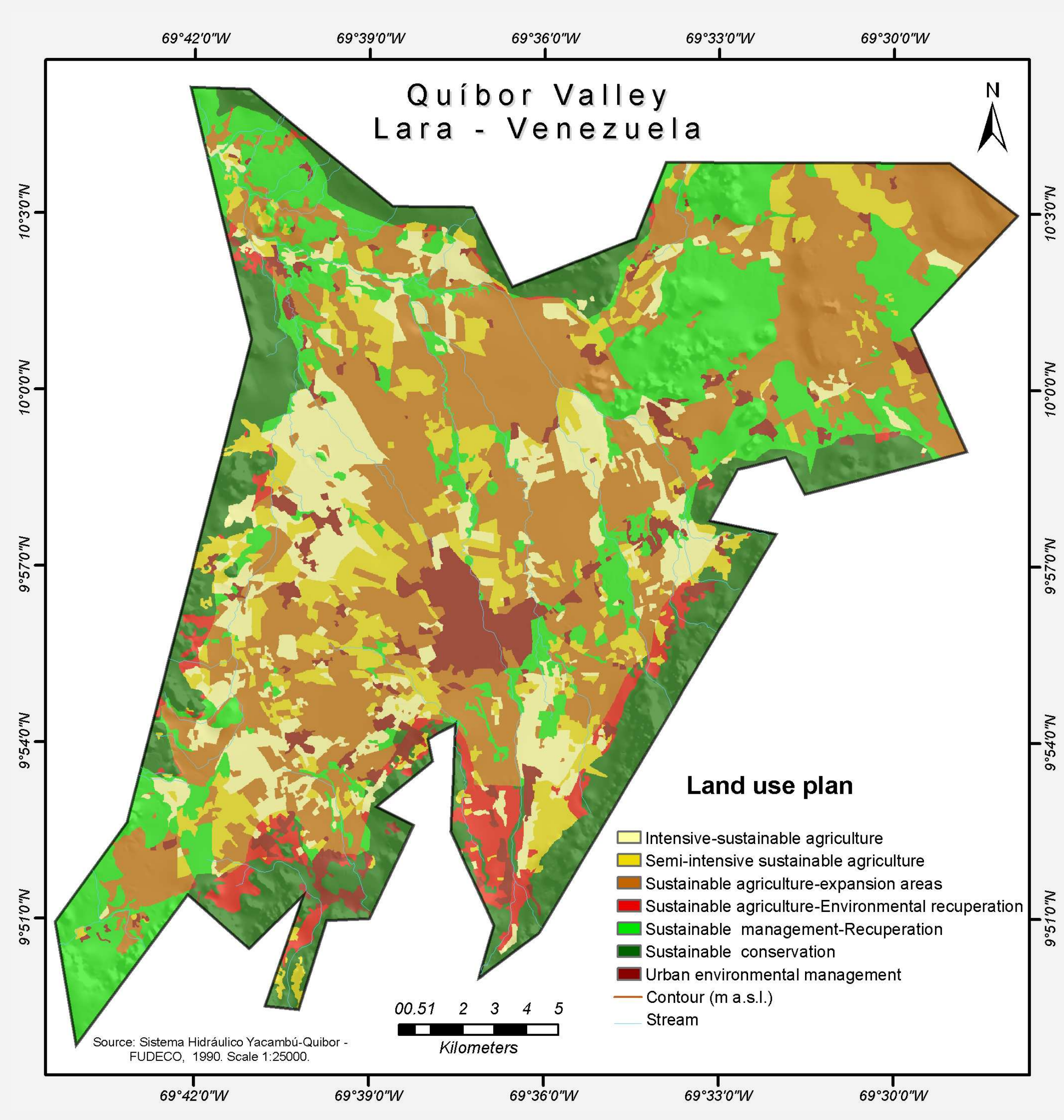
The recommended units of land uses are integrated by those in which the natural resources must be preserved in their current natural conditions. These areas represent about 35% of the Rivas Dávila. The proposed land units, where could be developed with more potentiality anthropogenic activities account for about 17% of the whole surface. Most of these zones are located in the valley bottom and in low hills.



Map 6.1: Proposal of land-use plan, Rivas Dávila Municipality.

6.4.2 Proposal of land-use plan. Case Quíbor Valley

Seven land-use types integrate the proposed plan of Quíbor Valley. In this proposal it was considered that the current agricultural activities define the area as one of the most important of the country, because of its production levels of onions, paprika and tomatoes. Additionally, the project carried out by the National Government in order to increase the farm production and the irrigated lands was also taking into account. The referred plan is shown in Map 6.2.



Map 6.2: Proposal of land-use, Quíbor Valley.

According to this, intensive sustainable-agriculture covers a surface of about 5,200 ha, which is 12% of the Quíbor Valley, while semi-intensive sustainable-agriculture covers about 4,700 ha (11%). The largest land-use type is constituted by those areas in which enlargement of the irrigation systems and the intensive sustainable-agriculture are possible, which have been proposed by the future operation of the “Sistema Hidráulico Yacambú – Quíbor” hydraulic project. This land-use represents about 15,000 ha (34% of the Quíbor Valley). The proposed intensive and semi intensive agriculture must be embedded into environmental production systems in which can be employed efficient technology of irrigation and mechanization of the soils and integrated pest management. Social organization which allows the advantageous participation of small farmers and workers and the improvement of their quality of life needs to be also strengthened.

Some sectors defined as high landscape fragility, which are used by intensive agriculture must be subjected to programs of environmental recuperation and sustainable agriculture of very low intensity. About 40% of the Quíbor Valley was proposed as natural areas in which programs of environmental management must be developed addressed to recuperation, maintenance and improvement of degraded natural resources.

It is emphasized that the land use proposed as result of the applied spatial analysis model represents a guideline which must be discussed with the all social actors in order to achieve a final land-use plan. This plan needs be produced by the consensus and compromise of local administration and communities in order to enhance its possibilities of fulfillment by both important social sector authorities and communities.