DECISION SUPPORT SYSTEM FOR SUSTAINABLE ECOSYSTEM MANAGEMENT

IN ATLANTIC RAIN FOREST RURAL AREAS

(ECOMAN)

The challenge of sustainable ecosystem development in Cachoeira catchment (South Bahia, Brazil)

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INTRODUCTION

To accomplish the necessary growth of well-being without compromising the capacity of natural resources also producing that well-being for future generations is a challenge that implies to cut with the existent relationship between economic growth and natural resources use, which has driven to the present situation of environmental degradation. It means also to shift to a paradigm of natural resources management, instead of natural resources exploitation, to bring to a halt the current unsustainable patterns of production and consumption (UNDP, 2003).

The development of rural areas is directly connected with the way land is used, which depends not only from the biophysical dimensions but also from the socio-economic dimensions (Bouman et al, 2000), especially in what relates with decision-making (Lourenço, et al, 1997 & 1998). So in regions where agriculture plays a significant role as provider of income to the individuals, it is important to invest in increasing agricultural productivity and restructure the current farming systems (UNDP, 2003). These efforts should aim at generating higher yields (within sustainable thresholds), decreasing the dependency to one type of production (diversifying the cash-crops for international and local markets and the livestock production) and diversifying the network of off-farm economic activities, to avoid the migration of rural population to urban areas. However, only in an integrated way it is possible to design policies aiming at reducing poverty of rural areas turning them attractive for public and private investment, which needs a critical mass of labour force, that is only possible to set if there is already some regional potential conferred by the natural resources and man made infrastructures.

This report aims at presenting the results of the scenario definition in the ECOMAN project for the Brazilian study area of Rio Cachoeira catchment, located in South Bahia. The main aim of this process of scenario definition is to find different potential strategies for sustainable local development of the studied rural areas, which are situated in a tropical rainforest region affected by intensive and growing human pressure. The considered alternatives of land management aim at improving the socio-economic conditions of local communities by upholding the sustainable use and protection of natural resources. However, these alternatives should also be considered under the perspectives of alternative income and the new market trends at regional and global levels.

The project ECOMAN focused on the impacts of growing economic activities and the production needs as the main causes of the exploitation of natural resources. The analysis of type and intensity of agricultural exploitation contributed to identify the limits of sustainable production in Cachoeira catchment. Moreover, the alternatives now presented correspond also to strategies to the rehabilitation and recuperation of degraded areas and their transformation to environmentally friendly sustainable production systems to improve the economic situation of the local population.

1 DECISION-MAKING PROCESSES AND DECISION SUPPORT SYSTEMS

Decision-making processes are an activity essential to individual, group, organizational, and societal life. It involves a consistent choice among alternatives / strategies of intervention in a given area, for the purpose of achieving a goal or a set of goals, according with the values and preferences of the decision maker (March, 1994 and Tkach & Simonovic, 1997). Therefore, one of the key challenges related with decision-making processes is how to manage large sets of diverse and suitable information.

1.1 Multiple dimensions of ecosystem management

Making decisions about the allocation of land is one of the most fundamental activities of resource development, but making decisions is one of the most difficult tasks for the responsible of ecosystem management. In fact it is frequent that the decision would be taken by a team and not by an individual, and in current days, participation of local communities is encouraged by national and international policies. Furthermore, a decision must meet several objectives, which are frequently conflicting. In fact it is not easy to harmonise the protection and conservation of natural resources, environment and ecosystems with the need for economic growth (Skinner, 1999).

All decision-making processes have a degree of uncertainty, ranging from a predictable (deterministic) situation to an uncertain situation (Malczewski, 1999). Decision-making would be less problematic if it would be possible to predict reliably the outcomes resulting from the decision taken. However, there is a dimension of uncertainty about the impacts of the decision to be taken, not only because the quality and quantity of data available doesn't allow predicting the future, but also because the human action can influence the future itself and the reality is almost never independent from the observer or the methods used to observe it (Gershenson, 2004). In fact the interactions of the multiple dimensions involved in the process turn hard to manage all the necessary information as well as reaching a general consensus among decision-makers and stakeholders.

Usually decision-making is structured in three major elements: the problem identification, the development of alternative solutions and the selection among the alternatives (Beynon *et al*. 2002). However it is possible to detail these elements in different steps, of which the following should be highlighted (Dodgson et al, 2000; Shim *et al.*, 2002; Beynon *et al*. 2002):

Assessing a problem and define objectives. The problem is frequently presented in very broad and unfocused terms, encompassing frequently the past experiences of possible environmental changes. Therefore, direct and indirect objectives should frame all the judgement criteria of the decision-maker. These objectives must be carefully identified in terms of strategic goals such as economic growth, social cohesion and environmental sustainability.

Identifying and designing alternatives of intervention to solve the problem and achieve the objectives defined. The alternatives can range from more or less broad policies to the selection of specific projects and actions of intervention. Nevertheless, the design of these alternatives depends very much upon the specificity of the situation and upon the skills and soundness of the specialists' work in finding the adequate solutions to the problem. Therefore, the collection and verification of reliable information is necessary to this stage of the decision-making process as well as the participation of the community.

Selecting criteria to be used to compare the options. The criteria should reflect the objectives defined and be based on the available information. Furthermore, they should be measurable, in the sense that it must be possible to assess, at least in a qualitative sense, how well a particular option is expected to perform in relation to the criteria.

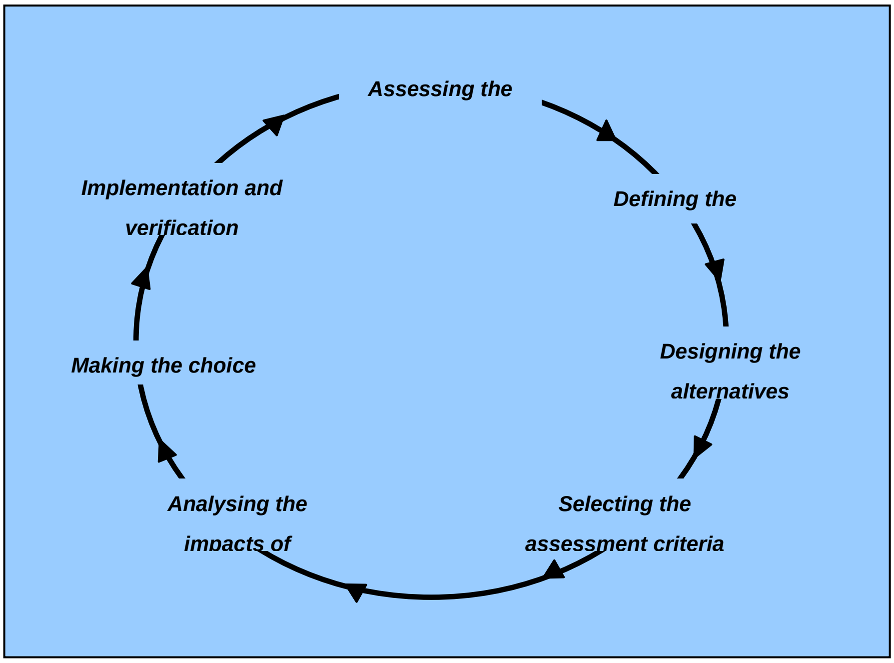
Anticipating consequences of decisions. It is one of the most difficult steps of decision making because frequently the information available is not enough to allow forecasting the total impacts of the alternatives in analysis. This step refers frequently to the analysis of each alternative in terms of social, economic and environmental costs and benefits. The use of different computer based techniques (financial analysis, cost-benefit analysis, or multi-criteria analysis) can give support to this stage of the analysis.

Making the choice. It is a responsibility of the decision-makers (individual or collective), but a sound and valid judgement has more hypotheses to be broadly accepted if there is a participation of public community. However, the final decision usually reflects the values and preferences of the decision maker. Therefore, this final decision should be communicated to the community accompanied by its fundamental motivations and justifications.

Evaluating decisions feedbacks is a continuous, but essential, task to assess and reassess the ways that decisions are shifting, or not, the system towards the accomplishment of the defined objectives.

However, the decision-making process is not as linear as it can be perceived from the above enunciation of phases and expressed in Fig. 1. Frequently the phases overlap and merge, with frequent backing up to earlier stages (Shim *et al.*, 2002 & Courtney, 2001).

Fig. 1. Scheme of a general decision-making processes



Source: adapted from Shim *et al.*, 2002 & Courtney, 2001

To face the complexity inherent to decision-making processes, some tools were developed to support decision-makers intervention in all steps of the decision-making process, from problem definition to the communication of final decision.

1.2 Decision support systems and spatial decision support systems

Decision support systems (DSS) are interactive computer-based systems intended to help decision-makers to manage the large volumes of information necessary to the process of decision-making (Shim *et al*, 2002). Therefore, they are powerful tools to assist decision-makers in the use and manipulation of data and of mathematical models, being frequently exploited to support complex, semi-structured and unstructured decision-making contexts.

Decision support systems provide integration of information and feedback loops to support investigation in the quest for scientific discovery. The intangible factors in the decision-making process may be accounted for through information supplied and choices made by a decision-maker who operates the DSS interactively or through an analyst (Shim *et al*, 2002). Therefore, DSS design comprises components for: database management capabilities with access to internal and external data; modelling functions accessed by a model management system; and powerful, yet simple, user interface designs that enable interactive queries, reporting, and graphing functions. Their final aim is to generate and evaluate alternative strategies for solving the problem in analysis (Sprague and Watson, 1996).

Notwithstanding, in the specialised literature (Holsapple and Whinston, 1991) DSS is mainly viewed as a mathematical technique or a set of techniques for decision making by optimising something under some specific constraints, we consider DSS in its broad meaning as an information system that can be used to support decisions at spatial level.

In general, decision problems involve a set of geographically-defined alternatives from which a choice of one or more alternatives is made with respect to a given set of evaluation criteria and objectives (Ascough, 2002). This means that analysis results depend not only on the value judgments involved in the decision making process, but also on the geographical distribution of attributes of the area in study. Therefore, it is necessary to provide decision-makers with tools that combine decision-makers' preferences and criteria, with spatial information about the geographical locations of the alternatives in judgement.

Spatial decision support systems (SDSS) are considered as the adequate tools for the development of highly integrated information systems, which include geographical information systems, remote sensing and image processing techniques, knowledge databases and logical modelling and expert systems, simulation and optimisation, multi-criteria decision analysis and a suitable user interface (Fedra & Feoli, 1998).

According to Densham (1991) and Geoffrion (1983), decision support systems have six focal characteristics: explicit design to solve problems; powerful and easy-to-handle user interface; ability to flexibly combine analytical models with data; ability to explore the spatial analysis solution by building alternatives; capability of supporting a variety of decision-making styles; and allowing interactive and recursive problem solving. Furthermore, the distinctive capabilities and functions of spatial decision support systems rely on: the mechanisms provided for the input of spatial data, allowing representation of the spatial relations and structures. They include the analytical techniques of spatial and geographical analysis and provide outputs in a variety of spatial representations, including maps.

Therefore, SDSS are user-driven interactive computer-based systems, which help decision-makers utilise spatial data, models and tools of Geographic Information Systems (GIS) and Image Processing (IP) to solve semistructured or unstructured problems. They can be developed as general-purpose tools for decision-making (Craig & David, 1991, Densham, 1991, Goodchild & Densham, 1990, Moon, 1992, NCGIA, 1992). These systems support, rather than replace, decision-makers to make their own decisions flexibly. However, the objective of SDSS is to improve the effectiveness of the decisions, not the efficiency with which decisions are being made.

2 METHODOLOGICAL APPROACH FOR THE EVALUATION OF ECOSYSTEM MANAGEMENT ALTERNATIVES IN CACHOEIRA CATCHMENT

The main objective of scenario definition in ECOMAN is to find different potential strategies for sustainable local development. Therefore, the chosen alternatives represent benchmarks of possible strategies which possess a certain potential to increase the income of local communities and to protect and conserve the natural resources in the study area.

Sustainability was the prevailing consideration in the definition of strategies for ecosystem management in this area. This concern is imbedded in all the process of analysis, from the choice of alternatives to their ranking as the most adequate to accomplish this main goal. Therefore, the analysis was restricted to a set of alternatives embracing an array of development strategies which have been assessed as implementable and suitable for the Cachoeira Catchment according to scientific expertise and stakeholders' interests. It was not in the frame of this work to make judgements among sustainable and unsustainable strategies for the Cachoeira catchment.

The evaluation of different ecosystem management alternatives was the corollary of the integrated analysis that coupled socio-economic and environmental data sets of different spatial and time scales for Cachoeira catchment[1]. The use of a DSS allowed developing integrated and prospective scenarios from local to regional levels, as well as to understand the dynamics of the system, by linking the interactions nature / society to promote alternative income generation from the use and management of natural resources including their protection.

2.1 Description of the system

The description of the system of Cachoeira catchment adopted a methodological approach to support and assist the resolution of environmental and socio-economic issues, with specific emphasis on interdisciplinarity and cross-sectoriality. This description allows to understand the socio-economic and institutional driving forces that produce land use changes; and to identify policies and measures to improve the socio-economic conditions by the use and protection of natural resources taking into account alternative income and the new market trends at regional and global levels.

Furthermore, it allows evaluating the intensity of use of biotic and abiotic natural resources (biodiversity, water and soils) and assessing the ecosystems resilience by using relevant key indicators under different gradients of human pressure.

2.2 Cluster analysis

Cluster analysis is an exploratory data analysis tool aiming at sorting different objects into groups in a way that the degree of association between two objects is maximal if they belong to the same group and minimal otherwise (Rogerson, 2001). Therefore, it allows organising the municipalities of Cachoeira catchment into a meaningful typology according to socio-economic data. Nevertheless, although discovering structures in data, this type of analysis doesn't provide any

1 This integrated analysis of environmental and socio-economic interactions was developed in the frame of workpackages WP2-WP8.

explanation or interpretation of the existent groups. Therefore, several correlation analysis were developed to identify which key variables contributed more (and to which extent) to the clustering obtained, allowing, therefore, to support the description of each cluster.

The socio-economic typology accomplished was used to better assign the management strategies for different areas of the Cachoeira catchment.

2.3 Evaluation and ranking of management alternatives

The evaluation and ranking of the different ecosystem management alternatives was made by using the DEFINITE software. DEFINITE (Decisions on a Finite Set of Alternatives) is an environmental planning analysis tool which uses judgement-based, ordinal, and cardinal data to help users characterise the system at hand and explore hidden interactions and emergent properties (Janssen, Hervijnen & Beinat, 2003). Furthermore, this software package evaluates interactions between different basic information types (biophysical, economic, and social), and allows to weigh up different alternatives and assess the most reasonable one(s) according to a set of criteria established by the user.

According with the software package DEFINITE it was necessary to produce a matrix (called *Effects Table*), which is the central element of the evaluation and ranking process in DEFINITE. In this effects table are included the alternatives identified (columns) and the effects considered as evaluation criteria (rows). The cell values of this table correspond to the importance of each effect in reference to each alternative (Janssen, Hervijnen & Beinat, 2003).

2.3.1 Identification and design of management alternatives for Cachoeira catchment

A decision is a choice between alternatives. The alternatives may represent different options of action based on different hypotheses among which a choice is desirable based on some criteria. A criterion is some basis for a decision that can be measured and evaluated. It is the evidence upon which a decision is based.

The design of the alternatives to be evaluated with the support of DEFINITE, was made trough a series of consultation meetings within and outside the research consortium. One of the main guidelines to this process of identification was that those strategies should comply with the goal of sustainable development and their implementation should be suitable to the natural and socio-economic conditions of the catchment.

Eleven management strategies were identified and a hierarchical structure was defined. So, these management strategies were later on grouped in four main alternatives that were also evaluated.

2.3.2 Selection of evaluation criteria (effects)

A decision is based on a set of rules by which criteria are combined to arrive at a particular decision. Decision rules are structured in the context of a specific objective, for example, to determine which area is suitable for a given activity. To meet a specific objective it is frequently the case that several criteria will need to be evaluated.

The effects represent the objectives to be reached trough the decision-making process. Therefore, if they don't agree with the objectives identified, the alternatives will also not comply with those objectives (Janssen, Hervijnen & Beinat, 2003).

The selection of these evaluation criteria was made through a series of consultation meetings within and outside the research consortium. For facility of dealing with the 29 criteria selected it was defined a hierarchical structure of the evaluation criteria. The criteria were arranged in subgroups within two main groups: socio-economic (social, income/costs, economic) and environmental (soil, water, vegetation and ecosystem).

2.3.3 Assigning scores to the evaluation criteria (effects) according with each alternative

The assignment of scores to each evaluation criteria was made within the research consortium and grounded on the research developed in the frame of workpackages WP2-WP8. DEFINITE allows different types of measurement of these scores. For lack of specific quantitative data concerning all the effects, in the case of Cachoeira catchment a qualitative measurement was applied using a - - - / + + + scale, which is the most transparent and reproducible method, as long as the results are carefully interpreted within the following context (Janssen, Hervijnen & Beinat, 2003):

– – – : very big negative effect
– – : big negative effect
– : small negative effect
0 : no effect
+ : small positive effect
++ : big positive effect
+++ : very big positive effect

2.3.4 Assigning weights to the evaluation criteria (effects)

This step of the process is necessary because the method used to rank the different management alternatives is the Multicriteria Analysis (MCA), which requires information about the relative importance of each evaluation criteria.

In a Multicriteria Analysis (MCA), an attempt is made to combine a set of criteria to achieve a single composite basis for a decision according to a specific objective (Eastman et al., 1995). Decisions about the allocation of land typically involve the evaluation of multiple criteria according to several, often conflicting-objectives (Eastman et al., 1995). The advantage of MCA is that it provides a flexible way of dealing with qualitative multi-dimensional environmental effects of decisions (Munda, 1995).

Assign weights to each evaluation criteria is one of the most critical steps in the process of evaluation and ranking of management alternatives, because assigning a weight to an individual criterion is a way to indicate its relative importance. Furthermore, since the criteria should reflect the objectives defined in the beginning of the process, the weights assigned to the criteria reflect the relative importance of each objective with respect to other objectives.

The approach used to assign weights to each of twenty-nine evaluation criteria was the Pairwise Comparison, which in the in the context of a decision making process is known as the Analytical Hierarchy Process (Saaty, 1990; Saaty, 1999/2000). In this approach, the user is asked to indicate, with a qualitative score (usually among 1-"equally important as" and 9-"extremely more important than"), which is the most important (and in what extent) of each pair of evaluation criteria, in the context of the decision being addressed. The comparisons are used to create a ratio matrix, from which the quantitative weights for all criteria are estimated (Janssen, Hervijnen & Beinat, 2003). In general, the Pairwise Comparison method to assign weights reflects quite well the priorities of the user. However, it implies to make a large number of comparisons, always time consuming and frequently driving to some inconsistency of the judgements.

After the pairwise assessment of the alternatives, an inconsistency index is calculated. This index indicates whether the pairwise comparisons are sufficiently consistent. A Consistency ratio < 0.1 indicates that the users had consistent judgements. In case of inconsistency, DEFINITE indicates the inconsistent comparisons and makes suggestions how to improve them (Janssen, Hervijnen & Beinat, 2003). This process was repeated for the sub-groups and main groups of evaluation criteria defined.

2.3.5 Ranking the management alternatives

Multicriteria Analysis is a method to face complex decision-making tasks which involve many stakeholders and/or decision-makers, a diversity of possible outcomes and many criteria by which to assess the outcomes. MCA techniques can be used to identify a single most preferred option, to rank options, to short-list a limited number of options for subsequent detailed appraisal, or simply to distinguish acceptable from unacceptable possibilities. By using MCA we can avoid the need for stakeholders to agree on the relative importance of each criterion. Instead stakeholders are able to submit their own judgements and make a distinct, identifiable contribution to a jointly reached conclusion. This avoids the need to reach a general consensus, which is often hard to achieve, especially among multidisciplinary teams.

One of the main reasons underlying the growing interest in multicriteria analysis for land use management is the need for an integrated approach to such complex problems. Multicriteria analysis can support the structuring of land use problems, allowing to assess and rank the concerns of major actors, giving trade-offs between conflicting goals, and leading to the evaluation of options from different perspectives (Beinat & Nijkamp, 1998).

This procedure displays the results of the multicriteria analysis. Normally the result is presented graphically with a simple bar graph. On the X-axis are all alternatives, and on the Y-axis the value of the ranking. Since a qualitative method has been applied rank numbers are used. The bar length indicates preference for the alternative. The higher the bars, the more suitable the alternatives (Janssen, Hervijnen & Beinat, 2003).

Several ranking of alternatives were made. Two comprising all the alternatives in judgment for the entire Cachoeira catchment, another three rankings separately for the groups of municipalities clustered by their socioeconomic typology (cluster 1, cluster 2 and clusters 3-4), and four more rankings to each of the aggregated alternatives. In the rankings concerning the clusters, only the more suitable alternatives for each cluster were considered.

2.3.6 Spatial scenarios: suitability maps

After the ranking of alternatives, some suitability maps were created in respect to the more suitable alternatives for Cachoeira catchment. These maps correspond to alternative spatial scenarios that determine the likely impacts on future land use patterns. Therefore, in this step was made an analysis and interpretation of geographical information that is related to the alternatives in question (Husdal, 2002).

First the necessary, and available geographic information was collected (river network, roads, land cover, land cover changes, soil type, slope, altitude, population census, soil erosion risk and soil pollution risk). Then it was necessary to define criteria for land cover and determine their weights. Furthermore, it was necessary to identify which of these criteria should be considered as constraints or as factors. In fact, a constraint is a criterion that is absolute in its inclusion or exclusion of possible outcomes (urban areas exclude forest area, too steep slopes exclude agriculture, etc.). A factor is a criterion that influences the suitability of the decision, according to its value (Husdal, 2002).

Different suitability maps were accomplished for cocoa/Cabruca, forest, capoeira, pastures and urban areas. At the end these maps were combined to have a new land cover map for the Cachoeira catchment. The cases of conflicting land cover were solved by considering that the most suitable land cover would be the one more corresponding to the more sustainable alternative as it was ranking in the outputs of DEFINITE.

3 DECISIONAL CONTEXT: MAIN TRENDS IN CACHOEIRA CATCHMENT

The Brazilian case study was carried out in the Rio Cachoeira Catchment. This area is located in southern Bahia, with a drainage surface of around 4 600 km^2, which encompasses twelve municipalities. Around 600 000 inhabitants live in the area of the catchment. There are two main activities in these municipalities: cocoa production and cattle husbandry. Nevertheless, the coastal municipalities, especially Ilhéus, have a potential tourist activity, which is being developed in the last years.

The region was responsible for the world's 2nd largest cocoa production. Cocoa plantations are situated in municipalities nearer to the coast-line and as cocoa is grown under shade trees (an agroforest model traditionally knows as Cabruca), this area is in great part associated to reminiscent of the Atlantic tropical rainforest: the Mata Atlântica. In this catchment there is a striking diversity of agricultural areas that are marked by diverse natural features and intensity of human intervention.

In the upper catchment area livestock production is dominant, and may be responsible for problems of soil erosion and striking environmental degradation. Hills and a lesser mountains range surrounds the lower area, in the centre of which is the catchment. These lowlands have a special importance in the development of cocoa plantations of the region. Much nearer the coast and to the south of the central hills, for reasons of soil type, are less productive to cocoa plantings and are characterised by concentration of small farmers.

Over the last 12 years cocoa plantations were subject to high disease pressure (witches' broom). As a result some farmers in search of alternative agricultural activities, uprooted cocoa and felled the shade trees associated to cocoa on farms. About 50% of the 600,000 ha under cocoa were partially or totally abandoned and with it the state of the forests suffered losses causing various levels of deforestation.

There are four main types of economic activity in the catchment:

- The cocoa production, with decreasing significance due to the disease "vassoura-de-bruxa" and the low prices of cocoa in the international markets;
- The cattle raising, which shows a significant trend of increase in the cocoa areas;
- The tourism, more significant in the coastal areas of Ilhéus, is nowadays in a phase of growth with incentives to the ecotourism by using old cocoa farms and exploiting natural features such as waterfalls, lagoons, and forest reserves;
- The industrial activity was related with agro-industrial activities during several years: milk in Itabuna and cocoa processing in Ilhéus. In the last years some incentives attracted some industries related with new technologies in Itabuna.

Due to the geographic location and the availability of adequate infrastructure, the cities of Ilhéus and Itabuna became the main centres of convergence and services of the region. On the other hand, they are the municipalities of greater population concentration in urban areas.

3.1 Main pressures identified in Cachoeira Catchment

The dynamics of territorial change in the Cachoeira catchment, identified trough the analysis of socio-economic data, are specially related with the cocoa production. In fact the strong dependence from this product makes that any incident affecting it influences significantly the changes in the territory, both in socio-economic and biophysical terms.

3.1.1 Dynamics related with the permanent crops

The most significant permanent crops in the catchment are: cocoa, coffee and sugar cane. These permanent crops have an important role in settling the rural population in the farms, preventing the massive migration towards the villages and bigger cities of the catchment or outside it. However, the events occurring during the 1990s drove to a crisis affecting the majority of the cocoa farms leading to conversion to other uses and to the release of a significant number of workers who then migrated towards the capitals of the municipalities and particularly to the cities Itabuna and Ilhéus.

However, in the last few years, some changes occurred. The international market prices rose again (as consequence of social instability in other cocoa producing countries in Africa) and great numbers of cocoa plantations were restructured by using clones resistant to the witches-broom disease. Therefore, it is foreseeable for the next years that there will be a strong impact on areas suitable for cocoa production.

3.1.2 Dynamics related with the pastures area

The recent increase of pastures, which occurred mainly in the 1950s, is associated directly with cattle rising, and indirectly with the cocoa crisis. In fact, both the decrease of the international market price and the disease known as “Witches’ Broom” drove to the abandonment of the cocoa plantations. The cocoa farmers fell the trees in order to take advantage of the commercial value of the timber, and converted the land to other production, such as livestock farming.

On the other side, the relative high income derived from large size cattle ranching (both for meat and milk production) stimulated also medium and small scaled farms to change their production systems to this kind of activity. The low carrying capacity and comparatively poor labour productivity of cattle rising was obviously not taken into account. Thus, frequently they only change the type of dependence and not diversify the activities in the farm.

3.1.3 Dynamics related with the expansion of urban areas

The expansion of urban areas is, in great part, associated with the cocoa crisis. The labour force released from the farms migrated towards the villages and cities, and especially to Itabuna and Ilhéus. This migration process produced an expansion of built-up areas, which wasn’t accompanied by the increase of quality of life of this migrants. Actually, this migration produced pouches and belts of “*favelas*” in the main cities of the Cachoeira Catchment.

3.2 Clustering the municipalities of Cachoeira catchment based on socio-economic variables

The procedures of the analysis of socio-economic data started with the factorial analysis of the variables and the construction of a typology of the administrative units (municipalities in Cachoeira Catchment).

A principal component analysis was applied to 245 socio-economic variables, which were reduced to a set of 38 socio-economic variables statistically significant to describe the region (Table 1). These 38 socio-economic variables have been processed in a way that the influence of the area of the particular municipalities has been eliminated, and therefore the classification obtained is not dependent of the size of each municipality present in the variables. To these set of socio-economic variables were added three more: agrodiversity in 1990; agrodiversity in 2001, and farm size distribution in 1992[2].

3.2.1 Socio-economic typology of Cachoeira catchment municipalities

The cluster analysis was applied to this set of 41 variables to define a socio-economic typology of municipalities in Cachoeira catchment. The approach used for clustering was the Hierarchical Cluster Analysis, which gives us the possibility of finding relatively homogeneous clusters of municipalities. This approach makes possible to combine clusters in a hierarchical way, reducing the number of clusters at each step until only one cluster is left. Furthermore, once two municipalities have been placed together in the same cluster, they will remain there until the end of the clustering process. From the resulting dendogram (where each step in the clustering process is illustrated by a join of the tree) it is easy to choose the number of clusters to work with (Rogerson, 2001).

The analysis followed two steps: first it was necessary to measure distances between the municipalities; second the municipalities were grouped according with the resultant distances (linkages). For the first step, (measuring similarities distances between the municipalities), the *Euclidean distances* measurement was chosen. For the second step (grouping the municipalities), the tree clustering method used was the *Ward Linkage*. If the squared Euclidean measure has been used (as it is suggested when using Ward clustering method), only three clusters would be defined, being clusters 3 and 4 on the same group.

From this analysis it was possible to obtain four clusters of municipalities (Fig. 2 and Fig. 3):

Cluster 1: Ilhéus and Itabuna

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2 The agro-diversity of a municipality has been determined on the basis of census data on harvested areas of individual crops (obtained from the IBGE for the years 1990 to 2002). One way of assessing diversity is the Shannon-Weaver entropy statistic, discussed by Shannon and Weaver (1949). If pi is the proportion of cover contributed by the ith species, entropy is defined as the sum over all species of –pi ln pi. The diversity of the municipalities was indexed accordingly: pi was calculated as the area ratio an individual crop occupied of the entire area harvested within a municipality. The indices ranged from about 0.1 to 1.8 (the greater value indicating a higher diversity).

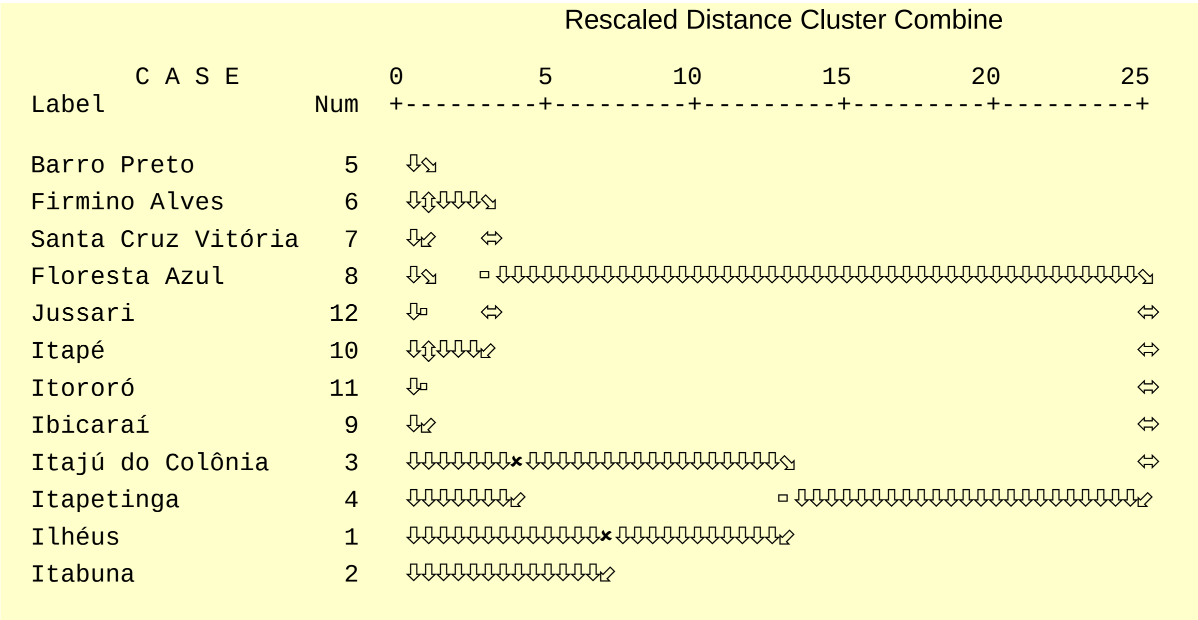
The raw data on farm sizes in the municipalities were provided as area of farms per size class (e.g. entire area of farms <10 ha, 10-100 ha, 100-500 ha, >500 ha). These data, after being expressed in ratios of municipal areas, were transformed to a single continuous variable representing the farm size distribution of each municipality. This continuous variable was derived from the first factor being the result of a principal component analysis computed from the covariance matrix of the variables. This first factor explained more than 97% of the variance of the variables describing the farm size distribution of the municipalities. Higher values of the derived variable "farm size distribution" stand for increasing dominance of large farms

Cluster 2: Itapetinga and Itajú do Colônia

Cluster 3: Barro Preto, Firmino Alves, and Santa Cruz da Vitória

Cluster 4: Floresta Azul, Jussari, Itapé, Itororó, and Ibicaraí

Fig. 2. Dendogram of hierarchical cluster analysis (Ward Method)



A second step of the analysis was the calculation of the averages of distances within each cluster (

Table 1). These averages were considered as variables, and added to the matrix of socio-economic variables. To this matrix were also added 25 variables resulting from the transition matrix of land cover changes; 4 variables concerning the interpretation of land-cover changes; 6 variables related with soil erosion and 6 variables related with water vulnerability. This new matrix was used to make several correlation analyses between all the variables, the clusters and the land-cover changes, soil, and water variables.

Fig. 3. Clusters of Cachoeira catchment

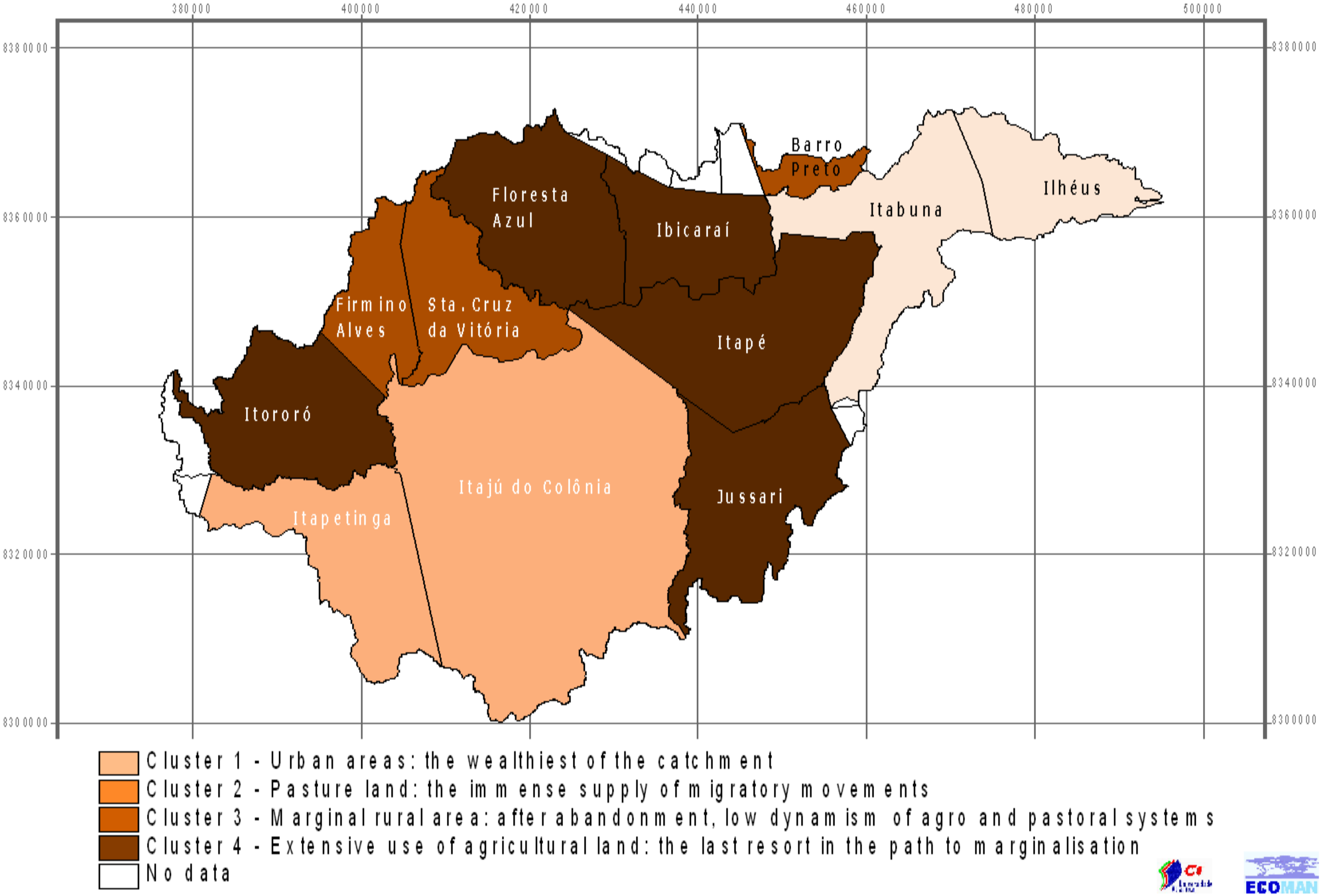


Table 1. Proximity matrix of clusters of Cachoeira catchment

Proximity Matrix (This is a dissimilarity matrix)

Case	Euclidean Distance									
	Cluster 1			Cluster 2			Cluster 3			
	1:Ilheus	2:Itabuna	Average	3:Itaju do Colonia	4:Itapetinga	Average	5:Barro Preto	6:Firmino Alves	7:Sta. Cruz Vitoria	Average
Barro Preto	390984,08	285198,46	338091,27	158995,11	247191,99	203094	0	9727,33	24914,70	17321
Firmino Alves	390953,52	287909,11	339431,31	154424,78	243424,93	198925	9727,33	0	19445,54	9724
Floresta Azul	367478,90	279435,55	323457,23	125156,72	213732,72	169445	34445,26	30413,68	40461,73	35107
Ibicarai	358199,01	255539,51	306869,26	144661,79	223054,53	183858	33474,03	35618,15	44015,47	37703
Ilheus	0	218298,70	218298,70	315858,56	229906,33	272882	390984,08	390953,52	395025,39	392321
Itabuna	218298,70	0	218298,70	309826,50	289075,26	299451	285198,46	287909,11	289555,42	287554
Itaju do Colonia	315858,56	309826,50	312842,53	0	109867,44	109867	158995,11	154424,78	160910,65	158110
Itape	357117,88	274242,70	315680,29	114522,82	201820,97	158172	46185,46	42210,71	51234,13	46543
Itapetinga	229906,33	289075,26	259490,80	109867,44	0	109867	247191,99	243424,93	247313,00	245977
Itororo	357727,64	266654,36	312191,00	127384,88	209388,90	168387	40484,76	36363,28	40678,50	39176
Jussari	374704,58	283638,94	329171,76	131089,40	220745,38	175917	30587,39	24483,95	34754,28	29942
Sta. Cruz Vitoria	395025,39	289555,42	342290,40	160910,65	247313,00	204112	24914,70	19445,54	0	22180

Case	Euclidean Distance					
	Cluster 4					
	8:Floresta Azul	9:Ibicarai	10:Itape	11:Itororo	12:Jussari	Average
Barro Preto	34445,26	33474,03	46185,46	40484,76	30587,39	37035
Firmino Alves	30413,68	35618,15	42210,71	36363,28	24483,95	33818
Floresta Azul	0	30463,87	12714,27	16984,59	11188,76	17838
Ibicarai	30463,87	0	34791,12	25729,18	34257,88	31311
Ilheus	367478,90	358199,01	357117,88	357727,64	374704,58	363046
Itabuna	279435,55	255539,51	274242,70	266654,36	283638,94	271902
Itaju do Colonia	125156,72	144661,79	114522,82	127384,88	131089,40	128563
Itape	12714,27	34791,12	0	17876,61	20234,03	21404
Itapetinga	213732,72	223054,53	201820,97	209388,90	220745,38	213748
Itororo	16984,59	25729,18	17876,61	0	20945,85	20384
Jussari	11188,76	34257,88	20234,03	20945,85	0	21657
Sta. Cruz Vitoria	40461,73	44015,47	51234,13	40678,50	34754,28	42229

3.2.2 Describing the clusters

After the procedures to accomplish the clustering of the different municipalities it was necessary to describe the clusters obtained and to assign them a label. Labelling the clusters is usually a difficult task, given the huge amount of data involved in the classification. Nevertheless, labels were assigned to each cluster aiming at describing their essential characteristics. Although the inherent simplification of the labelling process, the typology is certainly of more value if it communicates information about groups on an uncomplicated way.

3.2.3 Correlation analysis between the particular clusters and the original socio-economic data

The bivariate correlation analysis aims at identifying which key variables contributed more (and at which extent) to the clustering obtained, allowing, therefore, to support the description of each cluster. The procedure computed Spearman's correlation coefficient, which for this analysis[3] was considered as significant in the range from -0.7 > r > +0.7.

Cluster 1 (Ilhéus and Itabuna) is strongly related with the following socioeconomic variables:

1.	Economic Development Index 1996	-0,95
2.	Projected population 2015 (rate of 1991-2000)	-0,95
3.	GDP 2000 (Millions of Reais)	-0,95
4.	Resident population 2000	-0,94
5.	Human Development Index 1996	-0,91
6.	Iliteracy rate 2000	0,90
7.	GDP 1980 (Millions of Reais)	-0,88
8.	Youth Dependency index 1991	0,82
9.	Social Development Index 1996	-0,80
10.	%Non Agricultural area 1998	-0,80
11.	Population annual growth rate 1981-2000	-0,76
12.	Total Dependency index 1991	0,71

It is a cluster that in 1996 presented the highest values (more than 60) of municipal Economic Development Index (which summarises the municipal earnings, the qualification of labour force, and the infrastructures), and with highest contribution for the Gross Domestic Product in 2000 and 1980, which means that it is in this cluster that the creation of wealth, the municipal earnings, the qualification of labour force, and the infrastructures of the municipality are more significant.

It is also the cluster where the illiteracy rate in 2000 is lower, and the projected population for 2015 (and also the resident population in 2000) is more important (which is not strange since this are the two biggest cities in the region, being Itabuna one of the most important urban areas of the State of Bahia). Moreover, when the resident population growth rate of 1981-2000 is considered, it is the cluster with higher values. In this cluster, the non agricultural areas (in 1998) are also significant.

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3 To understand the analysis of the correlation matrix it should be noted that: high positive correlation coefficients between the cluster average distances and a given variable means that the variable has a low value for this cluster. So, the more distant municipalities (to the average distance with the cluster) have higher values for the specific variable. Furthermore, high negative correlation coefficients mean that a close correlation exists, with higher values of the variable for the cluster being considered and lower values for the other clusters.

It is also the cluster where the Human Development Index presents the higher values (0,70-0,75). This composite index, which follows the methodology of the UNDP (United Nation Development Programme) summarises information relative to three basic dimensions of human development: a long and healthy life (measured by the life expectancy at birth), knowledge (measured by the adult literacy rate and by the combined primary, secondary and tertiary gross enrolment ratio) and a decent standard of living (measured by the gross domestic product per capita).

In this cluster, the Total Dependency index[4] 1991 present the lowest values (42-45), which mean that for these two municipalities the number of dependents is lower than in the others, and therefore, it has a greater proportion of its population in the 15-64 year old age group, than the other municipalities, which can be a reflex from the migratory movements (specially of people in working age) to these urban areas. Furthermore, it also presents the lowest values (35-39) of the Youth Dependency index[5] 1991 in the catchment area.

Also in this cluster, the Social Development Index 1996 (which summarises information related with the level of education and level of health services, water and electricity supply and family income) presents the highest values (55-64) of the municipalities of Cachoeira catchment.

Cluster 1 (Ilhéus and Itabuna) can be described as follows:

- Greatest resident population, and with higher growth rates between 1981-2000;
- Greatest creation of wealth, qualification of labour force, and presence of infrastructures;
- Higher human and social development;
- Higher proportion of population in the 15-64 year old age group;
- Higher percentage of non-agricultural areas.

Cluster 2 (Itapetinga and Itajú do Colônia) is strongly related with the following socioeconomic variables:

1.	Vegetal production 1996 per ha	0,84
2.	Population Density 2000	0,77
3.	Resident population 2000	0,74
4.	GDP 2000 (Millions of Reais)	0,74
5.	Projected population 2015 (rate of 1991-2000)	0,73
6.	Economic Development Index 1996	0,72
7.	GDP 1980 (Millions of Reais)	0,71
8.	%Area of pastures 1998	-0,66
9.	%Area of pastures 1992	-0,63
10.	Permanent crops area 1998 per ha	0,62

Cluster 2 has the lowest population density in 2000 of the municipalities of Cachoeira, low (and stable for the period 1981-2000) resident population in 2000 which remains low in the projection for 2015.

4 The total dependency index summarises the age distribution of a population. It is a measure of the portion of a population which is composed of dependents (people who are too young or too old to work). It comprises two parts: those who are younger than working age (under 16) and those who are older (over 64). Regions that have a high total dependency index have more people who are not of working age, and fewer who are working and paying taxes. So, the higher the index, the more people that need looking after, and the greater demand on public and private services such as schools, child welfare, and health care and retirement facilities.

5 The youth dependency index is the ratio of the number of people under school leaving age (under 16) to the number of people in their working years. A high youth dependency index means there is a greater demand on public services such as schools and child welfare, as well as on public/private systems such as child care and health care.

It also presents the lowest vegetal production per ha in 1996 and the lowest weight of permanent crops in the farm area.

In cluster 2, the contribution for GDP is moderate (registering a slight increase from 1980 to 2000) as it is also the Economic Development Index 1996.

It presents the highest percentage of farm land dedicated to pastures both in 1992 and 1998.

Cluster 2 (Itapetinga and Itajú do Colônia) can be described as follows:

- Scarcely populated, and with low level of infrastructures and public services;
- Vegetal production with marginal significance;
- Pastures are extensively used;

Cluster 3 (Barro Preto, Firmino Alves, and Santa Cruz da Vitória) is strongly related with

1.	%Non Agricultural area 1998	0,92
2.	Resident population 2000	0,90
3.	Projected population 2015 (rate of 1991-2000)	0,90
4.	GDP 2000 (Millions of Reais)	0,90
5.	Economic Development Index 1996	0,89
6.	GDP 1980 (Millions of Reais)	0,88
7.	AREA_ha	0,83
8.	Human Development Index 1996	0,81
9.	Iliteracy rate 2000	-0,80
10.	Land owned by farmers	0,78
11.	Social Development Index 1996	0,76
12.	Area of farms 1998	0,74
13.	Population annual growth rate 1981-2000	0,73
14.	%Number of farms 1998	0,72
15.	Youth Dependency index 1992	-0,71
16.	Total Dependency index 1991	-0,70

In cluster 3, the weight of the non-agricultural area in 1998 is very low. Also the area of municipalities, the farm area, the number of farms and the land owned by farmers present low values. The resident population in 2000 and the projected population in 2015 are small, and the growth rate between 1980 and 2000 show a significant decrease of population.

In economic terms, this cluster presents a low contribution for the GDP (both in 1980 and 2000), and its economic development index, which is the lower in the catchment, reinforces this idea. It also presents the lowest human development index, and a low social development index. Furthermore, the illiteracy rate is the highest in the catchment.

This cluster also presents high dependency indexes, and therefore it has a less significant proportion of its population in the 15-64 year old age group, than the other municipalities, which can be the result of the migratory movements (specially of people in working age) to other municipalities. Furthermore, it reveals the highest youth dependency index of the catchment.

Cluster 3 (Barro Preto, Firmino Alves, and Santa Cruz da Vitória) can be described as follows:

- Medium to small size municipalities where agricultural area is of vital importance;
- Small and decreasing population, especially of people in working age;
- Agro and pastoral systems without great economic contribution;
- Low level of infrastructures, qualification of labour force and public services.

Cluster 4 (Floresta Azul, Jussari, Itapé, Itororó, and Ibicaraí) is strongly related with almost the same variables of cluster. In fact both clusters are very similar (it is necessary to remember that in the cluster analysis the separation between these two clusters was forced by measuring the distances using the *Euclidean distances*. If the squared Euclidean measure have been used (as it is suggested when using Ward clustering method), cluster 3 and 4 would be in the same group.

The main differences between the two clusters are related with the values of the variables that show a higher resident population in 2000, but also a higher decrease of this population since 1991. Cluster 4 presents the highest total dependency index, so it is the cluster where there are more dependents. However, the youth dependency index is lower than in cluster 3. This shows that in cluster 4 there is a more important proportion of dependents with more than 64 years old. In fact, of the four clusters, it is here that the elderly population has a bigger weight.

1.	Resident population 2000	0,92
2.	GDP 2000 (Millions of Reais)	0,92
3.	Projected population 2015 (rate of 1991-2000)	0,92
4.	Economic Development Index 1996	0,91
5.	%Non Agricultural area 1998	0,91
6.	GDP 1980 (Millions of Reais)	0,90
7.	Human Development Index 1996	0,80
8.	Illiteracy rate 2000	-0,80
9.	AREA_ha	0,79
10.	Social Development Index 1996	0,77
11.	Population annual growth rate 1981-2000	0,74
12.	Total Dependency index 1991	-0,73
13.	Land owned by farmers	0,73
14.	%Number of farms 1998	0,72
15.	Youth Dependency index 1992	-0,70
16.	Forest income 2000 (1000 reais)	0,70
17.	Area of farms 1998	0,70
18.	Cocoa income 2000 (1000 Reais)	0,70

Although the lower contribution for the GDP (both in 1980 and 2000) it is slightly higher than in cluster 3. The economic development index is higher, denoting a less problematic situation in terms of infrastructures, qualification of labour force and municipal revenue, which is also expressed by the slightly higher human development index. However, the social development index is lower (the lowest of the catchment) showing great difficulties in the improvement of public services (health, water supply, sanitation and energy).

Furthermore, cluster 4 also presents a low significance of income generated by forest and cocoa (although higher than in cluster 3).

Cluster 4 (Floresta Azul, Jussari, Itapé, Itororó, and Ibicaraí) can be described as follows:

- Medium size municipalities where agricultural area is still important;
- Decreasing population, especially of people in working age, and significant weight of older people;
- Agro and pastoral systems with low economic productivity;
- Low level of public services.

From the above analysis it is possible to indicate some designation to the identified clusters. However, it is necessary to have in mind that clusters 3 and 4 are not quite different from each other. So it is possible to identify clear differences between cluster 1, cluster 2 (the ones with only two municipalities) and clusters 3 & 4.

So, a tentative to assign a label to each cluster resulted in the following preliminary designations, which are mainly descriptive of the socio-economic situation of each cluster:

- Cluster 1: Urban areas: the wealthiest of the catchment;
- Cluster 2: Pasture land: the immense supply of migratory movements;
- Cluster 3: Marginal rural area: after abandonment, low dynamism of agro and pastoral systems;
- Cluster 4: Extensive use of agricultural land: the last resort in the path to marginalisation.

3.2.4 Correlation analysis between the clusters and the land cover changes

The clusters resulted from the analysis of the set of 41 socio-economic variables in Cachoeira catchment were correlated with a set of 29 variables related with the land cover changes identified by the interpretation of satellite images of 1988 and 2001. These variables correspond to the detailed transition matrix (25 variables) that indicates the percentage of land cover that remained or changed to another type of land cover from 1988 to 2001. The remaining 4 variables correspond to the interpretation of changes in terms of increasing or decreasing biomass, and to the percentage of area that registered some land cover changes in the municipality[6].

Cluster 1 (Ilhéus and Itabuna) is related with the following aspects of land cover changes (in order of magnitude of the correlation):

1.	change_88_01_upgrading	-0,858
2.	ca_ma	-0,746
3.	change_88_01_neutral_no	0,669
4.	co_ur	-0,646
5.	Percent_area_changes_88_01	-0,602
6.	ma_ca	-0,595
7.	pa_pa	0,518

In the municipalities of Cluster 1 there is a high degree of land cover changes; being even the cluster where the land cover changes between 1988 and 2001 were more significant in the catchment (more than 50% of the municipal area registered some type of change). It is also the cluster where there is a reduced significance of agricultural use, which has being replaced by vegetation of Capoeira type, that can be considered as a stage of natural regeneration. So, the upgrading changes, which contribute for increasing biomass, were rather important in this cluster.

Furthermore, it is a cluster where the expansion of urban perimeters was significant in the period considered.

6 This correlation analysis was hindered by the fact that there is some missing information in the land cover maps for some municipalities (especially Ilhéus and to Itajú do Colônia).

Note that a high negative correlation coefficient between the distance average and a variable signify that the respective cluster is characterized by a high value of this variable, e.g. the high negative value of -0,858 for upgrading changes in cluster 1 means that in this cluster more upgrading changes could be observed than in the other clusters, and in addition, the more distant (different) the other clusters are from cluster 1, the less upgrading changes occurred.

Cluster 2 (Itapetinga and Itajú do Colônia) is related with:

1.	ca_co	0,792
2.	pa_ur	0,746
3.	pa_ca	-0,711
4.	pa_ma	-0,683
5.	co_ca	0,669
6.	co_ur	0,652
7.	change_88_01_degrading	0,634
8.	co_co	0,627
9.	ca_ca	0,616
10.	co_pa	0,602
11.	co_ma	0,567
12.	ma_ur	0,554
13.	ca_ur	0,546

In general, cluster 2, which is the cluster where cattle production is dominant, presents a reduction of pasture areas. This reduction is indicated by the fact that capoeira and forest are growing on previous pasture lands. It seems that a process of decreasing the area grazed is occurring. This process reflects either an intensification of the production or a decrease of herd size?

Furthermore, in this cluster the degrading changes (decrease of biomass) are not of much significance. This can result from the fact that the departing land cover type (prevailing pasture lands) represents already a stage of utmost degradation of vegetation. However, this can also signify that there is no expansion of pasture lands in this cluster.

Cluster 3 (Barro Preto, Firmino Alves, and Santa Cruz da Vitória) is related with:

1.	ma_ca	0,825
2.	change_88_01_upgrading	0,811
3.	ma_ma	0,671
4.	co_ur	0,640
5.	pa_ma	0,622
6.	ca_ma	0,601
7.	change_88_01_neutral_no	-0,545

In Cluster 3 there are generally no significant land cover changes in the period of 1988 to 2001. However, it is possible to say that short term agricultural use of pristine forest area do quasi not occurs. The replacement of native forest by short-term cash crops would lead to a rapid loss of soil fertility and, thus, to the abandonment of the area within a few years, which is then subjected to natural regrowth (Cabruca). Over the comparatively long time span of 13 years this process would become perceivable as transition from forest to Cabruca. In cluster 3 the correlation coefficient between cluster distances and the variable for the respective land cover changes is positive, reflecting a very low value of transition from forest to Cabruca and consequently a low incidence of short term agricultural use of pristine forest area in comparison to the other clusters.

Furthermore, it is a cluster where the growth of urban areas is not taking place.

In Cluster 4 (Floresta Azul, Jussari, Itapé, Itororó, and Ibicaraí) the analysis didn't show any significant correlation with land cover changes. It is possible only to say that it is a cluster where urban growth is very weak or inexistent.

3.2.5 Correlation analysis between the clusters and the environmental vulnerability

The analysis of environmental vulnerability is always a critical problem when studying ecosystems' sustainable management. However, since it deals with uncertainty (resulting from not complete knowledge of causal relations, data availability, and generalisation in measurement or modelling) it is a rather difficult task. Furthermore, since the values are complexly interrelated, it turns difficult to consider them as statistically independent (Tran *et al.*, 2002).

In this analysis, environmental vulnerability was measured using two indicators: soil erosion risk[7] and surface water pollution risk. Some difficulties arise from the introduction of these variables. Due to the fact that both soil erosion and water pollution risk were structured in five classes it turns to be that for each of these two indicators, five variables were present. So, these five variables have been reduced to one variable by using the Principal Components Analysis. The factor loading explains 97% and 87% of the variance of respectively soil erosion risk and water pollution risk. In general terms the individual classes are well correlated with the respective factor loading. But in the case of the variable of highest water pollution risk it is not well correlated with the factor loading.

Nevertheless, the factors for erosion risk and for pollution risk are not correlated with the clusters. In fact when the absolute areas (in hectares) subjected to soil erosion risk or water pollution risk are correlated with the clusters, it is possible to see some correspondence. However, this result comes out because it is the size of the municipalities that is being correlated. However, when the environmental variables have been corrected for the weight of their area (by a process of standardisation that gives their relative values to each municipality) it is not possible to detect significant correlations with the clusters identified.

From the analysis of raw data, it possible to say that in Cluster 1 soil erosion risk is rather low[8], but surface water pollution risk is high. This is so because some of the factors used to assess soil erosion (for instance vegetation cover and slope) don't promote, in these municipalities, soil erosion. On the other side, urban areas are one of the main factors favouring water pollution, therefore since in this cluster urban areas are prevailing, it is the cluster with higher risk of water pollution.

3.2.6 Correlation analysis between the socio-economic variables and environmental vulnerability

After the correlation analysis between the cluster and different sets of variables, another type of correlation was applied aiming at understanding what socio-economic variables are more related with environmental vulnerability.

Soil erosion risk was closely correlated with the following variables[9]:

1.	change_88_01_neutral_no	0,91
2.	Percent_area_changes_88_01	-0,88
3.	div_ha_h90 (AgroDiversity 1990)	0,86
4.	Coffee income 2000 (1000 Reais)	0,83

7 Erosion data is not available for the municipality of Ilhéus.

8 As it was said before, erosion data is not available for the municipality of Ilhéus, which is one of the municipalities of Cluster 1. However the existing conditions of land cover and slope are not much different from the municipality of Itabuna, the other municipality of this cluster.

9 This analysis excludes the municipality of Ilhéus.

5.	Area cultivated with coffee 2000	0,82
6.	div_ha_h01 (AgroDiversity 2001)	0,82
7.	%Area of pastures 1998	0,76
8.	%Area of pastures 1992	0,75

Surface water pollution risk was closely correlated with the following variables:

1.	farm_size_distribution_92_cov	0,85
2.	%Area of pastures 1998	0,83
3.	%Area of pastures 1992	0,82
4.	change_88_01_degrading	-0,82
5.	Permanent crops area 1998 per ha	-0,82
6.	div_ha_h01 (AgroDiversity 2001)	0,81
7.	Percent_area_changes_88_01	-0,74
8.	Cocoa income 2000 (1000 Reais)	-0,74
9.	Permanent crops income 2000 (1000 reais)	-0,73
10.	change_88_01_neutral_no	0,73
11.	div_ha_h90 (AgroDiversity 1990)	0,72
12.	Animal production 1996 per ha	0,71

From the analysis of these correlations it is possible to say that it is frequent that the correlations (especially in what concerns soil erosion risk) reveal more indirect relations than explain causative relations. For instance, soil erosion risk presents relative high positive correlation coefficients with coffee income (r=0,83) and with area cultivated with coffee (r=0,82). In fact, coffee is frequently planted on hill sides, after the forest had been removed. Therefore, slope and destruction of vegetation cover (two factors of soil erosion) are there combined to increase soil erosion risk. In what concerns the relative high positive correlation with pasture lands, it reveals also the fact that sparse grasslands cover increases the erosion risk. Thus, the correlations regarding the modelled erosion risk reproduce what would be expected, since the highest correlation occurs with variables that were introduced in the model to assess the current risk.

In what relates the surface water pollution risk, the importance of large farms which are dominant in pasture areas, to the production of pollution risk in surface water, revealing therefore the importance of cattle production as a factor of water pollution.

3.2.7 Correlation analysis between the socio-economic variables and land cover changes

After the correlation analysis between the cluster and different sets of variables, another type of correlation was applied aiming at understanding what socio-economic variables are more related with land cover changes.

The bivariate correlation procedure computed Spearman's correlation coefficient, which for this analysis was considered as significant in the range from -0.84 > r > +0.84.

From the analysis it is possible to say that in the areas where pasture land is dominating, cocoa areas don't persist and therefore tend to be abandoned into another type of land cover. Large farm areas, which in Cachoeira catchment occurs concurrently with large size farms (more than 500 hectares), are correlated with the persistence of forest. Also in the areas where large size farms are dominant, there is a low level of change form cocoa to pasture and no natural regeneration (Capoeira) develop from cocoa plantations. Pasture areas are very persistent, and its conversion to another type of land cover it is not very frequent. But in the areas where small farms (less than 10 hectares) are more frequent, there are more land cover changes and cocoa has been removed to be replaced by other types of land cover. These correlations seem to indicate that cocoa plantations are not suitable for small farmers, because they cannot support them.

Furthermore, the larger the farms, the less overall land cover changes can be observed (r=-0.87) and particularly less degrading land cover changes (r=-0.94). On the other side, the more permanent crops, the more degrading land cover changes. These correlations seem to indicate that in areas with pastures (representing low biomass) any land cover change will drive to a biomass gain. By the contrary, the areas with permanent crops represents already a high biomass situation, thus, any land cover change will lead directly to biomass loss.

Variables defining well the urban clusters (GDP, population growth, etc.) are correlated with upgrading land cover changes. This is presumed to be an effect of reduced importance of agricultural land use and, thus, an increased incidence of natural regeneration of formerly used areas.

Moreover, from the correlation analysis arise two significant relations:

- The higher the agro-diversity, the lower the degrading land cover changes.
- In the cocoa growing regions there was a high degree of degrading land cover changes.

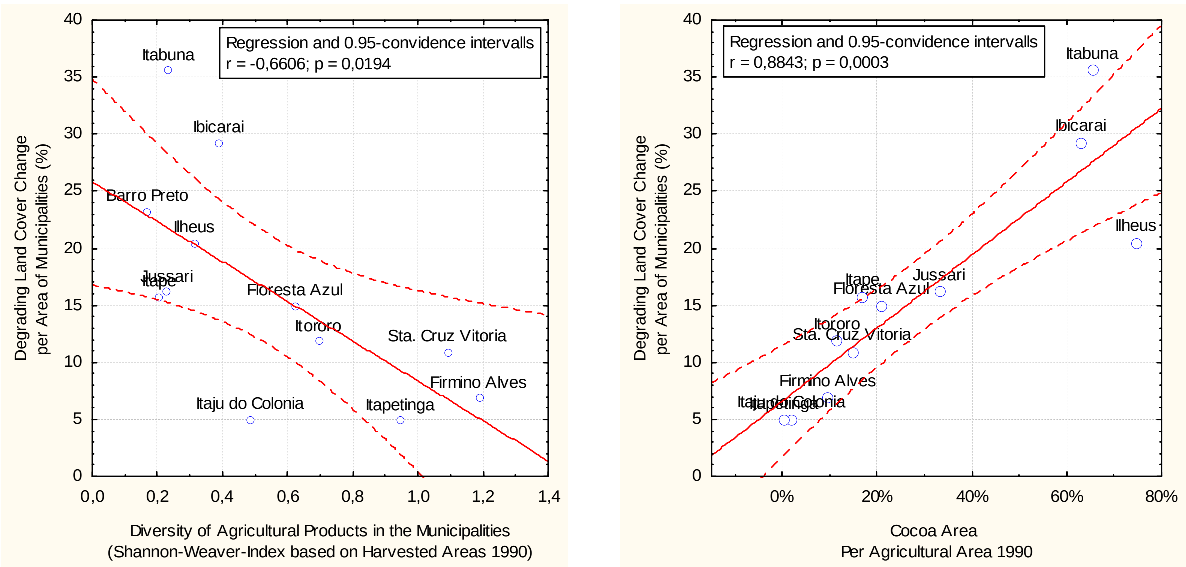


Fig. 4. Correlation between agro-diversity and degrading land cover changes and Correlation between prevalence of cocoa and degrading land cover changes

3.3 Regional and Local development goals

One of the crucial steps to formulate land management alternatives is to define goals that, in our times, should necessary be integrated within more broad (at regional and national levels) policies aiming at achieving sustainable development. Therefore, to establish these goals is a challenge faced by decision-makers that need sufficient information to identify and implement these objectives.

Sustainable development is being seen as the basis for a genuine balance between economic growth and environmental values. In fact, there is a considerable corpus of literature based on empirical evidence showing that the degradation or depletion of the environment affects in different ways people inside societies and among countries in different ways, creating and increasing reinforcing new ways of social and economic discriminations. However, to achieve the goals of sustainable development it is comprehensible that "*…economic growth must remain a legitimate objective of national governments and the world community…*" (Pearce & Warford, 1993). Nevertheless, it is clear now that the former models to pursuit economic growth, which don't give the adequate consideration to the environment, are unlikely to be sustainable (Lourenço, 2001). In fact it is important, at the same time man develops technology, which can enlarge the limits of the carrying capacity of ecosystems, to reduce, by means of effective policies, the patterns of consumption and to adapt practices of conservation of natural resources (Bartelmus, 1999).

Decades of human pressure on natural resources resulted in a new approach to development, which also points to the future but, contrarily to prior approaches, "*…to a bleak future of scarcities rather than a bright future of progress…*" (Sachs, 2000). Development is only possible when economic fairness, social equity and environmental sustainability are guaranteed. To find solutions to these problems is one of the main challenges of our society (Machado, 2002).

3.3.1 General aims for sustainable management alternatives

Each decision-maker has his own objectives, which will frame the ways how he evaluates the information on the alternatives. These objectives can be: Maximise profit; Maximise net income to local government and/or to local population; Maximise total benefits to the region or country; Equity in income distribution; maximise monetary benefits over costs; Maintain minimum level of relevant environmental stocks, Maximise environmental benefits; Minimise environmental damages.

The assessment of the alternatives now presented was made against a set of objectives which have three general aims:

- Increase economic benefits for local communities through the growth of employment and wages, diversification alternative income sources, and increase of local enterprises expectations;
- Enhance non-livelihood impacts through the increase of labour force expertise, growth of local access to infrastructures and public services, and mitigation of environmental impacts;
- Enhance participation and partnership through the increase of flows of information/communication as a means to improve supportive policy/planning frameworks, increase of local communities' participation in the decision-making processes, and building of public/private partnerships.

3.3.2 Specific objectives for catchment and municipality levels

In Cachoeira catchment (Bahia, Brazil) the main objectives of running the DSS were to design ecosystem management strategies which allow to:

- Increase framers' income;
- Settling the rural population in the fields (avoiding huge migrations to the major cities);
- Decrease the economic dependence from monocultures, by endorsing agricultural diversification and other activities such as agro-industry and sustainable tourism (ecotourism; agritourism; cultural tourism; and costal tourism);
- Promote the protection / conservation / restoration of the systems Mata Atlântica and Cabruca;
- Support the sustainable use / management of forest (sustainable logging; collection of non-timber products; use for scientific and leisure purposes, etc).

Sustainability was the prevailing consideration in the definition of strategies for ecosystem management in this area. This concern is imbedded in the whole process of analysis since the choice of the alternatives until their ranking as the most adequate to accomplish this main goal. Therefore, the analysis was restricted to a set of sustainable alternatives, since it was not in the frame of this work to make judgements among sustainable and unsustainable strategies for the Cachoeira catchment.

3.4 Alternative management strategies

The design of the alternatives to be evaluated with the support of DEFINITE, was made trough a series of consultation meetings within and outside the research consortium. Eleven management strategies were identified and a hierarchical structure was defined. So, these management strategies were later on grouped in four main alternatives that were also evaluated.

3.4.1 Environmental Conservation

3.4.1.1 Delimitation of protected areas

A protected area is defined as an area of land and/or sea especially dedicated to the protection and maintenance of biological diversity and of natural and associated cultural resources, managed through legal or other effective means (World Commission on Protected Areas). Usually, planning for biodiversity conservation concentrates on protecting core conservation areas and limiting land uses in buffer zones.

In Brazil, around 4% of the national territory is under some type of protection broadly grouped in two main categories framed by the SNUC (National System of conservation Units): **Integral Protection Units**, which aim at preserving the nature, being only allowed the indirect use of natural resources; and **Sustainable Use Units**, which aim at harmonising nature conservation with the sustainable use of natural resources in the delimited area.

In the last three decades, Atlantic Forest destruction and degradation in Brazil have been at least as devastating as in the previous three centuries. Today, the forests are highly fragmented and degraded in some regions, and the Brazilian Atlantic Forest is now an industrial centre of the country as well (CABS, 2000). Many of the remaining forest fragments in the Atlantic Forest need to be protected immediately in order to prevent species extinctions. However, many of those fragments and protected areas are too small and isolated to maintain populations of species over the long term (Myers *et al*. 2000). Therefore, those protected areas need to be linked in broader landscapes through conservation corridors to secure their long-term ecological viability, and must be considered as “core areas” around which such corridors should be built, rather than as a secondary consideration to restoration of the intervening spaces.

Another case refers to the Private Natural Heritage Reserves (RPPN) which are established on private land and are an important tool for biodiversity conservation, complementing the government efforts to protect nature.

Furthermore, protected area coverage for freshwater systems, notably rivers and lakes, also requires further attention, especially given the growing importance and scarcity of freshwater resources.

In the frame of Cachoeira catchment DSS, the delimitation of protected areas aims at promoting a balanced relationship between people and nature to reconcile the conservation of biodiversity with its sustainable use.

3.4.1.2 Reforestation / Regeneration

According with FAO (2001), reforestation is the re-growth of forests after a temporary (<10 years) condition with less than 10% canopy cover due to human-induced or natural perturbations; afforestation is the conversion from other land uses into forest, or the increase of canopy cover to the 10% defined threshold for forest. Regeneration is the natural succession of forest on temporarily unstocked lands that are considered as forest (FAO, 2001). In humid tropical regions it is often assumed that recovery of the degraded landscape through natural regeneration processes will take place within a time frame acceptable to the foreseen human use.

In a pressured landscape like the Atlantic Forest, conservation corridors that link up the patches of protected areas through a matrix of biodiversity-friendly land use and reforestation/regeneration would be one of the most effective conservation strategies in the long term (CEPF, 2001 and CI-Brasil, 2000). In fact, isolation of forest patches is advancing rapidly, and isolated protected areas and their buffer zones will not prevent the collapse of ecological functions and associated biodiversity.

An ecological or biodiversity corridor is a mosaic of land uses connecting fragments of natural forest across a landscape, aiming at facilitating the gene flow between populations, enhancing the long-term survival probability of biological communities and their component species. A corridor also is intended to ensure the maintenance of large-scale ecological and evolutionary processes. To achieve this it is necessary to stimulate the creation of additional protected areas, the introduction of more sustainable land-use management strategies and the restoration of degraded lands in critical areas. To ensure the long-term sustainability of these conservation strategies, the expectations of local communities of stakeholders must be taken into account as key elements of the conservation equation (Mittermeier and Fonseca, 2003).

In the frame of Cachoeira catchment DSS, Capoeira is considered a stage in the process of natural regeneration of the vegetation, and reforestation is the man-made re-growth of forests on areas with or without previous forest cover.

3.4.2 Agriculture

3.4.2.1 Agro-forestry systems

According with the Convention on Biological Diversity, an agro-forest is a complex of treed areas within an area that is broadly characterised as agricultural or as an agro-ecosystem. It is a land-use system in which woody perennials (trees, shrubs, palms, bamboos) are deliberately used on the same land management unit as agricultural crops (woody or not), animals or both, either in some form of spatial arrangement or temporal sequence.

Agro-forestry management enhances natural mechanisms of nutrient recycling on farm; minimises the use of chemical fertilisers or pesticides; helps to conserve local biodiversity and soil nutrients; crops grow together with local plants, forming a more biodiverse system, making possible to harvest different crops over the year, diversifying the seasonal timing of production; promotes independence of small farmers and values local knowledge; improves soil fertility over the long-term by managing organic matter through pruning and by mobilizing nutrients deep within the soil; provide a diversity of products with high nutritive value to support a healthy diet for farmers and consumers; and helps to maintain ecosystem health (Beetz, 2002).

In the frame of Cachoeira catchment DSS, agro-forestry is the practice of including trees in crop production agro-systems, that allows some spreading of financial risk through diversification. When designing agro-forestry systems, it is very important to consider the structure of local natural ecosystems and to choose species adapted to local conditions and to the farms and farmers feature.

3.4.2.2 Restructuring Cabruca system

The mid-south region of Bahia has been the heartland of cocoa cultivation in Brazil. In the 1990s, low prices and a devastating fungus disease, known as witches' broom, eliminated nearly one-third of the 600.000 hectares that were dedicated to cocoa cultivation at the peak of production in 1987.

Cabruca system (low-density plantations of cocoa cultivated under the shade cover of native canopy trees) created a structural diversity similar to natural forest. These diversified agro-forestry settings create habitat for a wide array of plant and animal species, including natural pollinators and predators of cocoa pests, both of which are vital to farm productivity. Shade cocoa farms can also maintain many natural ecological functions such as nutrient cycling, weed and pest reduction, water retention and erosion control. In addition, shade farms often include other species of economic value, reducing farmers' dependence on a single source of income (Johns, 1999). However, due to the economic constraints of this crop, it is doubtful that the Cabruca system of cultivation will enable cocoa plantations to serve their historical function as landscape links between remaining natural forests.

Nonetheless, this region's rare climate, without a marked dry season or temperatures below 20°C, ensures that cocoa cultivation will persist, but on the best soils, which have the potential to ensure the economic viability of these farms. Therefore, its restructuring arises as a significant step to increase productivity, and new public policies are necessary to provide a mechanism to compensate the necessary investments for improving this particular land use.

In the frame of Cachoeira catchment DSS, restructuring Cabruca system corresponds to increase the productivity of cocoa farms, by reducing the area of cocoa (maintaining only the current productive areas) and replacement of damaged cocoa plants by cloned varieties, which are more resistant to witches' broom.

3.4.2.3 Replacement of introduced shade trees in cocoa crops with other trees of higher returns

Shade trees such as leguminous tree species (*Gliricidia sepium* from Central America, *Erythrina poeppigiana* or *Inga edulis, both native in South America*) were used as mono-specific shade (Beer *et al*, 1997) in new cocoa plantations during the 1970. Although the use of these shade trees, especially when they are regularly pruned, accelerates nutrient cycling, they are of no (or minimum) economic value, being not appealing from the income generation point of view to the farmers.

In the frame of Cachoeira catchment DSS, the replacement of these trees, which are in agricultural land, by adequately designed cocoa-based agroforestry systems (combined with other type of shade trees with higher returns or other crops that can shade cocoa such as banana) can result in more productive, and more ecologically sound production systems.

3.4.2.4 Introduction of diversified agro-systems

Over recent decades economies of scale, rationalisation and specialisation have generally taken place within agriculture. These processes have resulted in the enlargement of farms associated with a strong reduction in the number of farms and employment opportunities, thereby contributing to the reduction of the rural population. Diversification offers an alternative business strategy to specialisation. In this diversification strategy, farmers have had to come up with new ideas and/or implement techniques that are often unfamiliar. For them, the introduction of a new product, process or activity, on the farm represents an innovation.

Growing alternative crops to diversify a traditional farm rotation increases profits while reduces adverse environmental impacts and the economic dependence on just one or two crops. Diversifying can spread economic risk and offer profitable niche markets, lessen impact on environmental resources strained by monoculture systems and, sometimes, offer new opportunities to strengthen communities (SAN, 2004).

Crop rotations can break insect and disease cycles, reduce weeds, restrain erosion, supplement soil nutrients, improve soil structure and conserve soil moisture. Diversification can also: stimulate the creation of new industries based on agriculture to process agricultural products, strengthening rural communities; and aid the domestic economy, enabling producers to grow crops that would otherwise be imported.

However, the occurrence of farm diversification and evidence of profitability from such activities are mostly dependent on farm size and the fundamental economy of the farm. Larger farms with the ability to invest and engage in large-scale projects are the ones most likely to achieve economical benefits from diversifying.

In the frame of Cachoeira catchment DSS, diversified agro-systems can be a good solution for land management at the regional, watershed, and farm scales because they optimise the interactions of increased food production, poverty alleviation, and environmental conservation.

3.4.3 Cattle production

3.4.3.1 Combining Leguminous with natural pastures

According with FAO, it is recognised the growing environmental problems (high erosion rates and less water availability) in “arid” regions, where animal husbandry is the main system of production. Therefore, it is necessary to adapt existing methods and to develop new ones to improve fodder production and decrease such environmental problems. Furthermore it can increase the vegetal cover, and therefore, increase the control of erosion and improve the soil fertility. Moreover, it tends to promote the reduction of the pasture areas accessible to livestock (Sere and Steinfeld, 1996).

In the frame of Cachoeira catchment DSS, the improvement of natural pastures through introduction of improved forage species can significantly increase daily weight gain of animals, by upgrading the quality and quantity of forage for livestock and regulating the forage availability.

3.4.3.2 Intensive cattle raising

Rotational grazing is the process of moving a herd of livestock from one pasture to another and allowing each pasture a period of rest before it is grazed again. This form of grazing management is gaining popularity because of the need to increase production efficiency to cover the high cost of land, labour, and operating expenses. Changing from continuous to controlled grazing allows livestock producers to (1) increase stocking rates, (2) extend the grazing season, (3) increase nutrient recycling, (4) decrease labour, and (5) improve animal health and potentially lower parasite loads (Sere and Steinfeld, 1996).

However, large numbers of farm animals, requiring huge quantities of feed (grown on vast areas of land using massive inputs of water, energy, fertilisers and pesticides), produce enormous amounts of waste, causing serious pollution and environmental degradation. Severe manure disposal problems can occur, increasing nitrogen concentration in soils surface water and groundwater.

In the frame of Cachoeira catchment DSS, intensive cattle raising means increasing the number of animals per hectare, by using processes of rotational grazing. This intensification of cattle raising should avoid the incorporation of new areas into the productive process (and the associated degradation of forest cover).

3.4.3.3 Agrosilvopastoral systems

The alternative related with the development of agrosilvopastoral systems is related with agroforestry systems that includes trees or shrubs and herbaceous food crops and pastures and animals. It allows the concurrent production of agricultural crops, forest crops and livestock production, providing environmental benefits such as water quality improvement, soil conservation, carbon sequestration, wildlife habitat protection, and aesthetics (Alavalapati *et al*, 2004). Furthermore, it decreases the dependency from one type of production and from the seasonality of forage and livestock production.

Although not always explicitly demonstrated in quantitative terms, livestock production is habitually considered as a driver of significant environmental degradation, especially in what concerns soil erosion, reduced soil fertility, biodiversity losses, water contamination, and greenhouse gasses emissions. In fact, the quality of the pastures, which replaced large areas of tropical forest, usually declines dramatically after a few years due to overgrazing, frequent burning, infrequent weeding practices, lack of fertilisation, etc. The decline in pasture quality is characterised by soil compaction, nutrient loss, decline in vegetation cover, reduced nutrient availability, increased susceptibility to pests and diseases, invasion of unpalatable weeds and shrubs, and a diminished capacity of the land to absorb periodic rainfall into the soil and release it into streams in a steady flow, leading to a more rapid run-off of rainfall, decreased soil and water quality, soil chemical deficiencies or imbalances, and erosion.

In the frame of Cachoeira catchment DSS, agrosilvopastoral systems, in which cattle and pastures are combined with trees, shrubs and other crops, are one strategy of rehabilitation of pasture lands that can contribute to increase the productivity with minimum negative impacts on the environment; even more if, on the crop side, soil conservation techniques are employed and, on the pastures side, appropriate associations of improved grasses, leguminous and rotations to maximise soil cover are used.

3.4.4 Tourism

Tourism is the strategy employed either by public agencies or private companies to promote a particular region for the purpose of providing goods or services to facilitate business, pleasure, and leisure activities away from the home environment (Mill & Morrison, 2002). It requires travel, which is the action someone undertakes to visit that region located outside of one's normal working or living area, from daytrips to overseas holidays.

Therefore, tourism is a service industry, comprising a number of concrete components (transportation systems, accommodation, foods and beverages, tours, souvenirs; and related services such as banking, insurance and safety & security) and insubstantial components (rest and relaxation, culture, escape, adventure, new and different experiences).

3.4.4.1 Leisure-tourism

Tourism is nowadays the world’s largest industry with an average annual growth rate of 6,6% in the period of 1950 -2002 (**Lindsay, 2003)**. Worldwide, tourism generates annual revenues of nearly 3 trillion dollars and contributes nearly 11% of the global GNP (Gross National Product), making it the world's largest industry (WTO, 1999). This activity has a strong importance for every country in terms of job creation, halting emigration, the contribution made by foreign currency to the balance-of-payments, and the share of the gross domestic product.

Environment is in the core of tourism development, which was seen during long time as the ideal smokeless industry, an activity inherently conservatory given that its sustainability relied on the preservation of the natural resource base and the local cultures. However it is now recognised that tourism is an industry just like any other, an industry which has been characterised by rapid, short-term ventures which have often damaged those very assets upon which they depend. "Tourism kills tourism" is acknowledged as a widespread phenomenon (WTO, 1999).

At present tourism (especially mass tourism which requires the increasing development of hotels, and related facilities) is one of the main drivers of environmental degradation, inducing changes in geomorphology and hydrology, increasing pressure on water resources and food supply, leading to the destruction of fragile habitats such as coral reefs and mangroves, increasing pressure on a variety of species, and introducing serious pollution problems through the production of sewage and solid waste. Moreover, tourism has also led to changes in local communities, introducing them to new consumption models and lifestyles often undermining local traditions and social frameworks.

Tourism enterprises are in the business for profit, and tourism is essentially an exploitative industry. Therefore, it is justified to regulate tourism, towards sustainability, as is done for any other polluting industry. In fact, projects that are economically feasible but not environmentally desirable should remain unbuilt. Nevertheless, this industry has also the power to enhance the environment, to provide funds for conservation, to preserve culture and history, to set sustainable use limits, and to protect natural attractions. Furthermore, WTO (2002) considered that sustainable tourism development is a top priority in the strategies to reduce poverty and in its recent Tourism Policy Forum[10], held in Washington, it was considered that tourism is an increasingly important development strategy to positively address poverty reduction, economic growth, biodiversity conservation generally, as well as the UN Millennium Development Goals (MDGs) specifically.

In the frame of Cachoeira catchment DSS, leisure tourism concerns the nature-based activities more related with relaxation. In fact this strategy is mainly related with the classic “3S” vacations: sea, sand and sun, but also includes some activities that can be named as sport tourism such as diving, fishing, surfing, and windsurfing. It also includes the secondary houses for domestic tourists that are also located near the sea-shore. However, this alternative is proposed not in terms of mass tourism but in sustainable terms: contribute to improve the standards of living of the host population in the short and long term; and satisfy the demands tourists without putting in risk the capacity to attract them in the future, by a soundly management of the natural resources that are in the root of the activity.

It requires the development of hotels and resorts near the coast line (beach-related tourism developments); and infrastructures related with accessibility, water, supply, sanitation, energy, and communications. Moreover, it requires infrastructure services such as: commerce, travel agencies, rent-a-car agencies, bank agencies, which should support activities such as shopping and sightseeing of cultural and “natural” landscapes. These supporting infrastructures not only facilitate tourism but also contribute to improving the quality of life for residents.

10 This forum was held in October 2004, under the subject of “Tourism’s Potential as a Sustainable Development Strategy for Least Developed Countries”. In this forum was approved the Washington Declaration on Tourism as a Sustainable Development Strategy, which calls called upon donors and recipients to join together with government, the private sector, universities and civil society stakeholders to form a global network to enhance tourism’s potential to contribute positively to the fulfilment of the Millennium Development Goals.

Ilhéus' beaches would be the main focus for this alternative. However, it should avoid the idea of a mass-tourism, which is often associated with large-scale developments, externally controlled, with high leakage (money spent by tourists ends up leaving the region), and concentrated in high-density tourist strips, leading to strong environmental degradation. On the opposite it should adopt a general approach to ensure that its activities are non-polluting and non-visually intrusive in the limits of the carrying capacity of the host environment.

3.4.4.2 Eco-tourism

Ecotourism, nature tourism, green tourism, low-impact tourism, alternative tourism, responsible tourism, and quality tourism are usual expressions to sustain or even enhance the quality and attractiveness of the natural environment. There are several definitions of ecotourism, however Goeldner (2000) defines ecotourism as the responsible travel to natural areas that conserves the environment and sustains the well-being of local people.

Ecotourism, with its principles of responsible tourism, may satisfy environmentalists, but they only would guarantee sustainability if the needs of the local population are also considered. In fact local populations rarely benefit from tourism, even from these new, and more environmental conscientious, forms of tourism. The creation of natural reserves to protect extensive tracts of land has frequently the wicked effect of denying the traditional access to local populations for agriculture, gathering of fuel wood, fodder and building materials (Cater & Goodall, 1992).

The benefits of ecotourism can result from the jobs and income provided to local people, making possible to have funds for purchasing and improving protected or natural areas to attract more ecotourists in the future; provide environmental education for visitors; encourages heritage and environmental preservation and enhancement. However, making ecotourism a reality and avoiding a new way of bring visitors to fragile environments ruining them rather than preserving them, is still problematic.

According with the Guidelines for a National Policy of Ecotourism (1994), the Brazilian government, considers ecotourism as a segment of tourism activity that stimulates the sustainable use of the environmental and cultural heritage, encourages their conservation and looks for the building of environmental awareness through the interpretation of the environment and enhances the well-being of the population involved.

Therefore, ecotourism is perceived as a nature-based form of alternative tourism that embodies the virtuous traits that mass tourism lacks. It emphasises learning as a result of the ecotourist and the natural environment. But due to the difficulties of ensuring a type of activity that completely lacks of an ecological foot-print (whatever is its size), some authors consider that ecotourism is present when its promoters make every reasonable effort to ensure that their operations are sustainable, and in line with current best-practice principles and guidelines (Weaver, 2001), i.e. minimising the negative impacts on natural and cultural heritage, increase the awareness of the tourists to the need of environmental conservation, ensure that the infrastructures are developed in harmony with the environment, and maximising the benefits and economic activities of local communities.

Ecotourism is characterised by small-scale outfits in more or less remote locations, tourists typically stay with local families, or at small, environmentally-friendly hotels called ecolodges, which facilitates cross-cultural exchange (Lindsay, 2003).

In the frame of Cachoeira catchment DSS, ecotourism is a form of nature-based tourism that make every effort to be ecologically, socio-culturally and economically sustainable while providing opportunities for: appreciating and learning about the "natural" environment, experimenting some activities that are more adventure oriented and offer some degree of risk (trekking, climbing, rafting, canyoning, tree climbing, canopy walking, horseback riding, kayaking, etc.), and activities related with agrotourism, in which the interaction of tourists, nature and on-farm activities is more effective.

These activities should promote: creation of local jobs, settling the population in rural areas, diversification of the local economy trough the creation of small and medium enterprises, improvement of social equipments and of transport, communication and sanitation infrastructures, and creation of an alternative income to the protected areas that can reinvest it on pursuing other conservation strategies.

Cachoeira catchment has some features with an important degree of attractiveness to this type of activities:

- The forest ecosystem of Mata Atlântica, with a structure and floristic composition highly diversified, and high degree of endemism of fauna and flora. However, the fragility and fragmentation of this ecosystem doesn't allow the existence of large groups of visitors, and the entire supporting infrastructure must be very light.
- Cabruca farms, where an agro-forestry system (cocoa cultivated under the shade cover of native canopy trees) created a structural diversity very similar to natural forest. Furthermore, the ecotourist can contact with the different phases of the cocoa production and processing.
- Farms with agrosilvopastoral systems, in this diversified farms the tourist can contact directly with producers and production systems. There he will be lodged, and participates in the day-life of the farm. Furthermore, he can buy products from the farm (eggs, legumes, fruits, meat, flowers, etc.) or that were there processed (jams, cheese, handicrafts, etc.).The contact with better quality and better price products, will promote another source of income to the farmer.

These two alternatives related with tourism are both nature-based. However, ecotourism is considered less aggressive to the environmental conditions of Cachoeira catchment. Some interactions can be seen between these two alternatives:

The people that go to the coastal resorts and hotels also visit protected areas, especially if they are near the resort. Therefore, ecotourism offers another type of activity (a chance to learn about natural attractions) when these tourists take a break from their moments of sea-side relaxation, tanning, shopping, and city sightseeing.

Protected areas (natural reserves, parks or private reserves) are ideal ecotourism venues and sustain the activity. Protected areas have regulations in place to ensure the maintenance of the unspoiled natural environments, and frequently have outstanding landscape settings which increase their attractiveness.

3.5 Evaluation criteria (effects)

The selection of the evaluation criteria was made trough a series of consultation meetings within and outside the research consortium. For facility of dealing with the 29 criteria selected it was defined a hierarchical structure of the evaluation criteria. The criteria were arranged in subgroups within two main groups: socio-economic (social, income/costs, economic) and environmental (soil, water, vegetation and ecosystem).

3.5.1 Socio-economic criteria

3.5.1.1 Social

Life quality:
The ***well-being*** or quality of life of a population is an important concern in economics and political science. There are many components to well-being. A large part is standard of living, the amount of money and access to goods and services that a person has; these numbers are fairly easily measured. Others like freedom, happiness, art, environmental health, and innovation are far harder to measure. This has created an inevitable imbalance as programs and policies are created to fit the easily available economic numbers while ignoring the other measures that are very difficult to plan for.

In the frame of the Cachoeira catchment-DSS, life quality aims at presenting those more subjective factors that contribute to human life, such as leisure, safety, cultural resources, social life, mental health, freedom, happiness, art, environmental health, and innovation, where monetary measures do not readily apply.

Aesthetic value of landscape
Nowadays, a qualitative layer of "value" or "quality" is frequently ascribed to landscapes, and refers to the quality of experience of place, associated with the visual variety, uniqueness, prominence and naturalness of the landform, vegetation and waterform, and with the positive emotions produced by its observation. The aesthetic value of landscape is, therefore, one subjective dimension associated with some visual properties (visibility and the scenic beauty) of the environment (Daniel and Vining, 1983).

In the frame of the Cachoeira catchment-DSS, aesthetic value of landscape refers to the qualitative appraisal of the scenic beauty of the landscape, based on its visual character, which is considered higher in forest areas and lower in pasture lands.

Rural Exodus:
A term used to describe the migratory patterns that normally occur in a region following:

- changes in the methods of production, which usually are introduced to increase the productivity, such as the mechanisation of agriculture, in which fewer people are needed to bring the same amount of agricultural output to market;
- crises in the international markets of agricultural commodities, which are enhanced if a situation of monoculture exists.

In such situations, usually occurs a movement of people from rural areas into urban areas, especially if other alternative economic activities are absent of the region.

In the frame of the Cachoeira catchment-DSS, it means the movement of people out from rural areas looking for jobs and better life conditions in urban areas or elsewhere, occurred as a consequence of two main factors: declining of cocoa plantations that freed a significant amount of labour force that emigrates to the main urban areas of the catchment or even to other regions located outside the catchment; the other factor is related with cattle farming, which is an activity that is not intensive in labour force, driving therefore to the displacement of people into the main urban areas of the catchment or even to other regions located outside the catchment.

Acceptance:
Acceptance is a cognitive activity or state that is the opposite of resistance. It is not the same as approval or liking. Acceptance means agreeing that something will happen or has happened, and living with it regardless of whether one previously liked it or not. Approval indicates judging something to be the right thing to do/happen. Liking means wanting something to happen.

In the frame of the Cachoeira catchment-DSS, acceptance indicates the degree in which the people agree and are willing to implement the decisions taken or to be taken.

Social value for population:
The concept of social value was discussed for the purposes of pure economic theory since the beginning of the XX century. In fact it is an operative concept which is based upon one question: How much the alternative in question is contributing to increase the social benefits/social equity by using the access to social equipments (also known as soft infrastructures related with education and health) as its indicator. Investing in these social equipments provides significant benefits to local economies in terms of income and jobs generation, which frequently are not directly assessed. In certain terms "Social Value" is similar to *Standard of Living***,** which refers to the quality and quantity of goods and services available to the people.

In the frame of the Cachoeira catchment-DSS, the expression "Social Value" is not considered merely in economic terms. We are not interested in knowing if a specific alternative is creating economic value only for the investor (public or private, individual or collective) but also for the community, considering that the social value of an alternative is high when it promotes the development of social equipments.

Costs of environmental risks:
Costs of environmental risks correspond to negative externalities, which occur when a decision causes costs to the community. This means that some effects of an activity are not taken into account when it is priced: Too much pollution may occur if the producer need not take into account the interests of the community that is adversely affected by the pollution; Too little nature conservation may occur if those who undertake such activities are not rewarded in relation to the increase in the quality of life they help to bring about for the general population.

In the frame of the Cachoeira catchment-DSS, this is related with the monetary costs for the community of the potential environmental losses resulting from a specific alternative.

3.5.1.2 Income/cost criteria

Cost of establishment:
The analysis of a typical system could include costs for: planning, design, development, production, maintenance, disposal or salvage.

In the frame of the Cachoeira catchment-DSS, costs of establishment are those related with the implementation of the alternative (planning, design, development, execution), which occur specially in the first two or three years of operation.

Cost of system maintenance:
In the frame of the Cachoeira catchment-DSS, costs of maintenance are those related with the need to maintain the production process. They are more or less constant on a long-term basis.

Stakeholders' income:
Income, generally defined, is the money that is received as a result of the normal business activities of an individual or a company.

In the frame of the Cachoeira catchment-DSS, income is the amount of money that an individual or a company earns after paying for all its costs.

Early income:
In the frame of the Cachoeira catchment-DSS, early income is the money earned after paying for all its costs on the first two-three years of the life span of the alternative implemented. It supplies financial returns for the early years of the investment, giving to the individual or company an amount of money that can absorb the shock of the initial costs of establishment, reducing the over-exploitation of natural resources by the stakeholder.

Long-term income:
In the frame of the Cachoeira catchment-DSS, is the more or less constant income that allows the economic stability of the investment.

3.5.1.3 Economic criteria

Regional Gross Domestic Product (GDP):
In economics, the gross domestic product (GDP) is a measure of the amount of the economic production of a particular territory in financial capital terms during a specific time period. A common equation for GDP is: GDP = consumption + investment + government expenditures + exports – imports.

However, GDP doesn't take into account the black economy, non-monetary economy or the informal creation of wealth. Furthermore, GDP doesn't measure the sustainability of growth, as a region may achieve a temporary high GDP by over-exploiting natural resources. In addition, GDP counts work that produces no net gain, and does not account for negative externalities. For example, if a factory pollutes a river, that boosts GDP, and when the taxpayers pay to have it cleaned up, that boosts GDP again.

GDP also does not tell us the actual distribution of the wealth of a region. Certain groups of people within a country might not be benefiting from its economic wealth. A high GDP could be the result of a case of a few very wealthy people contributing to the economy, while most of its citizens live at or below the subsistence level.

In the frame of the Cachoeira catchment-DSS, regional GDP is considered as a measure of economic size, to try to measure the creation of wealth in the municipalities, but not to measure well-being and standard of living.

Infrastructures:
The term is used most often in a territorial planning context to denote the facilities that support specific land uses and built environment. In this context denotes two general groups of support systems: transportation modalities (roads, highways, railroads, public transport, airports, sidewalks, etc.) and utilities (electricity, natural gas; coal delivery, water supply, sewers, telephone service, radio and television bandwidth allocation, cable service). It also considers some municipal services such as garbage collection, police protection, fire protection, flood protection, postal system.

In the frame of the Cachoeira catchment-DSS, infrastructures correspond to all the facilities that support specific land uses and built environment. In general they tend to be embedded in the natural landscape and cannot be moved from place to place.

Direct Employment:
Employment is a contract between two parties, one being the employer and the other being the employee. In a commercial setting, the employer conceives of a productive activity, generally with the intention of creating profits, and the employee contributes with labour and expertise to the enterprise, usually in return for payment of wages.

In the frame of the Cachoeira catchment-DSS, employment means the direct number of jobs created by a specific alternative.

Indirect employment:
Almost every development alternative has associated other activities that promote the creation of income and jobs: agriculture appeals to agro-industry, tourism needs services, etc. Nowadays it is very frequent to measure the impact of some type of policy or investment, in terms of jobs indirectly created.

In the frame of the Cachoeira catchment-DSS, indirect employment means the indirect number of jobs created by a specific alternative.

Need for Expertise:
The general view of expertise is that is based on special knowledge, skills, or talent. Nowadays, expertise distinguishes high performers from others by their experience and the way they think and solve problems rather than simply by their knowledge. However, although experience can lead to intuitive expertise through routinising, it may also lead to a deepening pothole. True expertise, it is argued, is not a static feature, to be achieved once and then abandoned, but a continual process over time, an approach toward one's career.

In the frame of the Cachoeira catchment-DSS, expertise is the mixed experience-knowledge necessary to implement/adapt the alternatives.

Economic resilience:
The term economic resilience refers to a country's ability to economically cope with or withstand its inherent vulnerability as a result of some deliberate policy. Some factors can strengthen economic resilience: improving the competitiveness in an open market situation; building a sound macroeconomic environment (less permeable to the external market changes); diversifying the production systems to reduce the dependence on a narrow range of products; strengthening the transport and communications infrastructure to reduce peripherality.

In the frame of the Cachoeira catchment-DSS, economic resilience refers to the alternatives' capacity of maintaining more or less constant the stakeholders' income without jeopardizing environmental resources.

Water demand:
Actual quantity of water required for various needs over a given period as conditioned by economic, social and other factors. The consumers in a region need high-quality water for their activities. The urban centres and tourism industry depend upon increasing supplies of clean water for economic growth. Watersheds upstream from reservoirs need forest cover to maintain water quality, especially in erodable landscapes.

In the frame of the Cachoeira catchment-DSS, water demand refers to the costs related with the water demand by each of the alternatives. It can be the amount paid to public or private water supply system companies, the costs of drilling wells, building small dam reservoirs, channels, etc.

3.5.2 Environmental criteria

3.5.2.1 Soil criteria

Soil fertility
The quality of a soil that enables it to provide essential chemical elements in quantities and proportions for the growth of specified plants. A major source of soil fertility is the decomposing crop residue from prior years. The greater the quantity and variety of life growing and feeding in and on soil, the better its fertility.

In the frame of the Cachoeira catchment-DSS, the effect of land use alternatives on soil fertility is assessed on the assumption that high standing biomass and high biodiversity effects positively the soil fertility: The higher the biomass, the higher the potential input to the soil organic matter being the key of many soil fertility parameters e.g. cation exchange capacity, porosity and soil biota. Vice versa, the lower the soil cover, the higher the erosive and leaching losses of soil nutrients. Regarding biodiversity, it is assumed that it increases complementary resource use which means an improvement of nutrient capture. Consequently the nutrient pool remains more or less constant since it is stabilized in a closed recycling system.

Erosion risk:

Erosion is the displacement of sediments by wind or water in response to gravity. It can be an entirely natural process, but it is frequently increased by human activities such as: deforestation, overgrazing and road or trail building.

In the frame of the Cachoeira catchment-DSS, the soil erosion risk was assessed by using the USLE equation, which allows to calculate the long term average annual rate of erosion on a field slope based on rainfall pattern, soil type, topography, crop system and management practices.

3.5.2.2 Water criteria

Surface water pollution risk

Every human activity affecting components of the hydrologic cycle can have an impact on the surface water pollution. People influence surface water quality by adding potential pollution sources to the watershed (farms, houses, shopping centres, industrial units, etc.). As rain washes over a parking lot, it might pick up litter and motor oil and carry these pollutants to a local stream. On a farm, rain might wash fertilizers and soil into lakes, rivers or sea. The main group of pollutants which can affect surface water bodies are: organic material; phosphorus; heavy metals; detergents, synthetic organic compounds and bacteria.

In the frame of the Cachoeira catchment-DSS, the main point sources are related with: on-site septic systems, municipal landfills, livestock wastes, leaky sewer lines. The main non-point sources are: Fertilisers and pesticides on agricultural land and forests, which are used in low amounts.

Groundwater pollution risk

Groundwater is all water, which is below the surface of the ground in the saturation zone and in direct contact with the ground of the soil. Groundwater pollution risk is the probability that groundwater contamination could occur beyond acceptable limits. The contaminant load that is being, will be, or might be applied to the subsurface or surface environment as a result of human activity. The pollution vulnerability which depends on the characteristics of the geological strata or soil, on the land use/cover and on the groundwater recharge into or onto which the contaminant load could be introduced.

In the frame of the Cachoeira catchment-DSS, groundwater pollution risk is the probability that groundwater resource contamination could occur.

Groundwater recharge

Groundwater recharge is the process by which water is added from outside to the zone of saturation of an aquifer, either directly into a formation, or indirectly by way of another formation. Some of the water that precipitates, flows on ground surface (surface runoff) or seeps through soil first, then flows laterally (interflow), and some continues to percolate deeper into the soil. This body of water will eventually reach a saturated zone and replenish or recharge groundwater. The amount of water recharging the groundwater systems depends in a high extend on the rainfall, real evapotranspiration, vegetation, soil and geological characteristics.

In the frame of the Cachoeira catchment-DSS, due to the unfavourable hydrogeological conditions groundwater can be characterized as poor in water in spite of the relatively high precipitation.

Flood risk
Flood risk is the probability of overflowing by water of the normal confines of a stream or other body of water, or accumulation of water by drainage over areas which are not normally submerged. It depends mainly on the intensity and amount of rainfall events, the land use/cover, soil permeability and slopes in the catchment area.

In the frame of the Cachoeira catchment-DSS, flood risk is very significant, due to the "*high*" probability of occurrence.

Low flow risk
Low flow is the minimum discharge occurring in a river. It corresponds to situations of hydrological drought, which result from periods of marked deficiency of precipitation. It depends on the occurrence and duration of dry periods, the losses due to real evapotranspiration and the storage characteristics of the aquifers in the catchment.

In the frame of the Cachoeira catchment-DSS, low flow risk, is of high importance, low flow situations often occur and are provoking higher pollution of the streams as effect of a reduced dilution of pollutants.

3.5.2.3 Vegetation criteria

Vegetation cover:
Vegetation cover is an indicator for the "health" of the ecosystem. The "climax vegetation" serves as optimum reference state, representing the vegetation which would exist if growth were only limited by the pedoclimatic conditions of the considered area. Thus, the optimum vegetation cover doesn't necessarily mean forest, it can also be grassland and shrub- or tree savannah, etc.

In the frame of the Cachoeira catchment-DSS, changes in vegetation cover include changes in biotic diversity, actual and potential primary productivity, soil quality, evapotranspiration, groundwater recharge, runoff, erosion and sedimentation rates. Some of the most profound changes in the vegetation have arisen from direct decisions by man concerning land-use, and these have affected both the quality of environmental resources, such as soils and water, and the sustainability of food production.

3.5.2.4 Ecosystem criteria

Biodiversity effects:
Biodiversity is a measure of the relative diversity among organisms present in different ecosystems, measured in terms of the total number of genes, species, and ecosystems of a region. Biodiversity has contributed in many ways to the development of human culture, and, in turn, human communities have played a major role in shaping the diversity of nature at the genetic, species, and ecological levels. The benefits from biodiversity arise from its: Ecological role: the more diverse an ecosystem the better it can withstand environmental stress; Economical role: biodiversity supplies humankind with important economic commodities, such as crops, livestock, forestry, fish, medicine, fibers, energy, and is a source of beauty and joy for many people; Ethical role and Scientific role.

In the frame of the Cachoeira catchment-DSS, biodiversity not only represents an ecological interest for the community. Its economic value is also increasing being a field of activity and profit for society. It requires a proper management setup to determine how these resources are to be used.

Ecosystem fragmentation

Ecosystem fragmentation is the transformation of a largely continuous, though often heterogeneous, ecosystem or habitat into one that consists of isolated patches or ecological islands in a predominantly human-altered landscape.

Fragmentation is usually the outcome of larger regional changes, often driven by economic, political, and other social forces. One of the main actions to avoid or reduce ecosystem fragmentation is the establishment of corridors between reserves, and the accommodation of both human and wildlife on the remaining habitat fragments.

In the frame of the Cachoeira catchment-DSS, ecosystem fragmentation is the increase of isolated patches of vegetation in the landscape.

Ecological resilience

The amount of change a system can undergo and still remain within the same state or domain of attraction, is capable of self-organization, and can adapt to changing conditions. Therefore ecological resilience reflects the magnitude of disturbance that a system can experience before it moves into an alternative stable state (stability domain) with different controls on structure and function.

More recent work emphasizes the possibility of a system to adapt to change as a major component of ecological resilience, in addition to recovery or reorganization after disturbances (Gunderson, 2000):

1. the amount of disturbance a system can absorb and still remain within the same state of domain of attraction
2. the degree to which the system is capable of self-organization (versus lack of organization, or organization forced by external factors) and
3. the degree to which the system can build and increase the capacity for learning and adaptation

In the frame of the Cachoeira catchment-DSS, the concept of ecological resilience is applied to natural as well as to man made ecosystems including production systems. For an actual estimation of ecological resilience of a considered system it is assumed that resilience is related with biodiversity and standing biomass (biomass remaining after seasonal losses, harvest, grazing etc.).

Biodiversity provides the basis for complementary resource use, leading to increased resource uptake and consequently lower losses - a prerequisite for biomass accumulation and ecosystem constancy. Biodiversity also enhances the probability of ecological redundancy, i.e. the presence of functionally equivalent plants with widely divergent genetic constitution. Ecologically redundant plants (e.g. different species, varieties or genotypes) are likely to respond differently to environmental variation or disturbance and hence, increase the resilience of the ecosystem.

Standing biomass is the base of many ecological key functions including ecological services as e.g. soil protection and maintenance or increase of soil fertility (mediated by soil organic matter and root density which both affect chemical and physical fertility parameters). These key functions are determinants of the system’s constancy and resilience. Also regional ecological functions with regard to water and carbon fluxes are correlated with standing biomass. These fluxes are part of the regional equilibrium system which in feed back affects resilience parameters of particular ecosystems and which determines the strength of climatic irregularities and extremes (disturbances).

3.6 Description of the evaluation matrix

After the identification of alternatives and effects it was necessary to produce a matrix (called *Effects Table*), which is the central element of the evaluation and ranking process in DEFINITE. In this effects table the alternatives identified (columns) and the effects considered as evaluation criteria (rows) are included. The cell values of this table correspond to the importance of each effect in reference to each alternative (Janssen, Hervijnen & Beinat, 2003).

The experts within the research consortium were invited to provide a qualitative measurement, for each evaluation criteria per management alternative. It was used a ---- / ++++ scale, where the four pluses mean “extremely positive effect”, zero mean “no effect”, four minus mean “extremely negative effect”, and so on. This was a task involving four meetings to progressively ameliorate the judgements provided (Table 2).

Table 2. Evaluation criteria per management alternative

			Management alternatives										
			Delimitation of protected areas	Reforestation	Agro-forestry	Ecotourism	Leisure-tourism	Restructuring Cabruca system	Replacement of introduced shade trees	Introduction of diversified agro-systems	Combining Leguminous with natural pastures	Intensive cattle raising	Agrosilvo-pastoral systems
Socio-economic criteria	Social	Life quality	++++	++++	++++	+++	++	+++	++	+++	+	-	+
		Aesthetic value of landscape	++++	++++	+++	+++	+	+++	++	++	-	--	+
		Rural exodus	---	--	+	++	+++	+++	+++	+++	--	-	-
		Acceptance	++	++	++	+++	++	++++	--	++++	+++	---	+
		Social value for population	-	-	+	+++	+++	+++	+++	++++	++	++	+++
		Cost of environmental risks	0	0	-	-	---	-	--	-	--	----	-
	Income / cost	Stakeholders income	--	--	+	++	+++	++	++	++++	++	++++	+++
		Long-term income	--	--	++	+++	+++	++	+++	++++	+	++++	++
		Early income	---	---	+	++	+++	+	++	+++	++	+++	+
		Cost of establishment	-	--	---	---	----	--	---	----	-	---	---
		Cost of system maintenance	-	-	--	--	----	--	---	---	-	---	--
	Economic	Regional GDP	---	---	+	++	++++	++	+++	+++	++	+++	++
		Infrastructures	+	+	+	++++	++++	++	++	+++	+	+++	+
		Direct Employment	+	+	+	+++	++++	+++	+++	++++	+	++	++
		Indirect employment	+	+	+	++	++++	++	++	+++	+	++	++
		Need for expertise	++	+	--	++++	++++	----	-	-	----	+++	+
		Economic resilience	0	0	++	++	++	++	+++	++++	+	+	+++
		Water demand	0	0	-	--	---	-	-	--	-	-	-
Environmental	Soil	Soil fertility	++++	+++	+++	++	+	+++	+	++	+	---	+
		Erosion risk	++++	++++	+++	++	+	+++	++	+	++	----	+++
	Water	Surface water pollution risk	++++	++++	-	-	--	+	--	-	-	---	+
		Groundwater pollution risk	++++	++++	--	-	--	+	--	-	-	---	+
		Flood risk	++++	++++	-	0	0	+	-	-	-	---	-
		Low flow risk	-	--	+	0	0	+	-	-	-	---	-
		Groundwater recharge	-	-	+	0	0	-	+	+	++	++	-
	Vegetation	Vegetation cover	++++	++++	+++	++	+	++++	+++	++	-	---	+
	Ecosystem	Biodiversity effects	++++	+++	++	+++	+	+++	+	+++	-	----	+
		Ecosystem fragmentation	++++	+++	++	+++	+	+++	++	++	-	---	+
		Ecological resilience	++++	++	++	+++	0	+++	++	+++	+	---	+

3.7 The use of Multi-Criteria Analysis (MCA)

The inclusion of conflicting criteria and decision-makers turns the selection of the more adequate strategy(ies) into a complex process of decision-making (Tkach & Simonovic, 1997), which requires the application of adequate techniques such as the multi-criteria analysis. The evaluation and ranking of alternatives by MCA techniques is based on criteria values (which refer to the objectives and preferences of the various decision-makers) associated with each of the alternatives.

3.7.1 Weighting according to different perspectives

In real decision processes it is necessary to consider several groups of interested parties. Since each decision-maker has his own objectives, which are very dependent from their type and level of intervention, it was decided to simulate two groups of decision-makers assign weights for the evaluation criteria. Although both have environmental concerns, one group tends to have a vision of sustainability. Nevertheless, they value a little bit more the evaluation criteria related with social effects. The other group tends to give more importance to the economic criteria, and therefore its objectives are related with the maximisation of individual economic benefits. For this group the importance of environment is in terms of resource to be exploited and therefore that should be preserved because their activities are depending on it. The procedure to assign weights for each criterion was the Pairwise Comparison. The results are expressed in the Table 3 and Table 4.

Table 3. Weights for each criterion: sustainable scenario

	Sustainable Scenario				
	Sustainable development perspective	Socio-economic perspective	Extreme socio-economic perspective	Environmental perspective	Extreme environmental perspective
	%	%	%	%	%
Socio-economic criteria	**50,0**	**75,0**	**95,0**	**25,0**	**5,0**
Social	**12,2**	**12,2**	**12,2**	**12,2**	**12,2**
Life quality	0,9	1,3	1,6	0,4	0,1
Aesthetic value of landscape	0,1	0,2	0,3	0,1	0,0
Rural exodus	0,6	1,0	1,2	0,3	0,1
Acceptance	0,3	0,4	0,5	0,1	0,0
Social value for population	2,5	3,7	4,7	1,2	0,2
Cost of environmental risks	1,7	2,6	3,2	0,9	0,2
Income / cost	**23,0**	**23,0**	**23,0**	**23,0**	**23,0**
Stakeholders income	0,4	0,6	0,8	0,2	0,0
Long-term income	4,0	6,0	7,6	2,0	0,4
Early income	1,5	2,3	2,9	0,8	0,2
Cost of establishment	1,6	2,3	2,9	0,8	0,2
Cost of system maintenance	4,0	6,0	7,5	2,0	0,4
Economic	**64,8**	**64,8**	**64,8**	**64,8**	**64,8**
Regional GDP	4,0	6,0	7,6	2,0	0,4
Infrastructures	2,7	4,1	5,2	1,4	0,3
Direct Employment	7,5	11,2	14,2	3,7	0,7
Indirect employment	5,8	8,7	11,0	2,9	0,6
Need for expertise	1,2	1,8	2,3	0,6	0,1
Economic resilience	10,5	15,8	20,0	5,3	1,1
Water demand	0,7	1,0	1,3	0,3	0,1
Environmental	**50,0**	**25,0**	**5,0**	**75,0**	**95,0**
Soil	**13,9**	**13,9**	**13,9**	**13,9**	**13,9**
Soil fertility	1,7	0,9	0,2	2,6	3,3
Erosion risk	5,2	2,6	0,5	7,8	9,9
Water	**9,6**	**9,6**	**9,6**	**9,6**	**9,6**
Surface water pollution risk	1,9	0,9	0,2	2,8	3,5
Groundwater pollution risk	0,2	0,1	0,0	0,3	0,4
Flood risk	1,8	0,9	0,2	2,8	3,5
Low flow risk	0,4	0,2	0,0	0,6	0,8
Groundwater recharge	0,5	0,2	0,0	0,7	0,9
Vegetation	**27,8**	**27,8**	**27,8**	**27,8**	**27,8**
Vegetation cover	13,9	7,0	1,4	20,9	26,4
Ecosystem	**48,8**	**48,8**	**48,8**	**48,8**	**48,8**
Biodiversity effects	1,4	0,7	0,1	2,1	2,7
Ecosystem fragmentation	5,1	2,5	0,5	7,6	9,6
Ecological resilience	17,9	9,0	1,8	26,9	34,1

Table 4. Weights for each criterion: economic growth scenario

	Economic Growth Scenario			
	Economic growth perspective	More economic growth perspective	Less economic growth perspective	Extreme economic growth perspective
	%	%	%	%
Socio-economic criteria	**50,0**	**75,0**	**25,0**	**95,0**
Social	**7,6**	**7,6**	**7,6**	**7,6**
Life quality	1,7	2,6	0,9	3,3
Aesthetic value of landscape	0,7	1,0	0,3	1,3
Rural exodus	0,2	0,3	0,1	0,3
Acceptance	0,6	0,9	0,3	1,2
Social value for population	0,5	0,7	0,2	0,9
Cost of environmental risks	0,2	0,2	0,1	0,3
Income / cost	**68,7**	**68,7**	**68,7**	**68,7**
Stakeholders income	3,2	4,8	1,6	6,1
Long-term income	1,3	2,0	0,7	2,5
Early income	15,4	23,0	7,7	29,2
Cost of establishment	12,0	17,9	6,0	22,7
Cost of system maintenance	2,5	3,8	1,3	4,8
Economic	**23,7**	**23,7**	**23,7**	**23,7**
Regional GDP	0,3	0,5	0,2	0,6
Infrastructures	4,9	7,3	2,4	9,3
Direct Employment	1,8	2,7	0,9	3,5
Indirect employment	0,7	1,0	0,3	1,3
Need for expertise	1,2	1,7	0,6	2,2
Economic resilience	2,7	4,0	1,3	5,1
Water demand	0,3	0,4	0,1	0,5
Environmental	**50,0**	**25,0**	**75,0**	**5,0**
Soil	**36,1**	**36,1**	**36,1**	**36,1**
Soil fertility	15,1	7,5	22,6	1,5
Erosion risk	3,0	1,5	4,4	0,3
Water	**30,1**	**30,1**	**30,1**	**30,1**
Surface water pollution risk	8,9	4,5	13,4	0,9
Groundwater pollution risk	0,5	0,3	0,8	0,1
Flood risk	2,7	1,3	4,0	0,3
Low flow risk	2,0	1,0	3,0	0,2
Groundwater recharge	0,9	0,5	1,4	0,1
Vegetation	**23,2**	**23,2**	**23,2**	**23,2**
Vegetation cover	11,6	5,8	17,4	1,2
Ecosystem	**10,7**	**10,7**	**10,7**	**10,7**
Biodiversity effects	3,3	1,6	4,9	0,3
Ecosystem fragmentation	1,0	0,5	1,6	0,1
Ecological resilience	1,0	0,5	1,6	0,1

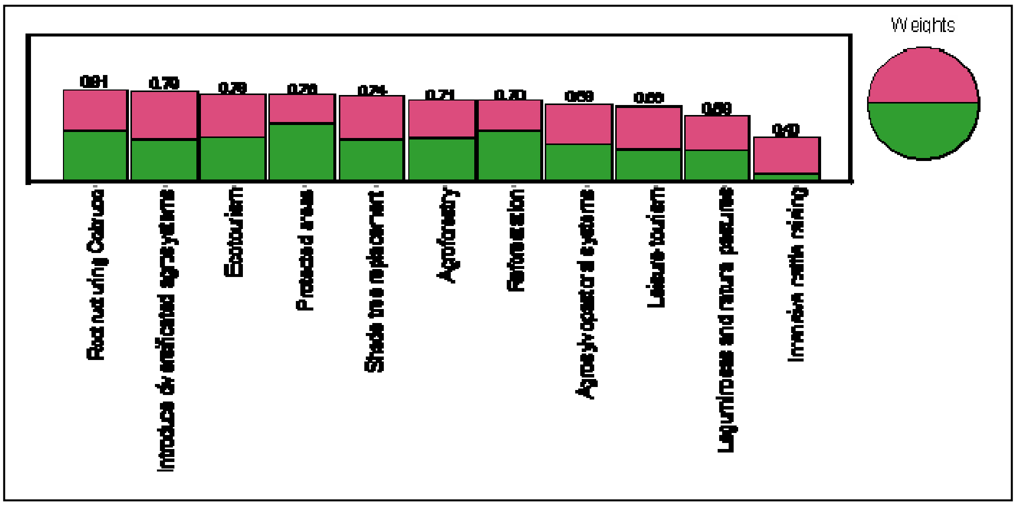
3.7.2 Ranking alternatives for the Cachoeira catchment

The combination of the weights and scores for each of the options allowed to derive an overall value, which was the base to rank the different alternatives in question for the entire catchment.

On a first step was decided to rank all the alternatives starting from a reference set of weights. From this analysis it was possible to achieve five perspectives/scenarios:

- The sustainable perspective: the two groups of socio-economic and environmental criteria were equally (50%) weighted (Fig. 5);

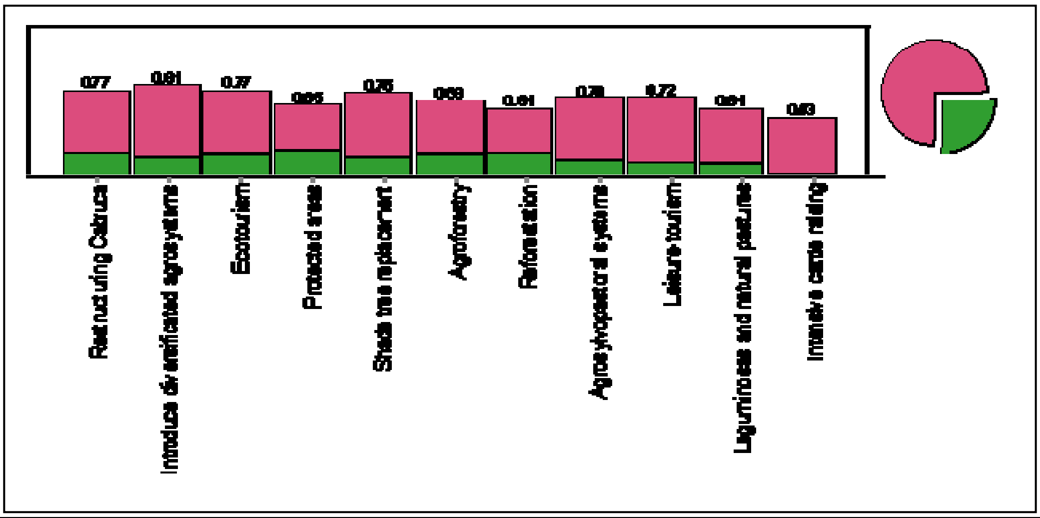
Fig. 5. The sustainable perspective. Socio-economic and environmental criteria equally weighted



According with the sustainable perspective (socio-economic and environmental criteria equally weighted), the set of management alternatives more adequate for the Cachoeira catchment is: the restructuring of Cabruca; the introduction of diversified agrosystems; the ecotourism and the definition of protected areas.

- The socio-economic perspective: all socio-economic criteria take on a higher weight, for instance 75% (Fig. 6);

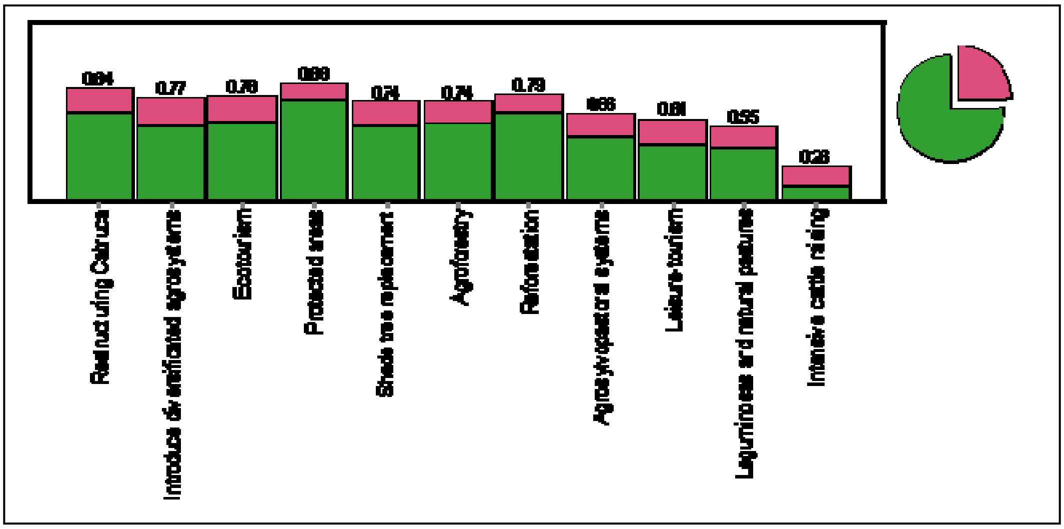
Fig. 6. The socio-economic perspective. Socio-economic criteria were weighted in 75%



According with socio-economic perspective (Socio-economic criteria were weighted in 75%), the set of management alternatives more adequate for the Cachoeira catchment is: the introduction of diversified agrosystems, restructuring Cabruca and ecotourism (with the same rank); and replacement of shade trees in cocoa plantations.

- The environmental perspective: all environmental criteria take on a higher weight, for instance 75% (Fig. 7);

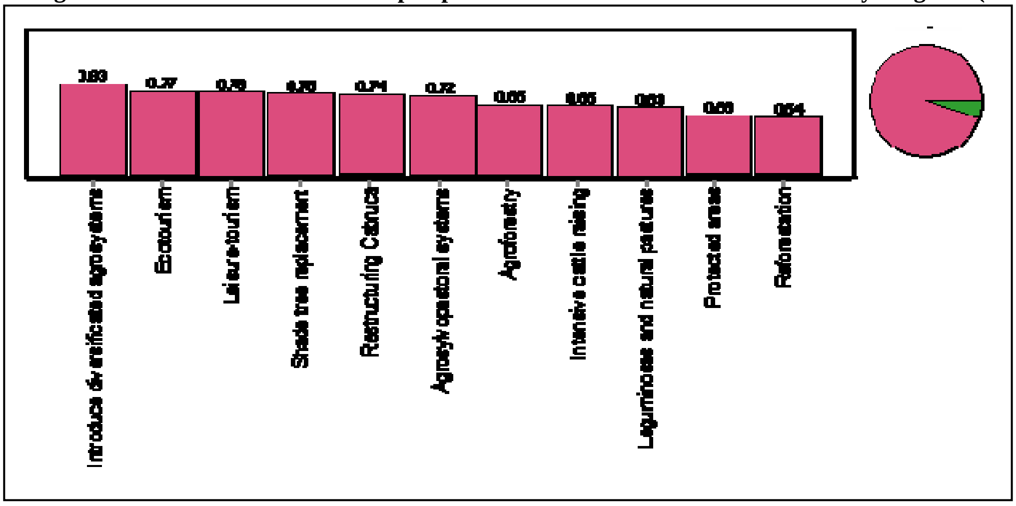
Fig. 7. The environmental perspective. Environmental criteria weighted in 75%



According with environmental perspective (environmental criteria were weighted in 75%), the set of management alternatives more adequate for the Cachoeira catchment is: the definition of protected areas; restructuring of Cabruca; reforestation; and the ecotourism.

- The socio-economic extreme perspective: the subset of socio-economic criteria take on almost all the weights (95%) while the other criteria have weight equal to 5% (Fig. 8);

Fig. 8. The extreme socio-economic perspective. Socio-economic criteria extremely weighted (95%)

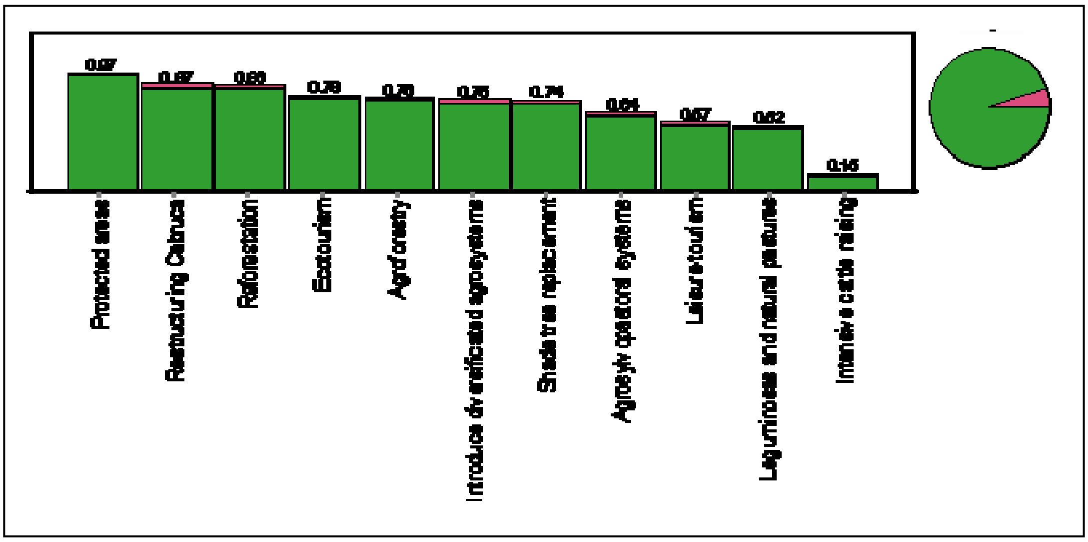


According with the extreme socio-economic perspective (Socio-economic criteria were extremely weighted in 95%), the set of management alternatives more adequate for the Cachoeira catchment is:

the introduction of diversified agrosystems; ecotourism; leisure tourism; and replacement of shade trees in cocoa plantations.

- The extreme environmental perspective: the subset of environmental criteria take on almost all the weights (95%) while the other criteria have weight equal to 5% (Fig. 9).

Fig. 9. The extreme environmental perspective. Environmental criteria extremely weighted in 95%

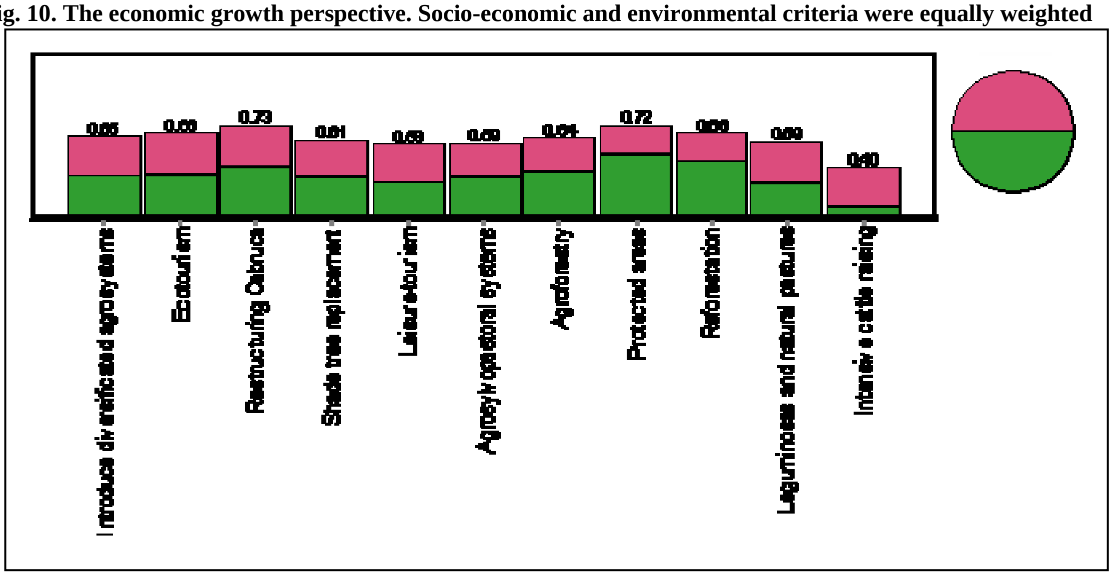


According with the extreme environmental perspective (environmental criteria were extremely weighted in 95%), the set of management alternatives more adequate for the Cachoeira catchment is: the definition of protected areas; restructuring of Cabruca; reforestation; and the ecotourism.

On a second step was decided to assign new weights according to a perspective of a group of decision-makers more interested in the maximisation of individual economic benefits. From this analysis four perspectives/scenarios were achieved:

- The economic growth perspective: the two groups of socio-economic and environmental criteria were equally (50%) weighted (Fig. 10);

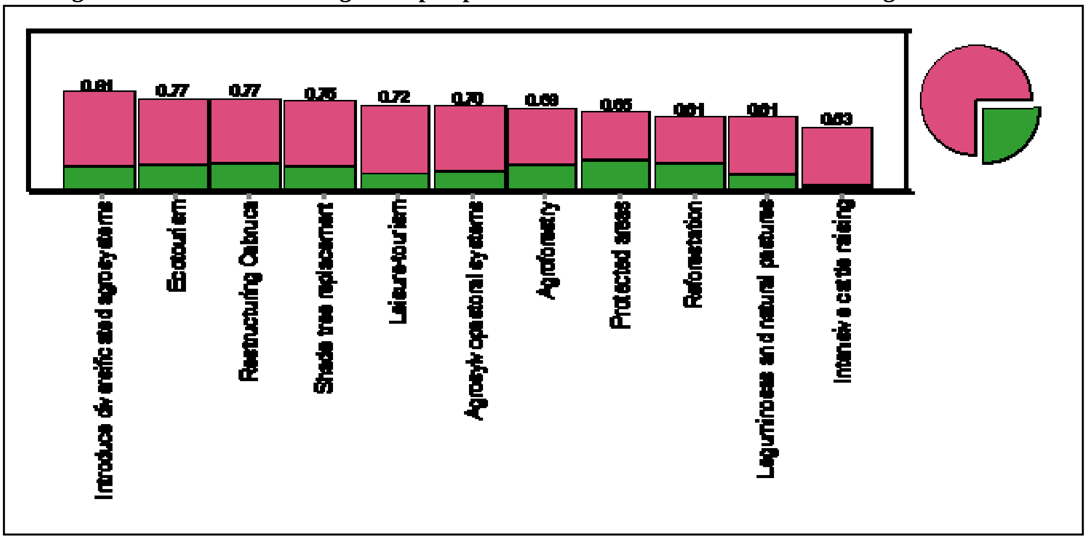
Fig. 10. The economic growth perspective. Socio-economic and environmental criteria were equally weighted



According with the economic growth perspective (Socio-economic and environmental criteria equally weighted), the set of management alternatives more adequate for the Cachoeira catchment is: restructuring Cabruca; definition of protected areas and ecotourism (with the same rank); and the introduction of diversified agrosystems.

- The more socio-economic perspective: all socio-economic criteria take on a higher weight, for instance 75% (Fig. 11);

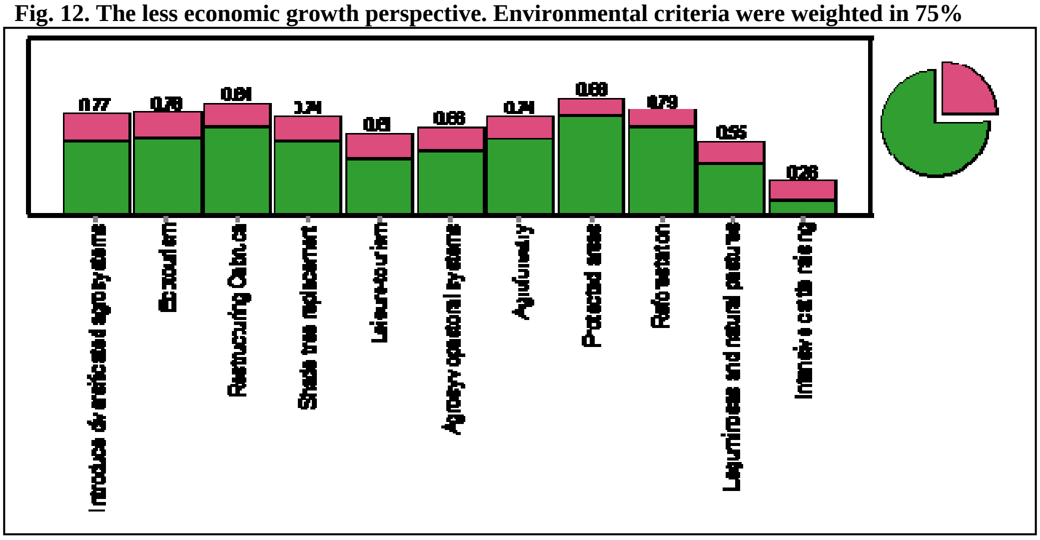
Fig. 11. The more economic growth perspective. Socio-economic criteria were weighted in 75%



According with the more economic growth perspective (Socio-economic criteria weighted in 75%), the set of management alternatives more adequate for the Cachoeira catchment is: introduction of diversified agrosystems; ecotourism and restructuring Cabruca (with the same rank); definition of protected areas; and replacement of shade trees in cocoa plantations.

- The less socio-economic perspective: all environmental criteria take on a higher weight, for instance 75% (Fig. 12);

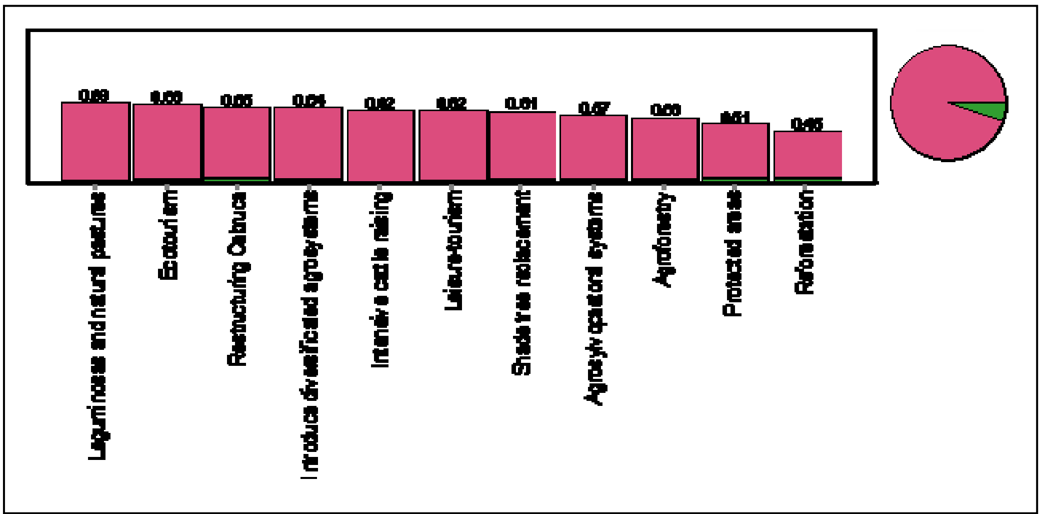
Fig. 12. The less economic growth perspective. Environmental criteria were weighted in 75%



According with the less economic growth perspective (environmental criteria weighted in 75%), the set of management alternatives more adequate for the Cachoeira catchment is: the definition of protected areas; restructuring of Cabruca; reforestation; and the ecotourism.

- The extreme socio-economic perspective: the subset of socio-economic criteria take on almost all the weights (95%) while the other criteria have weight equal to 5% (Fig. 13).

Fig. 13. The extreme economic growth perspective. Socio-economic criteria extremely weighted (95%)



According with the extreme economic growth perspective (Socio-economic criteria extremely weighted in 95%), the set of management alternatives more adequate for the Cachoeira catchment is: combining leguminous with natural pastures; ecotourism; restructuring Cabruca; and introduction of diversified agrosystems.

3.7.3 Ranking alternatives for the clusters

The DEFINITE software was also used to make another ranking of alternatives for the clusters achieved before. This ranking aim at identify the most suitable management alternatives according the characteristics of each cluster. Therefore, some of these alternatives were not considered in this phase of the analysis. So for Cluster 1 - Urban areas: the wealthiest of the catchment, the following alternatives were removed: Combining Leguminous with natural pastures; Intensive cattle raising; and Agrosilvopastoral systems. In cluster 2 - Pasture land: the immense supply of migratory movements, the alternatives related with tourism and cocoa plantations were not considered.

Clusters 3 (Marginal rural area: after abandonment, low dynamism of agro and pastoral) and 4 (Extensive use of agricultural land: the last resort in the path to marginalisation) were analysed jointly, and the alternatives related with tourism were not considered.

3.7.3.1 Ranking alternatives for Cluster 1 - Urban areas: the wealthiest of the catchment

The procedure to assign weights for each criterion was again the Pairwise Comparison. The results are expressed in Table 5.

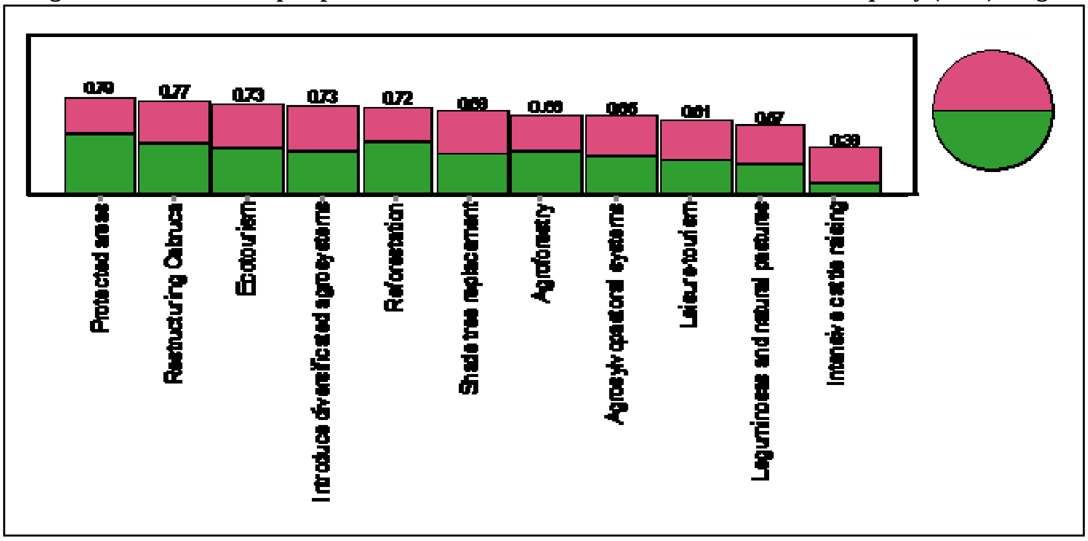
Table 5. Weights for each criterion: cluster 1

	Cluster 1			
	Sustainable development perspective	Socio-economic perspective	Environmental perspective	Extreme socio-economic perspective
	%	%	%	%
Socio-economic criteria	**50,0**	**75,0**	**25,0**	**95,0**
Social	**17,8**	**17,8**	**17,8**	**17,8**
Life quality	1,5	2,3	0,8	2,9
Aesthetic value of landscape	0,4	0,6	0,2	0,8
Rural exodus	0,2	0,3	0,1	0,4
Acceptance	0,4	0,6	0,2	0,7
Social value for population	4,1	6,1	2,0	7,8
Cost of environmental risks	2,2	3,3	1,1	4,2
Income / cost	**24,8**	**24,8**	**24,8**	**24,8**
Stakeholders income	0,6	1,0	0,3	1,2
Long-term income	2,5	3,7	1,2	4,7
Early income	0,8	1,2	0,4	1,5
Cost of establishment	6,0	9,0	3,0	11,4
Cost of system maintenance	2,5	3,7	1,2	4,7
Economic	**57,4**	**57,4**	**57,4**	**57,4**
Regional GDP	1,2	1,9	0,6	2,3
Infrastructures	2,3	3,4	1,1	4,3
Direct Employment	5,1	7,6	2,5	9,6
Indirect employment	8,4	12,5	4,2	15,9
Need for expertise	0,9	1,3	0,4	1,7
Economic resilience	9,1	13,6	4,5	17,3
Water demand	1,8	2,7	0,9	3,4
Environmental	**50,0**	**25,0**	**75,0**	**5,0**
Soil	**7,2**	**7,2**	**7,2**	**7,2**
Soil fertility	3,0	1,5	4,5	0,3
Erosion risk	0,6	0,3	0,9	0,1
Water	**24,3**	**24,3**	**24,3**	**24,3**
Surface water pollution risk	5,2	2,6	7,8	0,5
Groundwater pollution risk	0,5	0,3	0,8	0,1
Flood risk	4,5	2,3	6,8	0,5
Low flow risk	0,6	0,3	0,9	0,1
Groundwater recharge	1,2	0,6	1,8	0,1
Vegetation	**14,6**	**14,6**	**14,6**	**14,6**
Vegetation cover	7,3	3,7	11,0	0,7
Ecosystem	**53,9**	**53,9**	**53,9**	**53,9**
Biodiversity effects	3,8	1,9	5,7	0,4
Ecosystem fragmentation	7,7	3,8	11,5	0,8
Ecological resilience	15,5	7,7	23,2	1,5

From this analysis four perspectives/scenarios were achieved:

- The sustainable perspective: the two groups of socio-economic and environmental criteria were equally (50%) weighted (Fig. 14);

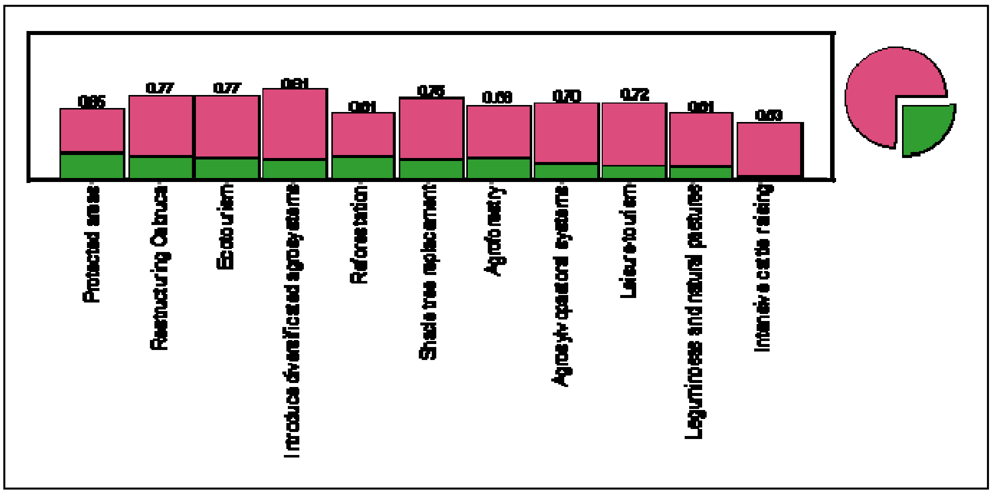
Fig. 14. The sustainable perspective. Socio-economic and environmental criteria equally (50%) weighted



According with the sustainable perspective (Socio-economic and environmental criteria were equally (50%) weighted), the set of management alternatives more adequate for the Cluster 1 is: delimitation of protected areas; restructuring Cabruca; ecotourism; and introduction of diversified agrosystems.

- The socio-economic perspective: all socio-economic criteria take on a higher weight, for instance 75% (Fig. 15);

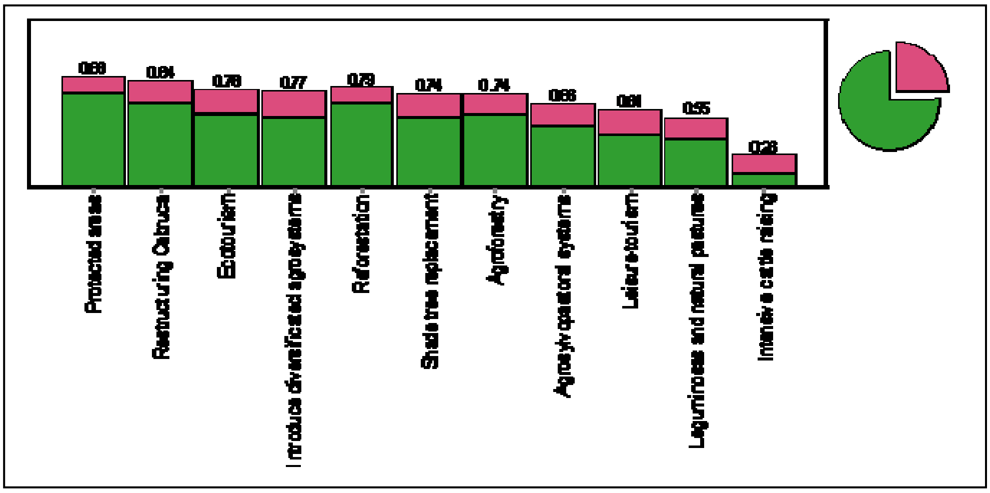
Fig. 15. The socioeconomic perspective. Socio-economic criteria were weighted in 75%



According with the socio-economic perspective (Socio-economic criteria were weighted in 75%), the set of management alternatives more adequate for the Cluster 1 is: introduction of diversified agrosystems; restructuring Cabruca and ecotourism (with the same rank); and replacement of shade trees in cocoa plantations.

- The environmental perspective: all environmental criteria take on a higher weight, for instance 75% (Fig. 16);

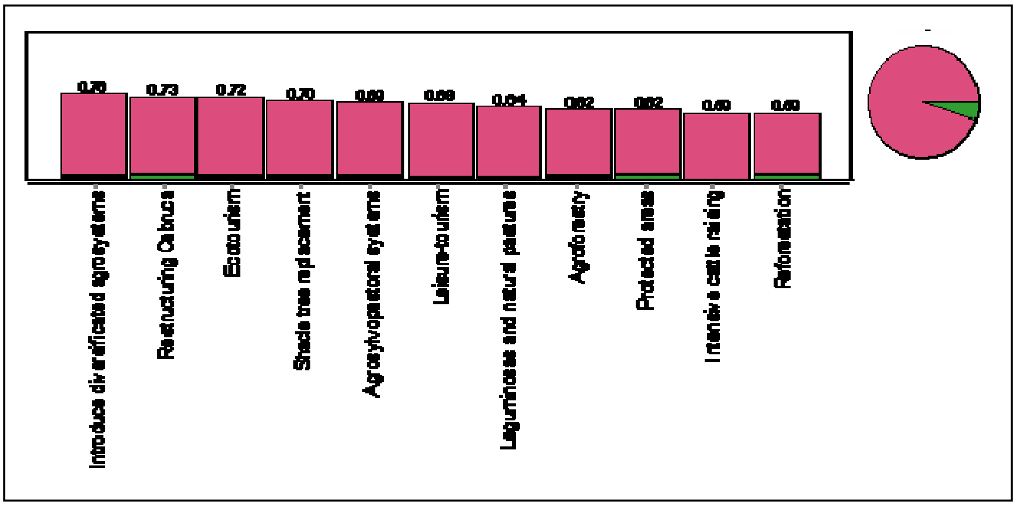
Fig. 16. The environmental perspective. Environmental criteria were weighted in 75%



According with the environmental perspective (environmental criteria were weighted in 75%), the set of management alternatives more adequate for the Cluster 1 is: delimitation of protected areas; restructuring Cabruca; ecotourism; and introduction of diversified agrosystems.

- The extreme socio-economic perspective: the subset of socio-economic criteria take on almost all the weights (95%) while the other criteria have weight equal to 5% (Fig. 17);

Fig. 17. The extreme socioeconomic perspective. Socio-economic extremely weighted in 95%



According with the extreme socio-economic perspective (Socio-economic criteria were weighted in 95%), the set of management alternatives more adequate for the Cluster 1 is: introduction of diversified agrosystems; restructuring Cabruca and ecotourism; and replacement of shade trees in cocoa plantations. This ranking is more or less the same as the perspective where the socio-economic criteria were weighted in only 75%.

3.7.3.2 Ranking alternatives for Cluster 2 - Pasture land: the immense supply of migratory movements

For the ranking of the alternatives for cluster 2 Pasture land: the immense supply of migratory movements, the alternatives related with leisure tourism and cocoa plantations were not considered, because the characteristics of this cluster show that they are not very suitable. The procedure to assign weights for each criterion was again the Pairwise Comparison, and the results are expressed in the Table 6.

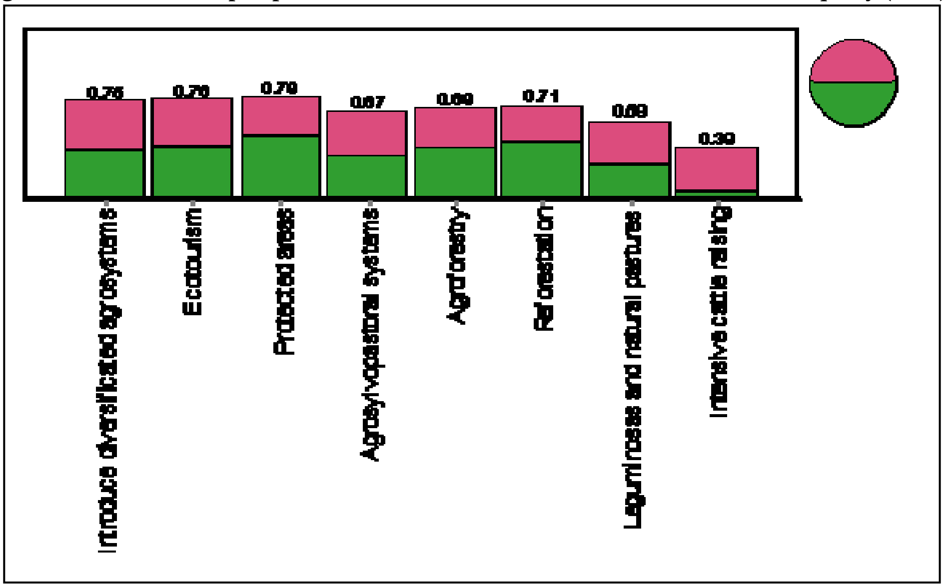
Table 6. Weights for each criterion: cluster 2

	Cluster 2					
	Sustainable development perspective	Socio-economic perspective	Environmental perspective	Extreme socio-economic perspective	Extreme maximisation of individual profits perspective 1	Extreme maximisation of individual profits perspective 2
	%	%	%	%	%	%
Socio-economic criteria	**50,0**	**75,0**	**25,0**	**95,0**	**95,0**	**95,0**
Social	**11,5**	**11,5**	**11,5**	**11,5**	**8,3**	**9,1**
Life quality	0,2	0,4	0,1	0,4	3,3	2,7
Aesthetic value of landscape	0,2	0,3	0,1	0,3	0,4	0,7
Rural exodus	0,9	1,4	0,5	1,7	1,7	2,7
Acceptance	0,3	0,5	0,2	0,6	0,8	0,7
Social value for population	3,1	4,6	1,5	5,8	0,8	1,3
Cost of environmental risks	1,0	1,6	0,5	2,0	0,8	0,7
Income / cost	**26,3**	**26,3**	**26,3**	**26,3**	**66,7**	**72,7**
Stakeholders income	0,8	1,1	0,4	1,4	17,5	21,4
Long-term income	2,8	4,2	1,4	5,3	15,3	16,6
Early income	1,3	1,9	0,6	2,4	15,3	19,1
Cost of establishment	5,7	8,6	2,9	10,9	8,7	7,1
Cost of system maintenance	2,6	3,9	1,3	4,9	6,5	4,8
Economic	**62,1**	**62,1**	**62,1**	**62,1**	**25,0**	**18,2**
Regional GDP	0,9	1,4	0,5	1,8	3,4	1,9
Infrastructures	2,5	3,8	1,3	4,8	5,1	5,1
Direct Employment	5,4	8,1	2,7	10,3	5,1	3,8
Indirect employment	9,8	14,8	4,9	18,7	3,4	2,6
Need for expertise	1,6	2,4	0,8	3,0	1,7	0,6
Economic resilience	7,3	11,0	3,7	13,9	2,5	1,9
Water demand	3,4	5,1	1,7	6,4	2,5	1,3
Environmental	**50,0**	**25,0**	**75,0**	**5,0**	**5,0**	**5,0**
Soil	**21,0**	**21,0**	**21,0**	**21,0**	**40,0**	**50,0**
Soil fertility	2,6	1,3	3,8	0,3	1,6	2,2
Erosion risk	7,9	4,0	11,9	0,8	0,4	0,3
Water	**7,8**	**7,8**	**7,8**	**7,8**	**30,0**	**25,0**
Surface water pollution risk	1,2	0,6	1,8	0,1	0,6	0,5
Groundwater pollution risk	0,3	0,1	0,4	0,0	0,2	0,1
Flood risk	0,5	0,3	0,8	0,1	0,2	0,2
Low flow risk	1,5	0,7	2,2	0,1	0,3	0,3
Groundwater recharge	0,4	0,2	0,6	0,0	0,3	0,2
Vegetation	**14,2**	**14,2**	**14,2**	**14,2**	**20,0**	**12,5**
Vegetation cover	7,1	3,6	10,7	0,7	1,0	0,6
Ecosystem	**57,0**	**57,0**	**57,0**	**57,0**	**10,0**	**12,5**
Biodiversity effects	3,2	1,6	4,8	0,3	0,3	0,3
Ecosystem fragmentation	7,6	3,8	11,3	0,8	0,1	0,2
Ecological resilience	17,8	8,9	26,6	1,8	0,1	0,2

From this analysis five perspectives/scenarios were achieved:

- The sustainable perspective: the two groups of socio-economic and environmental criteria were equally (50%) weighted (Fig. 18);

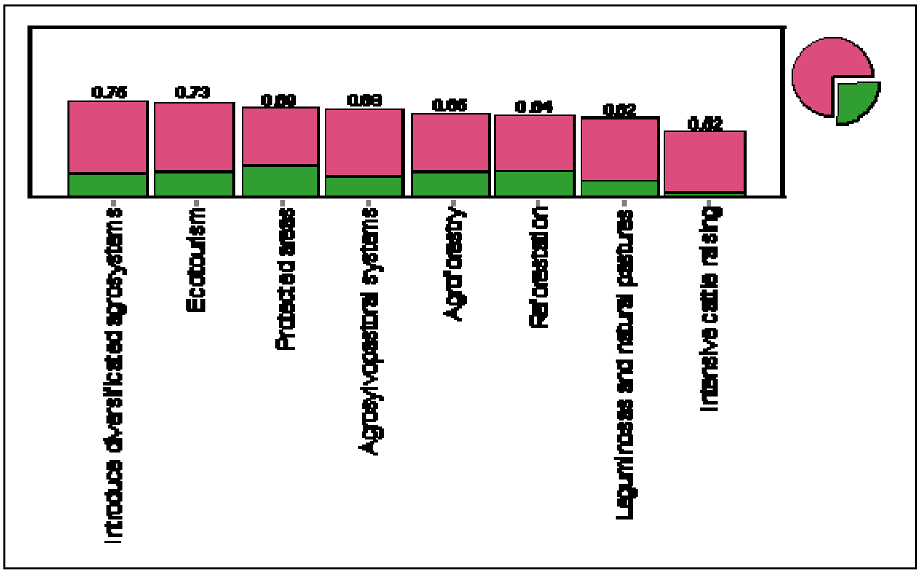
Fig. 18. The sustainable perspective. Socio-economic and environmental criteria equally (50%) weighted



According with the sustainable perspective (Socio-economic and environmental criteria were equally (50%) weighted), the set of management alternatives more adequate for the Cluster 2 is: introduction of diversified agrosystems; ecotourism; delimitation of protected areas; and agrosilvopastoral systems.

- The socio-economic perspective: all socio-economic criteria take on a higher weight, for instance 75% (Fig. 19);

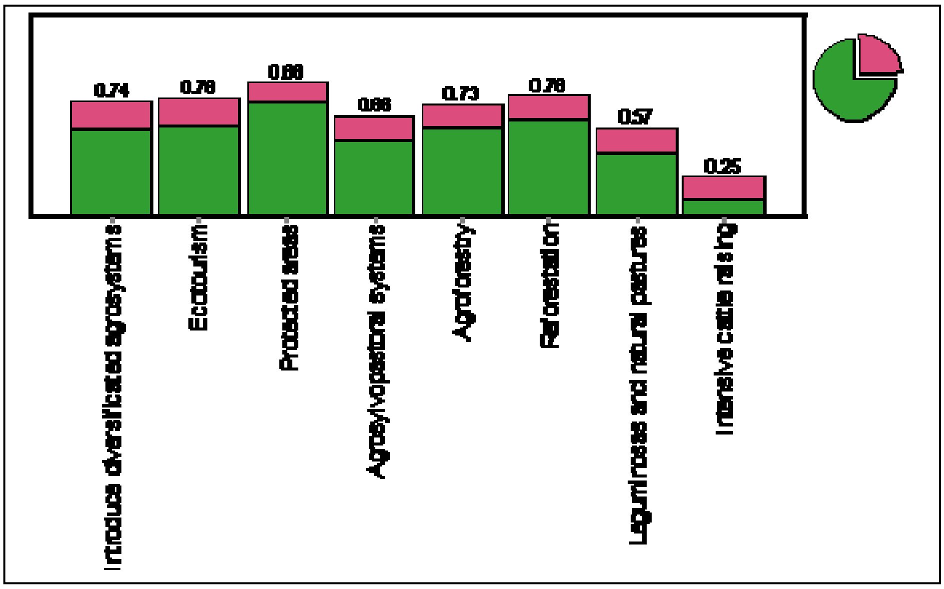
Fig. 19. The socio-economic perspective. Socio-economic criteria were weighted in 75%



According with the socio-economic perspective (Socio-economic criteria weighted in 75%), the set of management alternatives more adequate for the Cluster 2 is the same as for the sustainable perspective: introduction of diversified agrosystems; ecotourism; delimitation of protected areas; and agrosilvopastoral systems.

- The environmental perspective: all environmental criteria take on a higher weight, for instance 75% (Fig. 20);

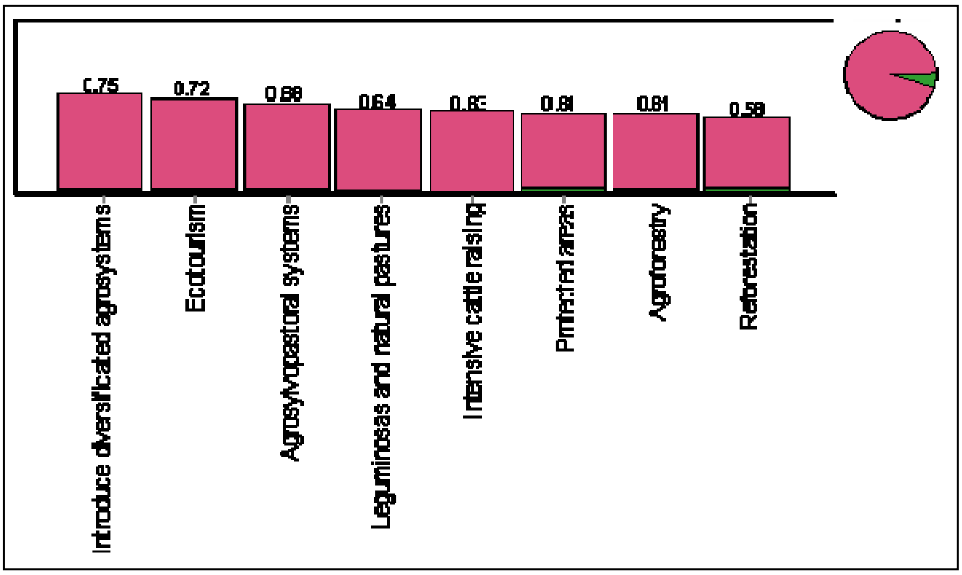
Fig. 20. The environmental perspective. Environmental criteria were weighted in 75%



According with the environmental perspective (environmental criteria weighted in 75%), the set of management alternatives more adequate for the Cluster 2 is the same as for the sustainable perspective: delimitation of protected areas; ecotourism and reforestation (with the same rank); and introduction of diversified agrosystems.

- The extreme socio-economic perspective: the subset of socio-economic criteria take on almost all the weights (95%) while the other criteria have weight equal to 5% (Fig. 21);

Fig. 21. The extreme socioeconomic perspective. Socio-economic criteria extremely weighted in 95%

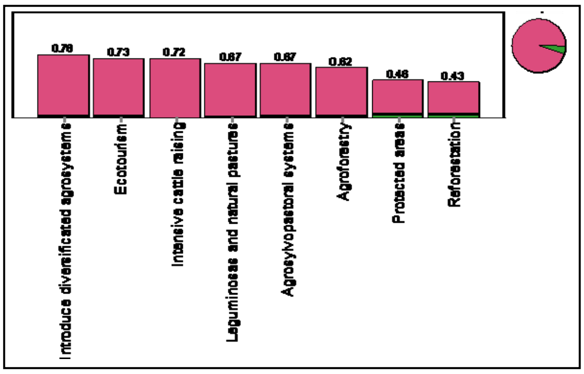


According with the extreme socio-economic perspective (Socio-economic criteria were weighted in 95%), the set of management alternatives more adequate for the Cluster 2 is: introduction of diversified agrosystems; ecotourism; agrosilvopastoral systems; and combining leguminosas with natural pastures.

- The extreme maximisation of individual profits perspective (Fig. 22 and Fig. 23): the subset of income/cost criteria take on almost all the weights (>60%);

For this perspective it was important to find which alternatives were more adequate if the aim was to maximise the individual profits, and not taking into attention any kind of social concerns to the community and not considering the environment as something to preserve because the economic activity depends on it. It is a rather extreme scenario, but not too much apart from the reality. Nevertheless, this is of course a not sustainable scenario.

Fig. 22. Extreme maximisation of individual profits perspective. The subset of income/cost criteria was extremely weighted in > 60%



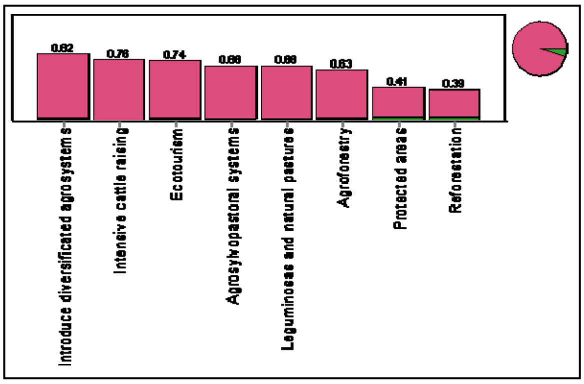


Fig. 23. Extreme maximisation of individual profits perspective. The subset of income/cost criteria was extremely weighted in > 70%

Two ranks of alternatives were made. The main difference is that in the second, the weight of the individual income (specially the early income) was considered as the most important criteria to define the alternatives. However, the five more suitable alternatives (according with this criterion), are the same for both ranks. The differences concern only the rank of intensive cattle raising, which is higher on the rank when the early income is more weighted.

According with this extreme individual profit perspective, the set of management alternatives more adequate for the Cluster 2 is: introduction of diversified agrosystems; ecotourism; intensive cattle raising; agrosilvopastoral systems and combining leguminosas with natural pastures (with the same rank).

3.7.3.3 Ranking alternatives for Clusters 3 (Marginal rural area: after abandonment, low dynamism of agro and pastoral) and 4 (Extensive use of agricultural land: the last resort in the path to marginalisation)

For the ranking of the alternatives for cluster 3 (Marginal rural area: after abandonment, low dynamism of agro and pastoral) and 4 (Extensive use of agricultural land: the last resort in the path to marginalisation) the alternatives related with leisure tourism were not considered. The procedure to assign weights for each criterion was the average of cluster 1 and cluster 2, since in this clusters there is a kind of mixture of the characteristics of the first two clusters. The resulting weights are expressed in Table 7.

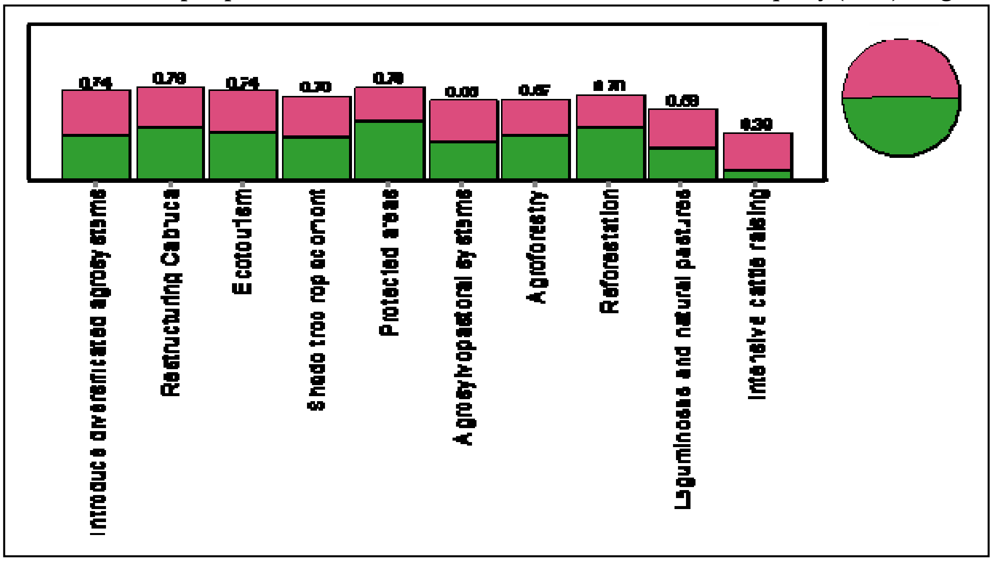
Table 7. Weights for each criterion: clusters 3 and 4

	Clusters 3 - 4			
	Sustainable development perspective	Socio-economic perspective	Environmental perspective	Extreme socio-economic perspective
	%	%	%	%
Socio-economic criteria	**50,0**	**75,0**	**25,0**	**95,0**
Social	**14,7**	**14,7**	**14,7**	**14,7**
Life quality	0,8	1,2	0,4	1,5
Aesthetic value of landscape	0,3	0,4	0,1	0,5
Rural exodus	0,7	1,0	0,3	1,3
Acceptance	0,4	0,5	0,2	0,7
Social value for population	3,6	5,5	1,8	6,9
Cost of environmental risks	1,6	2,4	0,8	3,0
Income / cost	**25,6**	**25,6**	**25,6**	**25,6**
Stakeholders income	0,7	1,1	0,4	1,3
Long-term income	2,6	3,9	1,3	5,0
Early income	1,0	1,6	0,5	2,0
Cost of establishment	5,9	8,8	2,9	11,2
Cost of system maintenance	2,5	3,8	1,3	4,8
Economic	**59,8**	**59,8**	**59,8**	**59,8**
Regional GDP	1,1	1,6	0,5	2,1
Infrastructures	2,4	3,6	1,2	4,6
Direct Employment	5,2	7,8	2,6	9,9
Indirect employment	9,1	13,6	4,5	17,3
Need for expertise	1,2	1,8	0,6	2,3
Economic resilience	8,3	12,4	4,1	15,7
Water demand	2,6	3,8	1,3	4,9
Environmental	**50,0**	**25,0**	**75,0**	**5,0**
Soil	**14,1**	**14,1**	**14,1**	**14,1**
Soil fertility	3,8	1,9	5,7	0,4
Erosion risk	3,2	1,6	4,9	0,3
Water	**16,1**	**16,1**	**16,1**	**16,1**
Surface water pollution risk	2,9	1,5	4,4	0,3
Groundwater pollution risk	0,5	0,2	0,7	0,0
Flood risk	2,1	1,0	3,1	0,2
Low flow risk	1,7	0,9	2,6	0,2
Groundwater recharge	0,8	0,4	1,2	0,1
Vegetation	**14,4**	**14,4**	**14,4**	**14,4**
Vegetation cover	7,2	3,6	10,8	0,7
Ecosystem	**55,5**	**55,5**	**55,5**	**55,5**
Biodiversity effects	3,5	1,8	5,3	0,4
Ecosystem fragmentation	7,6	3,8	11,4	0,8
Ecological resilience	16,6	8,3	24,9	1,7

From this analysis four perspectives/scenarios were achieved:

- The sustainable perspective: the two groups of socio-economic and environmental criteria were equally (50%) weighted (Fig. 24);

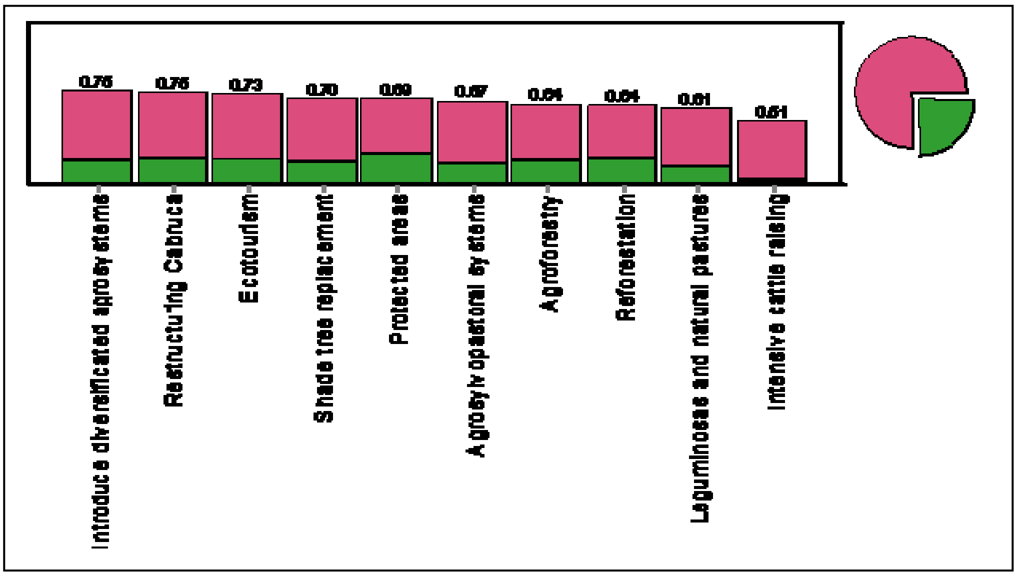
Fig. 24. The sustainable perspective. Socio-economic and environmental criteria equally (50%) weighted



According with the sustainable perspective (Socio-economic and environmental criteria were equally (50%) weighted), the set of management alternatives more adequate for the Clusters 3 and 4 is: delimitation of protected areas and restructuring Cabruca (with the same rank); introduction of diversified agrosystems and ecotourism (with the same rank); and replacement of shade trees in cocoa plantations and reforestation (with the same rank).

- The socio-economic perspective: all socio-economic criteria take on a higher weight, for instance 75% (Fig. 25);

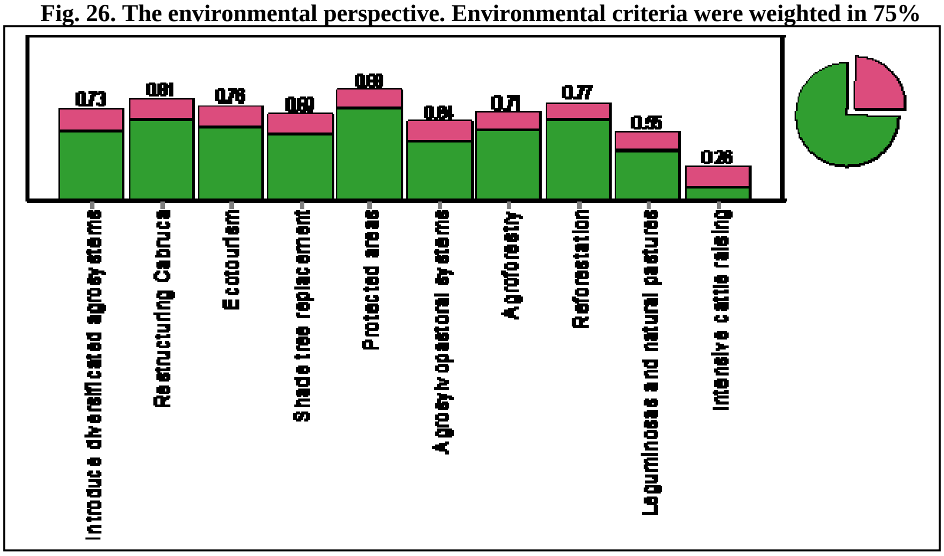
Fig. 25. The socio-economic perspective. Socio-economic criteria were weighted in 75%



According with the socio-economic perspective (Socio-economic criteria weighted in 75%), the set of management alternatives more adequate for the Cluster 2 is: introduction of diversified agrosystems; restructuring Cabruca; ecotourism; delimitation of protected areas; and replacement of shade trees in cocoa plantations.

- The environmental perspective: all environmental criteria take on a higher weight, for instance 75% (Fig. 26);

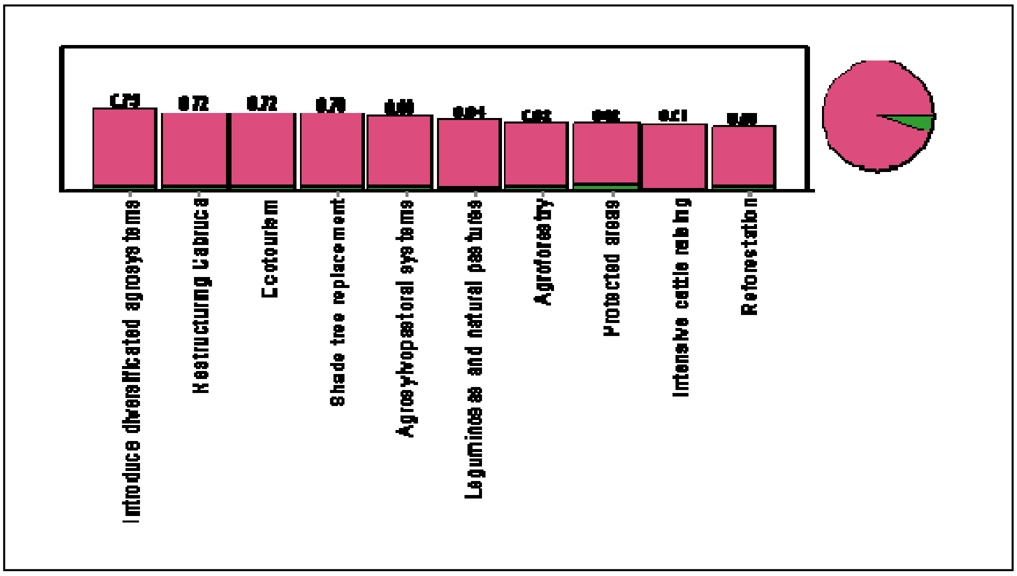
Fig. 26. The environmental perspective. Environmental criteria were weighted in 75%



According with the environmental perspective (environmental criteria weighted in 75%), the set of management alternatives more adequate for the Cluster 2 is the same as for the sustainable perspective: delimitation of protected areas; restructuring Cabruca; reforestation; and ecotourism.

- The extreme socio-economic perspective: the subset of socio-economic criteria take on almost all the weights (95%) while the other criteria have weight equal to 5% (Fig. 27);

Fig. 27. The extreme socioeconomic perspective. Socio-economic criteria extremely weighted in 95%



According with the extreme socio-economic perspective (Socio-economic criteria were extremely weighted in 95%), the set of management alternatives more adequate for the Cluster 2 is: introduction of diversified agrosystems; restructuring Cabruca and ecotourism (with the same rank); and replacement of shade trees in cocoa plantations.

3.7.4 Sustainable alternatives for ecosystem management in Cachoeira catchment

The exercise presented in the later paragraphs shows the most adequate alternatives for land management in Cachoeira catchment according with different sets of criteria, which represent different viewpoints of development for the region.

Two main situations were defined: first, alternatives for the entire catchment were established, and then alternatives for each cluster were ranked. These sets of alternatives could be chosen by decision-makers with a regional intervention. In fact the diversity of the studied region is not too big, but, nevertheless exists. So, a regional decision-maker (for instance, someone with powers to draft a regional plan (or a regional policy) for the development of the catchment) would probably be faced with different options (and priorities of intervention). The ranking of alternatives presented shows the way. It is a prerogative of the decision-maker to choose how to intervene. Therefore he can decide to invest in a sustainable approach or to favour a more economic growth approach.

Curiously, and according with the results obtained with DEFINITE, in both approaches there are five alternatives (of the eleven in question) that appear as the most suitable to the regions, differing only in the ranking of their prioritisation: Delimitation of protected areas; Restructuring Cabruca system; Reforestation; Eco-tourism; and Introduction of diversified agro-systems. These five alternatives show the importance of diversification of the economic activities in the regions and within agriculture in particular (which is reinforced by the fact that when the socio-economic perspective is highly weighted, the replacement of shade trees in cocoa plantation by other species with higher economic returns appears as a suitable alternative). However it shows also the importance of environmental preservation (delimitation of protected areas and reforestation) for the accomplishment of sustainable development in the region. In fact these two activities, together with ecotourism, should be in the core of a policy for the sustainable development of the region.

The less sustainable alternative is the intensive cattle raising. This alternative always appears in the last position of the rankings obtained. Only when the economic criteria (and specially the individual benefits) are maximised as objectives to be achieved, this activity climbs into the top four alternatives.

4 EPILOG: WHAT FUTURE FOR THE CACHOEIRA CATCHMENT?

When decision-makers choose an alternative, or a set of alternatives, of intervention in a given area, they should be aware of the possible consequences of their decision for the future development of the region. In fact, decision-makers should use scenarios to evaluate what interventions should be made in the present according to their possible consequences in the future (Wollenberg, 2000).

Scenarios are a tool that has been proved to be very efficient to synthesise and communicate the complex information underneath the decision to be taken, and therefore to think about the future (Alcamo, 2001). Scenarios are not predictions or forecasts, but rather descriptive narratives of plausible alternative projections, based on the extrapolation of expected trends in exogenous and endogenous factors (Ratcliffe, 2000), or in the introduction of changes by policies and management plans (Wollenberg, 2000). They are a methodology for understanding the whole range of possible alternatives, that doesn't have to capture and represent all the complexity in the world, but that should, in a simple and dynamic way, provide a logical sequence of consistent and plausible images of hypothetical future pathways (Rotmans et al, 2000).

Based on the information collected and on the work done with DEFINITE software, a set of four scenarios for Cachoeira catchment was developed. Scenarios are by definition hypothesis about the future, so the set of scenarios that is now presented is composed by four hypotheses, which have the purpose to be a synthetic way to provide decision-makers and stakeholders with information about the more adequate strategies of land management for Cachoeira catchment.

The scenarios now presented are of a qualitative form, and a narrative style was chosen in order to facilitate the communication of the implications of different future outcomes, without predicting the likelihood of a certain outcome. They aim at describing the system of Cachoeira catchment according with the views of several different stakeholders and experts. However, due to their qualitative attributes, they don't provide any numerical information. This cannot be considered as lack of accuracy, since the models used in quantitative scenarios, often simplify and extrapolate information, that tend to represent only one point of view. Furthermore, these narratives rely on the information collected and analysed in the frame of the workpackages 2-8 of ECOMAN.

Making exception for the baseline scenario (the persistence of present trends), none of the other scenario presented can be considered too bright or too dark. Since they intend to describe four plausible hypotheses of sustainable development of Cachoeira catchment, they contain positive and negative aspects, which together make for a glimpse of the reality of the catchment. Furthermore, the objectives of this scenario design is not to make value judgements since "*good*" strategy or "bad" strategy, put in a specific context, mean different things to different people.

As it was said before, sustainability was the prevailing consideration in the definition of strategies for ecosystem management in this area. This concern is imbedded in the design of the different alternatives to be ranked. The main aim of this exercise was to know which alternatives would be the most adequate for the region. It was not to identify the impacts (positive and negative) and then to choose the sustainable ones. In fact the alternatives were designed to be sustainable. Of course they have a gradient of sustainability. It is possible to say that the scenarios that are going to be presented now show different ways of valuing sustainability: i.e. each of the three dimensions of sustainability social, economic and environmental are valorised differently in the scenarios achieved.

In fact, in what concerns the scenarios developed it was considered that the population will maintain the growth rate verified between 1991 and 2000. In the overall of the catchment this means the maintenance or only a slight increase of population. Nevertheless, in the urban areas there will be a more considerable growth of resident population. One of the main objectives of these scenarios is to avoid the depopulation of rural areas, but for that it is necessary to diversify the economic structure in a way that the rural population would have an increase of income that will restrain their displacement to urban areas. Furthermore, the next scenarios aim also at the preservation of the environmental resources, as a means to ensure the natural conditions of development for future generations. Therefore, not only the conservation of actual forest area and reforestation should be promoted, but also other interventions, such as the development of sewage systems, water treatment and urban planning should take place.

4.1 Baseline scenario: Non-intervention or business as usual

This baseline scenario describes the possible future state of Cachoeira catchment (in terms of society and environment) in the absence of different development policies.

The trends observed in the last 10-20 years in Cachoeira catchment show us:

Important forest reduction

Significant decrease of biomass resulting from land cover changes;

Important pollution of surface and groundwater;

Significant flood risk;

Significant soil erosion risk, especially in the pasture areas;

Important exceeding agricultural labour force;

Strong rural exodus and concentration of population in urban areas;

Strong concentration of tourism infrastructures next to the coastline;

Strong dependency to some cash-crops (cocoa) and livestock;

Low income available to families;

Low support of public administration;

Low qualification of labour force;

The maintenance of this situation will lead to a high impact over natural resources and environment in general. In the same way, negative impacts over the households will increase. Incomes will become lower because the activities of the farmers are mainly of a subsistence type or extremely dependent from external markets, which will maintain the flow of population to the main urban areas specially Ilhéus and Itabuna, or to outside the catchment, decreasing the critical mass of population necessary to attract the investment. Furthermore, it will contribute for the increase of insecurity and violence in the main cities which will compromise tourism.

The lack of investment in sewage systems, water treatment plans, residual water treatment plants, waste treatment, and soil conservation measures for protection and restoration, will lead to an increase of environmental degradation expressed in the increase of surface and groundwater pollution and soil erosion. Furthermore, the expansion of urban areas in a not planned way will contribute for the increase of flood risk.

4.2 Sustainability scenario: a utopian balance

The sustainability scenario is inherently utopian, since it describes an *almost* unattainable ideal. The definition of sustainable development represents an ideal in which the environmental, social and economic dimensions are standards to which the community should aspire in a balanced way to encourage development that creates less and less negative impacts. However, until present very often the economy still prevails…

The main drivers of this scenario are related with agriculture, tourism and environmental conservation.

Restructuring the Cabruca system and the diversification of agro-systems would be the most adequate strategies to increase farmers' income without jeopardising the environmental resources of the region. These two strategies would contribute for increasing the productivity of high quality cocoa (which is one of the main requirements of external markets) based on resistant cloned varieties of cocoa, and leaving space for forest growing in the areas not currently productive, due to witches' broom disease. Furthermore, the diversification of agro-systems would contribute for the decrease of dependency of farmers in relation to one cash-crop (always dependent of the international market fluctuations) and therefore providing alternative income for farmers. Moreover, the implementation of this type of diversification would have significant impacts in terms of the increase of food production, poverty alleviation, and environmental conservation.

The other strategy in this sustainable scenario would be the investment in ecotourism. This type of tourism has the quality and attractiveness of the natural environment in the core of its development, but one of its main aims is to provide well-being to local populations. However, this strategy should be carefully considered because even if it is mainly targeted for small groups of people, its success can transform it in new forms of "*mass*" tourism with all the negative impacts inherent to the presence of big crowds in "*natural*" places.

Nevertheless, adventure oriented activities and agrotourism activities would promote the creation of new local jobs, the settling of population in rural areas, the diversification of local economy trough the creation of small and medium enterprises, the improvement of social equipments and of transport, communication and sanitation infrastructures, and the creation of an alternative income to the protected areas that can reinvest it on pursuing other conservation strategies.

The third strategy in this sustainable scenario is related with environmental preservation, especially in what concerns the delimitation of protected areas. This strategy should be related with ecotourism, given the fact that they could play the role of attractive areas for ecotourists. However, investing only in the delimitation of protected areas could not be enough for ensuring the preservation of the forest, being necessary to promote the reforestation (through the construction of ecological corridors) between these isolated patches.

4.3 Socio-economic scenario: economic growth and social equity

The socio-economic scenario proposes an image of the future of Cachoeira catchment where the main aim is to maximise profits and the rate of economic growth of the region. It is considered an extreme perspective of this scenario which concerns the maximisation of individual economic benefits. For this scenario the importance of natural environment relies on being a resource to be exploited and therefore that should be preserved not because of its intrinsic value, but because the proposed strategies are depending on it.

The main drivers of this scenario are related with cattle production, tourism and agriculture (especially in what concerns cocoa production). No major changes in the current activities present in the region are proposed, but mainly their restructuring in terms of complying with the objectives.

Cattle farming are a major activity in the Cachoeira catchment. A strategy related with the improvement of grazing land through introduction of improved forage species would improve fodder production, which would significantly increase daily weight gain of animals, by upgrading the quality and quantity of forage for livestock and regulating the forage availability. Therefore the income resulting would be higher and more permanent throughout the year. However, cattle farming is a system of production usually associated with growing environmental problems, expressed in high erosion rates and less water availability, which can jeopardise this production system. Improve fodder production would contribute to the decrease of such environmental problems, because the increase of the vegetal cover would increase the control of erosion and improve the soil fertility. Moreover, it tends to promote the reduction of the pasture areas accessible to livestock.

Ecotourism could be considered as another activity that would contribute for the diversification of the economic basis of the region and of the farms, trough the creation of small and medium enterprises, improvement of social equipments and of transport, communication and sanitation infrastructures, new jobs, increase the circulation of foreign currency, and would contribute for the increase of the regional domestic product.

The diversification of agro-systems would be a strategy that not only have environmental benefits, but also provides a diversification of the economic basis of the farm, and an increase of income for the farmers, which can sell their production in local markets.

In what concerns the cocoa production, the restructuring of cocoa plantations would encompass the increase of the productivity of cocoa farms, by reducing the area of cocoa (maintaining only the current productive areas) and replacement of damaged cocoa plants by cloned varieties, which are more resistant to witches' broom; and the replacement of introduced shade trees in cocoa crops with other trees of higher returns. The replacement of these trees, which are in agricultural land, by adequately designed cocoa-based agroforestry systems (combined with other type of shade trees with higher returns or other crops that can shade cocoa such as banana) can result in more productive, and more ecologically sound production systems.

In an extreme perspective of this scenario, aiming at maximising individual economic profits, also the intensive cattle farming could be considered, especially in those areas where livestock production is dominant. This strategy would increase the number of animals per hectare, by using processes of rotational grazing. This intensification of cattle raising should avoid the incorporation of new areas into the productive process and the associated degradation of forest cover.

4.4 Environmental scenario: deep green fields

This environmental scenario depicts a view of the future in terms of development of new environmental policy measures. In it is given a strong priority to environmental conservation as a means to increase the ecological awareness of the society, the management of forest areas for biodiversity conservation and the restoration conditions and ecosystems existing before the human disturbances.

The main drivers of this scenario are related with environmental conservation, agriculture, and ecotourism.

The remaining forest fragments in the Atlantic Forest need to be protected immediately in order to prevent species extinctions. One strategy to achieving this goal would be the delimitation of Integral Protection Units or Sustainable Use Units, of governmental responsibility, aiming at promoting a balanced relationship between people and nature to reconcile the conservation of biodiversity with its sustainable use. Another measure would be the spreading out of Private Natural Heritage Reserves (RPPN) which are established on private land and are an important tool for biodiversity conservation, complementing the government efforts to protect nature. However, the creation of natural reserves to protect extensive tracts of land has frequently the wicked effect of denying the traditional access to local populations for agriculture, gathering of fuel wood, fodder and building materials.

Nevertheless, isolation of forest patches is advancing rapidly, and isolated protected areas and their buffer zones will not prevent the collapse of ecological functions and associated biodiversity. Therefore, conservation corridors that link up the patches of protected areas through a matrix of biodiversity-friendly land use and reforestation/regeneration would be one of the most effective forest conservation strategies in the long term. Furthermore, in humid tropical regions the recovery of the degraded landscape through natural regeneration processes will take place within a time frame acceptable to the foreseen human use.

Restructuring Cabruca system, which has a high structural diversity, is also a strategy that would contribute for environmental conservation. In fact, this region’s rare climate, without a marked dry season or temperatures below 20°C, ensures that cocoa cultivation (low-density plantations of cocoa cultivated under the shade cover of native canopy trees) will persist, but on the best soils, which have the potential to ensure the economic viability of cocoa farms. Therefore, its restructuring arises as a significant step to increase productivity. Furthermore, Cabruca system has diversified agro-forestry settings that create habitat for a wide array of plant and animal species, including natural pollinators and predators of cocoa pests, both of which are vital to farm productivity. Cabruca cocoa farms can also maintain many natural ecological and climatic functions with respect to nutrient balance, erosion, water redistribution, energy partitioning, and the control of weeds, diseases and pests.

Another strategy of the environmental scenario would be the ecotourism, profiting from the natural protected areas (natural reserves, parks or private reserves) and from the cocoa farms, which are ideal ecotourism venues and sustain the activities. Protected areas should have regulations in place to ensure the maintenance of the unspoiled natural environments and outstanding landscape settings, which increase their attractiveness. The activities to be developed should profit from the Mata Atlântica´s highly diversified structure and floristic composition, and high degree of endemism of fauna and flora, and from the Cabruca farms, where the ecotourist would contact with a structural diversity resembling natural forest, and with the different phases of the cocoa production and processing.

The main activities, to be developed by small groups would be: appreciating and learning about the "natural" environment, experimenting some activities that are more adventure oriented and offer some degree of risk (trekking, climbing, rafting, canyoning, tree climbing, canopy walking, horseback riding, kayaking, etc.), and activities related with agrotourism, in which the interaction of tourists, nature and on-farm activities is more effective.

5 SPATIAL DECISION SUPPORT SYSTEM

5.1 GIS and DSS

In general, decision problems involve a set of geographically-defined alternatives from which a choice of one or more alternatives is made with respect to a given set of evaluation criteria and objectives (Ascough, 2002). This means that analysis results depend not only on the value judgments involved in the decision making process, but also on the geographical distribution of attributes of the area in study. Therefore, it is necessary to provide decision-makers with tools that combine decision-makers' preferences and criteria, with spatial information about the geographical locations of the alternatives in judgement.

Spatial decision support systems (SDSS) are considered as the adequate tools for the development of highly integrated information systems, which include Geographical Information Systems, Remote Sensing and Image Processing techniques, knowledge databases and logical modelling and Expert systems, Simulation and Optimisation, Multi-Criteria Decision Analysis and a suitable User Interface (Fedra & Feoli, 1998).

In the last years, considerable interest has been focused on the use of GIS as a toll for a Decision Support System. For some, this role consists of simply informing the decision making process. However it can really give a huge contribute to simulate spatial effects and predicted decisions in different context, especially for the environmental management (Eastman, 2001).

1.1. Objectives

In our challenge for a sustainable ecosystem management in Cachoeira catchment we produced a SDSS to provide the Decision Makers with a tool that foresees a Sustainable Development Scenario for the whole catchment. Thus we built the SDSS using several spatial data and integrating Geographical Information System, spatial modelling and expert's knowledge.

In order to obtain the general objective of a Sustainable Development Scenario, we need to assess the sub-objectives of a sustainable management for the principal land cover type. For that reason, the first step was produce a suitability maps for each land cover type.

5.2 Suitability maps

Suitability means appropriateness according to preordained conditions or requirements. It is a common term in decision making where tracts of land are to be allocated according to their suitability for one or more objectives (Eastman, 2001). Thus a suitability map displays the appropriateness of a specific objective in terms of spatial distribution.

Different suitability maps were accomplished for general land cover type as cocoa/Cabruca, forest/Mata, capoeira, pastures and urban areas (Fig. 28).

In our studied case, each suitability map was achieved by Multi-Criteria Evaluation based on the pair-wise comparison among criteria in terms of their importance (Saaty 1999) and strictly dependent on knowledge of the area's ecology and its dynamics.

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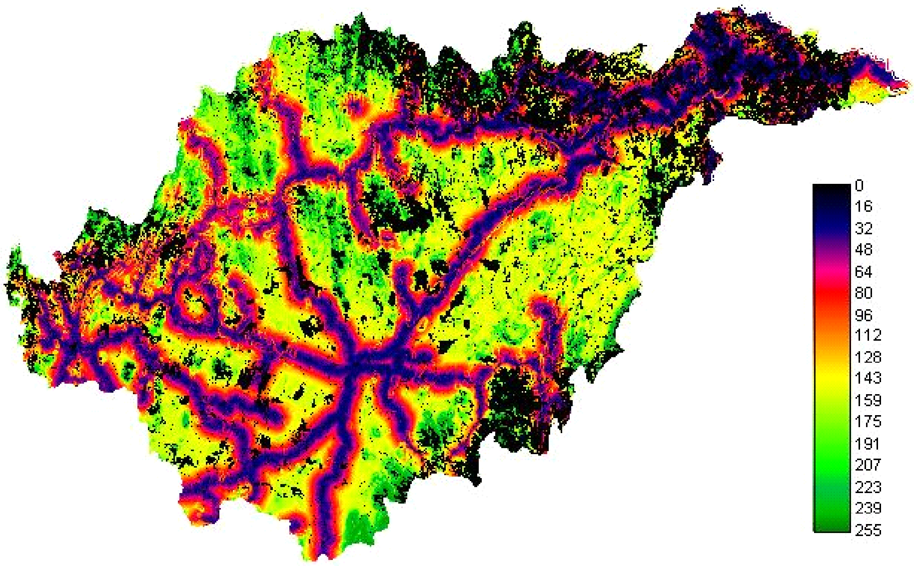

Fig. 28. Suitability map for forest/Mata

5.2.1 Data available

First of all, the available geographic data were collected (river network, roads, land cover, land cover changes, soil type, slope, altitude, population census, soil erosion risk and soil pollution risk,…).

Then, within this data, it was necessary to define the criteria more characterizing the land cover suitability and determine their weights. At that point, the principal problem found was low resolution and no-specificity of some data for an adequate assessment of land cover suitability. In spite of that a good set of criteria was collected and used in a MCE to obtain rather accurate suitability maps.

5.2.2 Criteria and weights

In a decision process we need to make a choice between two or more alternatives or conditions. The basis for make a decision is known as a criterion. Through a Multi-Criteria Evaluation, a set of specific criteria can be combined to obtained a single suitability map.

Usually the criteria are two types: "constraints", that are used to exclude certain areas from consideration (i.e. protected wildlife areas) , and "factors", that generally are continuos in nature (es. slope gradient, elevation, urban area proximity…) and indicate the suitability of certain areas for a specific objective.

We used the same constraints for each suitability map: roads, rivers, urban area, forest area and cocoa area. While the factors used were: distance from roads and urban areas, potential and real erosion, slope and elevation. For the suitability maps of cacao/Cabruca and pasture we used also the criterion "distance from cacao zone" (more exactly the municipalities of Itabuna and Barro Preto) that resulted very describing the appropriateness of specific land cover type.

Further step in a multi-criteria evaluation is assigning a weight to each criteria in order to obtain a classification of all criteria in terms of their assumed importance.

In our case we used pairwise comparison method that permit to give weights comparing the relative importance of criteria for land cover suitability. These weight are then standardized to produce a set o weights that sum to 1 (Saaty, 1977).

5.3 Results

The sub-objective of a sustainable management for the principal land cover type was achieved obtaining different suitability maps for the land cover type as cocoa/Cabruca, forest/Mata, capoeira, pastures and urban areas. At that point each suitability map was divided in ten level of suitability and only the 10^{th} class ("the highest suitability") was taken into consideration. Thus we obtained maps representing the best solution for a sustainable management of each land cover type (Fig. 29).

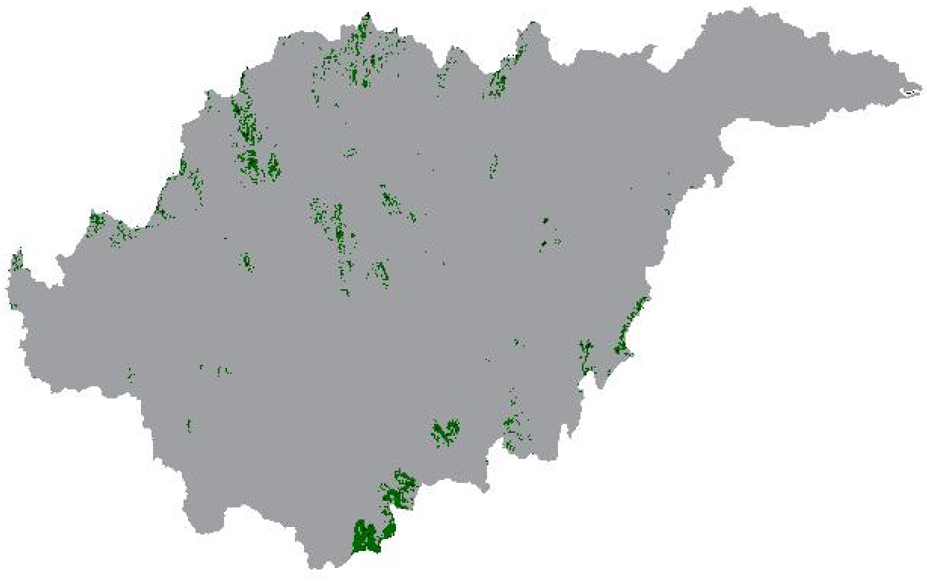

Fig. 29. Map representing the best solution for a sustainable management of forest/Mata

In order to obtained a primary sustainable management map of the whole catchment during the next years, the new "best suitability" maps were combined together and the cases of conflicting management were solved by considering that the most suitable land cover would be the one more corresponding to the more sustainable alternative as it was ranking in the outputs of DEFINITE (Fig. 30).

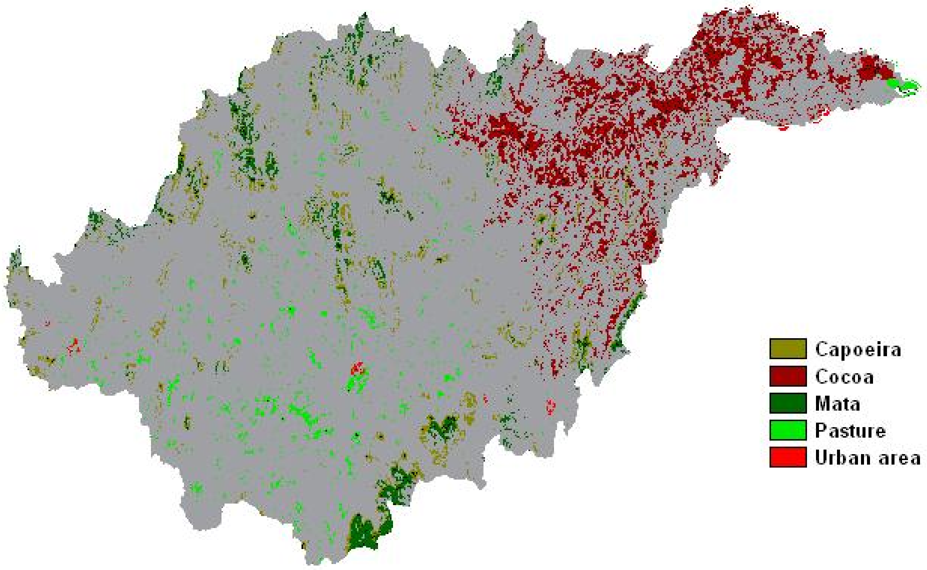

Fig. 30. Primary sustainable management map of the whole Cachoeira catchment for the next years

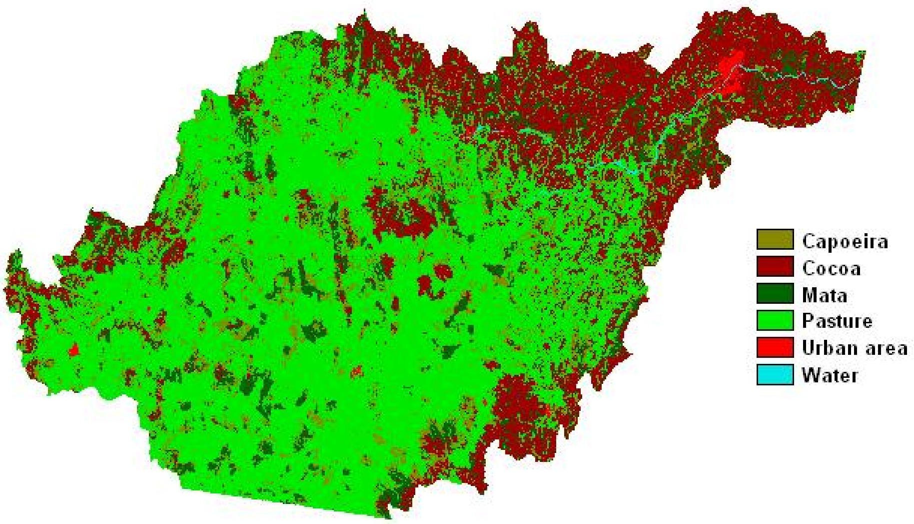

Fig. 31. Sustainable Development Scenario

Finally, to achieve the objective a sustainable future management of the Cachoeira catchment region a Sustainable Development Scenario was obtained merging the sustainable management map with the land cover map of 2001 (Fig. 31). The result is a possible and desirable land cover scenario to hit in the next future.

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