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Order and chaos in landscape: the role of suitability maps to plan sustainable development

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Abstract. The role of suitability maps as produced by Spatial Decision Support Systems (SDSS) is revisited under the perspective of sustainable development. A method using suitability maps as neutral models to measure the divergence from an ordered landscape situation is suggested. The concept of land use niche in landscape multidimensional space is introduced as the theoretical framework to support the method. Two case studies are presented in which suitability maps are used to measure the order of the landscape.

Key words: land use, multidimensional space, multi-criteria analysis, niche, neutral models, performance, SDSS.

1. Introduction

Within the many definitions of the term landscape the one proposed by Farina (2000) is one of the most simple and general. He suggests that: "we could define landscape as "a piece of real world" in which we are interested in describing and interpreting processes and patterns".

When such "a piece of real world" is selected for a study, it automatically represents a complex system with geographically located states determined by all the spatial interactions between man, plants, other living organisms and the chemical-physical environmental factors. The selected landscape may contain one or several ecosystems. The interactions between them or their parts may be direct and indirect and may differ in nature (chemical-physical, as microclimatic effects and energy flows; biological as grazing, hunting, migrations and cultural as information transfer etc.) and intensity. As consequence of different land uses different land cover types and land cover patterns are emerging. They correspond to the man-made ecosystems (or artificial ecosystems) that may have different degrees of naturalness (van der Maarel 1975, 1980, 1993). The same land use may produce different land cover types depending on several factors such as the type of ecosystems involved and their reaction to the impact, the way in which a land use is implemented, the intensity of land use etc. If we consider the DPSIR (Driving forces, Pressures, States, Impact, Responses) model of SEA (Strategic Environmental Assessment) supported by the majority of national environmental agencies (Therivel 2004; Dalal-Clayton & Sadler 2005), the land use may be considered the result of the driving forces behind the economy of the area where the landscape is located. The land use of a given landscape is the result of choices made between different alternatives considered appropriate (or good enough) in that area to reach some economical goals (generally income growth). Today the choices of land uses are almost always and everywhere mediated and/or supported by local, national and international policies (Nijkamp & Vindigni 2003) notwithstanding a certain degree of freedom is always in the hand of the land owners. As a matter of fact, after the conference of Rio de Janeiro (Earth Summit of June 1992 in Brazil), the implementation of Agenda 21 for sustainable development is considered at all the administrative levels in almost all the countries of the world (Filho 2002). It follows that sustainable development depends on the land use, therefore tools are needed to support spatial decisions for "sustainable land use". Landscape ecology is the specific discipline dedicated to develop such tools (Jongman et al. 1995; Farina 2000). In fact it aims at understanding all the aspects of landscape systems, i.e. its composition (diversity), structure (spatial pattern and spatial relationships of land use cover types), functions and dynamics (the ways and the causes of landscape changes in space and time).

In the present paper we suggest a method that uses suitability maps of land use as reference tools to measure the order and chaos of the landscape. The idea relies on the divergence between land use pattern and the suitability maps of land uses: the higher the divergence the higher the chaos in the landscape. Suitability maps can be obtained in several ways, however all the ways may be considered specific cases of Multi-Critera Evaluation (Eastman 1999) and can be obtained with GIS technology combined with Spatial Decision Support Systems (Malczewski 1999). In the present paper we suggest the use of suitability maps as an alternative to the traditional neutral models based on random spatial distributions such as those for species (see With & King 1997; Ulrich 2004). In agreement with the idea of Ricotta et al. (2002) we think that the traditional neutral models have little relevance in the study of land use spatial pattern when real problems have to be solved. The question for the landscape ecology practitioner is what is the scientific relevance of finding if a land use pattern is fitting or non fitting a random arrangement?

The potential vegetation as alternative to neutral landscape models, as suggested by Ricotta et al. (2002) is certainly interesting, however the application is confined to measure the human impact on vegetation. In the case of planning sustainable development potential vegetation is less meaningful than the suitability maps of land use because it is a reference system that neglects the human dimension. The use of suitability maps, would be more realistic because they keep into consideration the "human dimension" expressed by the criteria that are established by "planners" to reach specific goals in planning the socio-economic development. If they are formulated in terms of sustainable development the maps show where a certain land use could be optimally located and where its location would be unsustainable.

2. Landscape Ecological Multidimensional space and land use niche

In analogy with ecology, landscape ecology is dealing with a multidimensional space (ecological space), that may be called landscape ecological multidimensional space (LEMS). This is a dynamical space that according to the general system theory (including the chaos theory, complex system theory, self organisation system theory etc.) is the phase space (von Bertalanffy 1968; Ulanowicz 1997). In this space the land use types have trajectories towards stable positions (attractors) as the species and communities have in the ecological space. A land use type can be considered as the phenetic-functional expression of socio-economic driving forces and their interactions with the ecosystems. As species and communities have their niches in the ecological multidimensional spaces (Feoli et al.1988), land use types have their "niches" in LEMS. Land use type niches may be partially or completely represented in a matrix **X** where the set of OGUs (Operational Geographic Unit), in which the landscape is subdivided for a study (cells of grids, polygons of different shape or circles, exagons, Thiessen polygons, etc.) are described by a set of landscape variables (Feoli & Zuccarello 1996). With the help of GIS technology (Aronoff 1989; Burrough 1986; Malczewski 1999) it is easy to describe the OGU in terms of spatial variables and other variables stored in data bases. In the space generated by matrix **X** each variable has a number of co-ordinates equal to the number of OGUs and each OGU has a number of co-ordinates equal to the variables that are describing it, however the dimensionality of the space represented by **X** is equal to the number of positive eigenvalues of **X**. Variables and OGUs may be seen as vectors with a common origin, namely the origin of LEMS. Furthermore, it should be always kept in mind that **X** is a data matrix that may represent only partially the complex system of the chosen landscape because only the variables of interest are taken into consideration.

3. Suitability maps

The suitability maps of the land use types may be used to identify the niches of land use types in the landscape since they are obtained by weighting the variables in **X** in such a way that the OGUs most suitable for the land use types are identified. One of the simplest and most common formula that is used to identify the suitable OGUs for a given land use is:

$$S_{jk} = \Sigma_i w_i x_i \qquad (1)$$

where S_{jk} = suitability of OGU j-th to land use type k-th, w_i = weight given to variable *i*-th, x_i = score of variable *i*-th. Considering formula (1) under the perspective of LEMS described by matrix **X** (matrix algebra perspective), we can say that S_{jk} is the scalar product between the vector W_k and the vector X_j. When W_k and X_j are normalized, S_{jk} is the cosine between the two vectors. It ranges between 0 and 1. It is 1 when the scores of X_j have the same behaviour of the "weights" in W_k: low scores in X_j low weights in W_k and high scores in X_j high weights in W_k. Under this perspective the vector of the weights (W_k) may be interpreted as the reference vector representing the ideal most suitable situation to host a given land use type, in other word the "core" of its niche. S_{jk} is just a measure of similarity of OGU j-th with the vector W_k describing the importance (weights) of the variables in **X** in defining the suitability of the OGUs in **X** for land use type k-th.

The OGUs with high S may be interpreted as the geographical sites where a given land use type may have the best "performance" with respect to the complex gradients of the landscape. We prefer to use the term "performance" rather than response used for species and communities (Biondi et al. 2004), because a land use type is not only an ecological entity that may have a high or low response, but it is a socio-economic-ecological entity that may have a good or bad performance with respect to three perspectives: social, economical and environmental. It may well happen that a good performance with respect to economy would be very bad for environment and vice-versa. To have optimal performances for all the three perspectives would be difficult or even impossible, at least when short terms are considered; may be if the performance would be evaluated with respect long terms, as sustainable development is requiring, a choice would be good for the three perspectives.

Since the vector of the weight is the reference vector to estimate the suitability of the site described by the Xj vectors, the suitability maps obtained for each land use types, are similarity maps showing the similarity of the OGUs with the vector representing the most suitable site for a given land use.

The selection of the criteria on which the suitability maps are based is arbitrary and the decision will depend on them. It is for this reason that Malczewski (1999) describes the problems solved with Spatial Decision Support Systems (SDSS) as semi-structured problems. They are based on a first step that is completely in the hands of the involved stakeholders and decision makers: the definition of criteria (variables in **X**) on which to base the decision, and a second step that is completely and univocally solved by the computer: ranking the alternatives. In the context of SDSS each OGU is a possible alternative or a component of an alternative. The criteria (variables) are of two kinds: factors influencing the decision and constraints that exclude OGUs from any decision. Therefore formula (1) becomes as following:

$$S_{jk} = \Sigma_i w_i x_i \Pi_h C_h \qquad (2)$$

where C_h represents the constraint for which the land use type k would be impossible to be located in the j-th OGU.

S_{jk} can range between 0 to a certain number depending on the scale of values of w and x, however it can be scaled easily between 0 and 1. For each land use type a suitability map can be obtained. The same OGU may be suitable for different land use types, conflicts between different land uses may arise that can be solved with cost benefit analysis or other techniques (Janssen & Herwijnen 1994; Eastman 1999), however for the aim of this paper we are only interested if a land use type is located in a suitable site and what is the degree of suitability of the site.

4. Order and chaos in landscape

The concept of order refers to the spatial and/or temporal assessment of sets of elements (and/or events): if the elements of one set are in the right spatial and/or temporal position then the set is ordered. On the contrary a set of elements shows a chaotic situation. As the species and ecological communities have their niche in the ecological space and within the niche their optimal position, all the land use types have their niches and optimal position in LEMS. The suitability maps are showing the spatial distribution of the land use types niches in the landscape. Accordingly if the spatial pattern of land use types fits the distribution of the optimal position of land use types in the LEMS, the landscape is ordered otherwise it is more or less chaotic. Many can be the consequences of a chaotic situation for example: erosion, slides, floods, extra energy consumption etc.

For planning sustainable development we think it is useful to suggest a function to measure the order of the land use types in the landscape and to suggest to policy makers to develop policies that should maximize such a function. To measure the order of landscape we propose the following functions:

$$O(L) = (\Sigma_k P_k A_k)/\Sigma_k A_k \, (k = 1, ..., N) \qquad (3)$$

where A_k is the area or number of OGUs of land use type k-th, N is the total number of land use types in the landscape,

$$P_k = \Sigma_j S_{jk} a_{jk} / A_k \quad (j = 1, ..., s) \qquad (4)$$

a_{jk} is the area or number of OGUs with S_{jk} suitability value to land use k-th (S_{jk} is ranging between 0 and 1), s is the number of suitability classes in which the suitability values calculated with formula (2) have been grouped, Σa_{jk} is the area or number of OGUs of k-th land use type. P_k is the weighted average suitability of each k-th land use in the landscape and it is a measure of order within the land use type. $O(L)$ is the weighted average suitability of the k land use types, it ranges between 0 and 1, 0 representing the full chaos, 1 representing the full order. If the area of each land use has to be kept fixed, i.e. the economy of the area requires a certain proportion between the k land uses, then the order can be calculated by:

$$O(L) = (\Sigma_k P_k)/N \quad (5)$$

because the value does not need to be weighted according to the area of each land use type.

The values P_k are obtained by overlapping the maps of the actual distribution of k land use types with the corresponding suitability maps. For doing this a GIS is almost indispensable.

5. Two cases studies

We want to present in this section the application of the formulas (3) and (4) to two case studies in which the suitability maps are used to plan sustainable development. One is located in the district of Adwa (Tigray, Ethiopia), the main problem of the area is soil erosion. One is located in Bahia (Brazil), where the main problem is a socio-economical issue related to the crisis of cocoa.

The case of ADWA district (Tigray, Ethiopia)

The Adwa district is one of the most degraded area of Tigray. Description of the area can be found in Egziabher et al. (1998), Feoli et al. (1995, 2002), Altobelli et al. (2001), Zerihun and Feoli (2001).

A Multi-Objective (MO) oriented SDSS based on Multi-Criteria Decision Analysis (MCDA) was developed among the many possible methods and techniques of SDSS (Rosenthal 1985; Malczewski 1999) by Dragan et al. (2003). The SDSS was constructed with the Decision Support modules available in IDRISI 32 (release 2) for Windows (Eastman 1999), that is a widespread, friendly and affordable GIS software tool. The area taken into consideration was equal to 5,030 ha. The average soil erosion rate for the area was estimated in 4.5 t ha^{-1} yr^{-1}. In this area only the crops with actual erosion higher then 1 t ha^{-1} yr^{-1} have been considered.

In order to reduce the soil erosion without reducing the crop area (i.e. leaving the same proportions between the k land uses) three specific and consecutive objectives were identified:

1. Crop reallocation in croplands to reduce the actual soil erosion below the threshold of 1 t ha^{-1} yr^{-1}, and identification of areas not suitable for cropping from where crops have to be removed.
2. Identification of non-cropped areas suitable to host the crops removed in objective 1.
3. Identification, in the whole Adwa district, of areas of high actual erosion where the only feasible protective measure could be enclosure and/or terracing.

To achieve the first two objectives the modules MCE (Multi Criteria Evaluation) and MOLA (Multi Objective Land Allocation) of IDRISI were applied.

The weights of the factors were obtained by the pairwise comparison method according to the Analytic Hierarchy Process (AHP) proposed by Saaty (1977, 1999). In the pairwise comparison the decision makers evaluate the relative importance of each factor in determining the suitability of OGUs for a specific crop. In this case study a raster based approach is taken and the OGUs are the individual pixels. The comparisons are based on a scale with values from 1/9 to 9 and written in a square reciprocal matrix (Saaty matrix). Several pairwise comparison Saaty matrices were generated using the information obtained through interaction with stakeholders (decision-makers, users and researchers). The final set of weights was the one corresponding to the Saaty's matrix with the highest consistency (see Saaty 1999). MCE was applied on the basis of the following criteria: potential erosion, altitude, proximity to croplands, proximity to water, proximity to the crop of the same type, proximity to roads.

The MOLA is used for solving multi-objective land allocation problems for cases with conflicting objectives. In our case conflict arises when a pixel has the same suitability for two or more crops. MOLA seeks for a compromise solution using the set of suitability maps (from MCE), one for each crop, a relative weight and the amount of area to be assigned to each crop type.

The third objective, namely identification of areas for enclosures and terracing, was achieved, according to objective 1, by considering the pixels not suitable for cropping and the pixels of non cropped areas with actual erosion above the threshold of risk (1t ha^{-1} yr^{-1}). The detailed description of the application is given by Dragan et al. (2003). Here we present in table 1 the summary of the steps that have been followed in order to limit the soil erosion by keeping constant the crop area according to the three objectives for which the SDSS has been applied.

The application of SDSS as in table 1, would allow a significant reduction of soil loss from an average of 4.53 t ha^{-1}yr^{-1} to 0.53 t ha^{-1}yr^{-1} . The order of the landscape, according to formula (5), before and after the application of the results of the SDSS is respectively 0.25 and 0.71. It is calculated on the basis of the data in table 1 rearranged and presented in table 2. This table shows the suitable areas and the unsuitable areas for crop and for the open woodland and natural areas. From these results it is evident that a remarkable increment of the order in the landscape would strongly reduce the soil loss by erosion.

Table 1. Steps followed with a Spatial Decision Support System to reduce the soil erosion in a pilot study area of the Adwa district

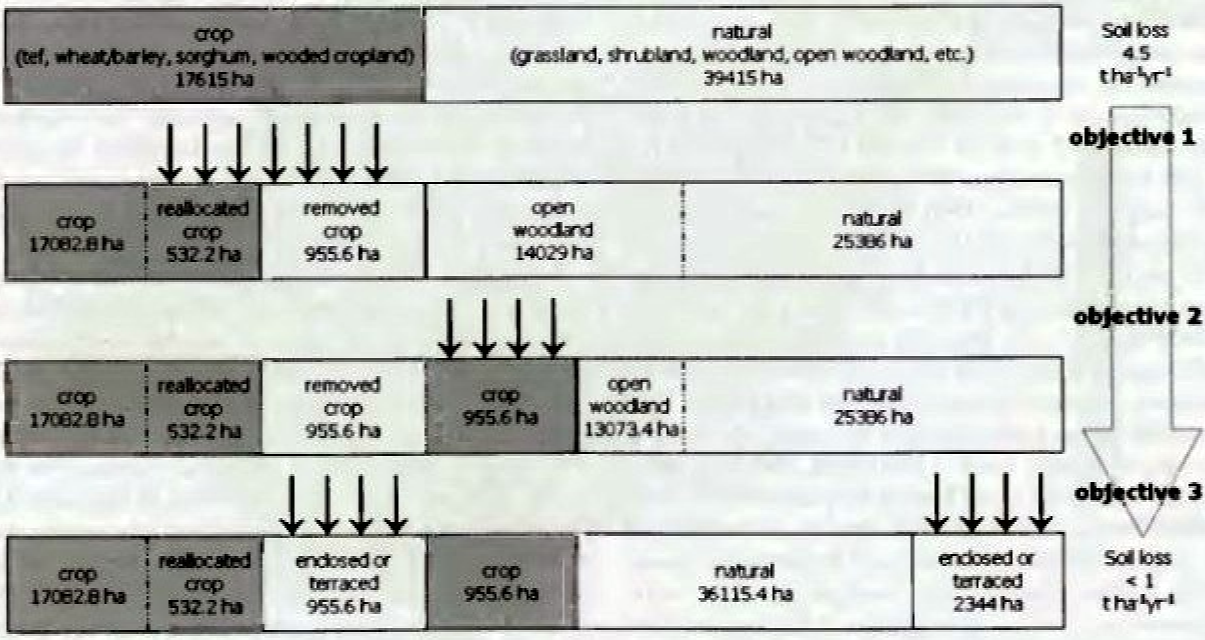

Table 2. Data obtained from Table 1 and from the suitability maps obtained with the GIS included in the SDSS used to reduce soil erosion in the pilot study area of Adwa district. The average suitability for each land use is obtained with formula (4). The *O(L)* calculated with formula 3 is 0.25 for the situation before the changes, it is 0.71 after the changes, see the text for explanations

Cropped area with soil erosion less than 1t $ha^{-1}yr^{-1}$ 1,6127.2 ha	**Cropped area to be reallocated 532.2 ha**	**Area of crops to be removed 955.6 ha**	**Open woodland suitable for crops 955.6 ha**	**Open woodland and natural areas 36,115.4 ha**	**Degraded natural areas 2,344 ha**
average suitability for crop 0.60	average suitability for crop 0.00	average suitability for crop 0.00	average suitability of the area to remain natural area in the specific circumstances 0.00	average suitability to remain as it is 0.60	average suitability to remain as natural area 0.30
Crop with soil erosion less than 1t $ha^{-1}yr^{-1}$ 16,127.2 ha	**Reallocated cropped area 532.2 ha**	**Area enclosed or terraced 955.6 ha**	**Cropped area 955.6 ha**	**Open woodland and natural areas 36,115.4 ha**	**Degraded natural areas enclosed or terraced 2,344 ha**
average suitability for crop 0.60	average suitability 0.65	average suitability 0.90	average suitability 0.70	average suitability 0.60	average suitability 0.80

The case of Cachoeira catchment area (Bahia, Brazil)

From the beginning of the last century the economy of Bahia was based on the cultivation of cocoa (cacao). In the sixties the Brazilian government developed policies to support the cultivations in South Bahia that became the second producer of the world after Ivory Coast. However from 1986 to 1992 the price of cocoa fell down from 2,500 to 1,000 US$ per ton, provoking the economical crisis of Bahia (Alger & Caldas 1996). The land owners fired the majority of the workers in the cocoa plantations and started to cut the trees of the forest hosting the plantations (cabruca) notwithstanding the Brazilian law was forbidding the deforestation of the area. The crisis of cocoa increased in 1989 when the pest *Crinipellis perniciosa* (a fungus from Amazonas) infested the plantations. The land owners fired the majority of the workers because the production of cocoa was reduced in many cases of about 95%, and they started to cut the trees of the forest hosting the plantations (Cacau-cabruca). In many cases the cocoa farms were transformed into rangeland farms where the most important economic activity is cattle breeding. The consequences of the cocoa crisis were two. One was the migration of the families of the cocoa workers to urban areas with all the socio-economic implications related to the new settlements, mainly slums (favelas). The second was the deforestation of Cacau-cabruca with the unavoidable impact on water cycle, soil protection and biodiversity conservation. However today there are the conditions to reverse the tendency because the price of cocoa is growing again and because the pest seems under control. As a consequence of this new situation it is very important to evaluate the possibility of reintroducing the cocoa plantations in an agro-forestry context for reversing the migration of people towards the urban areas and to protect the biodiversity of the forest (Mata Atlantica). This because the agro-forestry system that could be originated with the cocoa plantations within the natural forests (Cacau-cabruca) in a process of natural secondary succession or by artificial plantations, beside being again a good economic resource, would constitute very useful ecological corridors connecting the patches of the primary forest. The ECOMAN project was dedicated to develop a Spatial Decision Support System to analyse and support the possibility of cocoa reintroduction in an integrated perspective of agro-forestry development. Of the three main towns Ilhéus, Itabuna and Itapetinga only the one most related to the economy of cocoa, namely Ilheus was decreasing its population from 1991 to 2000. The decrement of population in the country side was of 14,381 people, while the increment of Itabuna and Itapetinga was of 15,853 people. This increment is not very large, however the analysis of the households in urban areas according to the Census of 2000 (IBGE 2002) shows that the urban-periurban areas of the most crowded municipalities (Itabuna and Ilhéus) are those with the worst public infrastructures with very bad conditions of the great part of the slums. Owing to the low rate of population growth it is obvious that people are migrating towards the big cities such as Salvador, Rio de Janeiro and Sao Paulo. As an indication of the tendency that the land is left uncultivated and the forest still exploited, we can see the increment of the spontaneous reforestation (capoeira), the decrement of forest (Mata Atlantica) and the decrement of pasture (see table 3). According to this trend we propose that the implementation of Cacau-cabruca in the less suitable areas for pasture and more suitable for Cacau-cabruca, would be a good action towards sustainable development of the area. In order to suggest the implementation of Cacau-cabruca the suitability maps for pasture and for Cacau-cabruca have been obtained by the multicritera evaluation (MCE). As in the previous case study the following criteria have been compared: slope, elevation, distance from road and urban area, potential erosion and actual erosion. The suitability maps are presented respectively in fig.1 and 2. If we consider only the landscape relative to the pasture, with an area of 276,985 ha, it has, according to formula (4) and table 4 an order value of 0.51. It is remarkable that the 28% of this area covers areas prone to soil erosion that are not suitable for grazing. If the area of pasture would be used all for Cacau-cabruca the order of the landscape according to table 4 would be 0.62. From the suitability maps of fig. 1 and 2 we can see that almost all of the area unsuitable for pasture is suitable for Cacao-cabruca, so if Cacau-cabruca is implemented in the 47,943 ha of pasture with very high suitability for it, the order of the landscape would improve, according to table 5, and formula (3) to 0.67. The positive consequences of this increment of order would be the reduction of soil erosion risk and the possibility to develop ecological corridors among the forest patches. As far as the social aspects, the increment of Cacau-cabruca areas would be positive both for the farmers that were used to breed cocoa and for the population living in the slums because many people will find again the job in the cocoa plantations.

5. Discussion and conclusion

In this paper our approach to measure the order and chaos of landscape, is very direct, simple and concrete. It is based on three real case studies relevant for working on sustainable development in line with the work of Nijkamp and Hermanides (1998). We wanted to avoid philosophical discussions about the order of nature for which we refer the reader to the book of Marshall (2002) and references therein. In our approach we are considering the land use as the most important expression of the economic human activities in landscapes. By definition land use is the way in

Figure 1. Suitability map for Cacau-cabruca in the Cachoeira catchment (Bahia, Brazil)

which land is used, not only in farming and city planning, but also in natural parks, reserves and protected areas in general. We cannot forget that man is using the land and its resources for his life in a way that depends on his culture. As a matter of fact the "ecological footprint", namely the area of biosphere necessary to support man in all its activities, is directly related to his living style and therefore to his culture (Wackernagel & Rees 1993, 1996). Therefore, the plans and actions for sustainable development should be directed to reduce the ecological footprint. In this paper we have presented a simple method to calculate the order of land use in landscape on the basis of suitability maps as produced in Spatial Decision Support Systems. We think that improving the order of land use in landscape could be one of the important aims directed to reduce the ecological footprint and therefore to increase the sustainability. We also do not want to enter in the discussion about sustainability, for which we send the reader to the immense literature that he can found very easily in internet. Here we want to address a discussion on the question if the suitability maps of land use as those obtained in SDSS are appropriate tools to measure the order of the landscape and if the measured order can be useful to reconsider the land use pattern in the landscapes.

The functions we are proposing with formulas (3), (4) and (5) have been applied to two different case studies. In the first, the order is calculated before and after the possible rearrangement of crops and natural areas in such a way to reduce the soil erosion by letting the area for crops unchanged. Formula (4) was applied to calculate the order (weighted average suitability) within the land use types, while formula (5) was applied to calculate the order (average suitability) of the landscape according to the land use types. In this case the increment of order in the situation suggested by multi-criteria evaluation, calculated with the formula that gives the un-weighted average suitability (formula 5), was high and the effect foreseen to the reduction of soil erosion was also relevant. The comparison of the actual order with the one that would be obtained according to suitability maps is suggesting that the situation is far from an optimal situation as calculated with multi-criteria evaluation, the divergence being equal to 0.46, i.e. 46%. On the basis of this result we can conclude that the actual chaotic situation is responsible of soil loss by erosion more than 8 times higher than that corresponding to the rearranged land use. The second case study is dealing with the reintroduction of Cacau-cabruca in an area that was transformed from "forest" to pasture. The order was calculated only for the landscape defined by pastures. The results prove that according to the criteria chosen and the weights given to them the coexistence of pastures with Cacau-cabruca would be a good choice to improve the order of landscape and the

Figure 2. Suitability map for pasture in the Cachoeira catchment (Bahia, Brazil)

sustainability of the area since the performance of the land use would improve both from socio-economical and environmental points of view.

These examples show that suitability maps obtained with Spatial Decision Support Systems (SDSS) may constitute meaningful alternatives to compare actual spatial pattern of land use. Suitability maps may be used as reference maps in order to measure how much a landscape situation is diverging from an optimal one based on specific criteria. If these are sustainability criteria the divergence measures how much land use maps are diverging from a sustainable situation.

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Table 3. Land use/cover changes in the Cachoeira catchement from 1975 (75) to 2001 (01)

Land Use - Area (ha)						
	Capoeira75	Cocoa75	Mata75	Pasture75	Urban area75	TOTAL
Capoeira01	3,896.55	9,189.81	4,839.39	23,150.7	12.06	41,088.51
Cocoa01	8,600.94	29,539.98	8,483.49	20,741.4	10.53	67,376.34
Mata01	2,604.96	8,373.33	5,964.66	12,536.1	10.89	29,489.94
Pasture01	10,667.16	15,653.88	24,510.33	225,766.35	387.18	276,984.9
Urban area01	60.75	69.39	1.98	589.59	1,060.47	1,782.18
TOTAL	25,830.36	62,826.39	43,799.85	282,784.14	1,481.13	416,721.87

Table 4. Distribution of suitability values for pasture and Cacau-cabruca in the area covered by pasture. According to formula (4) the order of the landscape with pasture is 0.51, while the order in case Cacau-cabruca would substitute the pasture would be 0.62

Suitability for Pasture	(ha)	(%)
Very low (0.10)	78,379	28.30
Low (0.25)	45,060	16.27
Medium (0.60)	33,398	12.06
High (0.75)	24,461	8.83
Very high (0.90)	95,686	34.55
Total	276,985	100.00

Suitability for Cacau-cabruca	(ha)	(%)
Very low (0.10)	6,591	2.38
Low (0.25)	15,008	5.42
Medium (0.60)	137,934	49.80
High (0.75)	69,509	25.09
Very high (0.90)	47,943	17.31
Totals	276,985	100.00

Table 5. Distribution of suitability values for pasture and for Cacau-cabruca in one hypothesis of changing land use/cover for getting a more ordered landscape. The order of the landscape when the low suitability area for pasture will be used for Cacau-cabruca will be 0.67

Suitability for Pasture	Pasture (ha)	Suitability for Cacau-cabruca	Cacau-cabruca (ha)
Very low (0.10)	30,436	very high 0.90	47,943
Low (0.25)	45,060		
Medium (0.60)	33,398		
High (0.75)	24,461		
Very high (0.90)	95,686		
Pasture + Cacau-cabruca			276,985

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