Conceptual and Operational Needs in Land Evaluation for Sustainability in Venezuela

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1. Introduction

During the last 7 years, different schemes of Land Evaluation suggested by F.A.O. (6, 7, 8) have been applied in Venezuela to different geographical regions and with different objectives. In most cases, agricultural production under rainfed and irrigated coditions, forest , rangeland and environmental protection uses have been considered alone or simultaneously for the same areas(12, 13, 14). The general impression is that they represent an important and appropiate tool to analyze land use options under agroecological and economical considerations. The main difficulties are related to the limited amount of information and criteria to evaluate many land use requirements and to qualify many land qualities, but at the same time this situation has encouraged specific lines of research that have solved, partially or completely, some of the problems. Examples are, in special, those of local or regional nature like: erodability and tolerance to erosion in highly weathered soils, impact of red ants in different land uses (12), sealing of silty tropical aluvial soils(14), etc.

Nevertheless, when we analyze in a more systematic way how well are these schemes taking into consideration the new paradigma of land management sustainability (9), certain aspects may be considered insufficiently accounted.

2. The Five Pillars of Sustainability

According to the most recent concepts expressed on this subject, and also related to land management (9), the five most important aspects in Sustainability should be: maintenance or enhancement of productivity, economic viability, social acceptability, risk aversion, and protection of natural resources.

How well are these aspects considered in the F.A.O. schemes of Land Evaluation? Our general answer, according to the above mentioned experiences of their application is:

1. Productivity is fairly well taken into consideration, as, by methodology, yields always have to be predicted, but, specially for short cycle crops , there is no emphasis on the long term view of the yields; other is the case of permanent crops or rangeland. An improvement is fairly easy to implement.

2. Economic viability is also considered, when an economic land evaluation is complementary to the physical evaluation; nevertheless, the type of economic or financial criteria used influences very much whether a long or short term of the viability is stressed. Cash flow sytems of a long term, even for short cycled crops, and criteria, like local or regional satisfactory family incomes for periods of several years, seem more in line with the concepts of sustainable systems

3. Social acceptability, to our understanding, is being preliminarily considered when we select pertinent land use types in the process of evaluation. Nevertheless, we could also evaluate how far land uses that have resulted as suitable for large areas, fit into the cultural, economic pattern and aspirations of the major part of the population that is settled in that area under evaluation. This exercise could improve the consideration of this sustainability factor in the present schemes.

4. Risk aversion, seems highly related to the selection of land use types which are capable of maintaining a productivity and an economic viability under different conditions like: changes in the prize of inputs, significant changes in weather, etc. A sensitivity analysis could help for a better consideration of this aspect.

5. Protection of Natural Resources is rather well considered but mostly in the resource Soils. Other resources like fauna, and specially water, seem insuficiently considered. These, could be said that were supposedly considered in the general environmental impact assessment that is requested at the end of the evaluation, but to our viewpoint, other treatment has to be provided, specially with the strategic importance that water is getting in many places of the world.

In summary, even though all pillars are considered in the present schemes, it is needed to complement the concepts, and add some more operations, to assure that sustainable management of the land is well taken into account.

Now, we would like to briefly discuss two ideas, which from our experience merit further work. They are, firstly, a concept related to the sustainability of Natural Resources, in this case on the resource WATER. Secondly, an operational factor affecting the “trust“ of the predictions and consequently influences all pillards, in this case the consideration of spatial VARIABILITY in land evaluation.

3. Is There Merit for a Water Unit?

For many countries, Venezuela is one of them, water resources are becoming critical for agricultural use, energy sources, industrial operations, and most important, for domestic consumption. It is a matter of quantitty as well as quality. Some people predict that future wars may be related to this resource. An adequate system to appraise this resource seems an obvious conclusion.

When we have applied the F.A.O. land evaluation schemes to watersheds in which the production of water is, at least, part of the objective, many questions arose in relation to how do we treat the resource water, and especially surface water. Is it part of the definition of land as defined in F.A.O.? Is there merit to separate different sectors of the water course , and treat them as different bodies? Could we characterize and map them? What would be the use of such bodies? Would it be similar to the use of land units? Could water be also considered as a type of Use? For domestic consumption, irrigation, etc, are they water utilization types?

From our analysis, hydrology as a general concept is included in the definition given by F.A.O. to land (5). In this case we think it refers to availability of water to make feasible a given land use type that requires irrigation. But, when doing land evaluation, in Venezuela or in other countries, and as far as we know, water segments have not been separated as different land units. Nevertheless, especially in watersheds that include different reliefs, climates, and ecological zones, there are definitely different sectors of the watercourse that will have different characteristics and different responses to natural or anthropic activities affecting them. Those characteristics can be physical, chemical, biological as well as geographical, and justify, intrinsically and in our view, the establishment of water units.

The consideration of water as a physical unit may bring doubts, mostly related to the establishment of geographical units, as evidently they would be more gradual than in most soil limits, but also, evidently, less gradual than boundaries. This does not seem an unsurmountable problem, specially considering techniques like GIS and interpolation methods. In relation to its side limits, there seems to be fewer problems, although the limits in many cases would vary with time, that is with high and low stream levels.

In relation to characteristics that may serve to identify each water unit we suggest the following preliminary list:

- Physical, like average: yearly and seasonal temperature, speed, turbulence; type of stream channel; yearly flow regime; sediment content; etc.
- Chemical, like: average yearly and seasonal salt content and its predominant kind, type and content of inorganic pollutants; pH; etc.
- Biological, like: avereage yearly and seasonal organic matter content; type and content of organic pollutants; type and content of microorganisms; etc.
- Geographical, like: distance to source of sediments, to pollutants, etc.

In a similar way, as with land, there would be some water qualities, that integrate a group of water characteristics, and that allow a better analysis of interactions with uses or an analysis of impacts. Some of these qualities may be: Oxigenation capacity; potability of the water; erodability of the channel; buffer capacity; biological demand of oxigen; etc.

In relation to the question on the possible use of the proposed water units, we suggest that it would depend very much on the type and objective of the evaluation. If it is concentrated on land uses that do not give much importance to water uses, then the water bodies could be useful to improve the analysis of environmental impact assessment. Because, after their definition of bodies with different chacteristics, we can better assess their capacity to receive and respond to impacts. In other cases, when water is an important aspect of the evaluation, like the case of water production for domestic or agricultural uses, then it could be considered more like an utylization type, creating specific requirements against which, the characteristics of the different water bodies could be match. Finally, a full use could be played, when water utilization types like trout or other different kind of fishes, alligators or capibarras, are going to be evaluated in different water bodies. In this last case, the same schemes as the ones available could be applied.

No doubt, further work on this subject is needed with special participation of specialists in the area of water resources.

4. Considerations of Soil Variability in Land Evaluation

Variability in Natural Resources, used in Land Evaluation, is a well-known fact for any one who has done such studies. Nevertheless, in F.A.O schemes (7), the main resource in which attention is paid to this factor is variability in time of climate and its effects upon crops, management practices, etc. But, climate is just one of the elements necessary to build up Land Units. Soil is another important resource, and its spatial variability is well documented (1, 3); methods to characterize and handle it have been devised, with special emphasis on the construction of Soil Cartographic Units (16). Both variabilities will then be incorporated into the variability of the Land Units that will be subjected to Land Evaluation.

The problem is that such variability is not generally incorporated into the suitability of a given land use for a given land unit , and consequently the risk involved in producing an uncertain prediction is not presented to the user. This situation evidently will affect the quality of the evaluation as well as the sustainability of the recommended use.

There are several possible situations and associated solutions:

1. When confronted with the situation of having a soil survey already made, and when there is no chance of doing additional soil characterizations, then the only possibility is to apply the land evaluation criteria to each soil observation that we find in the cartographic unit. In most cases, it will only be representative pedons of those cartographic units and/or soil augers that have sufficient information to do the evaluation. In those cases, showing the proportion (%) of each suitability class in that unit will be possible. This is better than showing only the predominant class. This kind of procedure has been applied in some studies (12) in Venezuela but using, as interpretative system, adaptations of the USDA eight classes (4); this information, has also has been useful in the process of soil correlation and construction of cartographic units.

The main problems with this kind of procedure is that it carries several uncertainties which are not declared, such as:

- the pedons may not come from the delineation we are evaluating
- the augers generally will not have enough information to do a complete evaluation
- the sampling process is generally spatially biased, because the general trend is to sample near the limits of soil boundaries and/or in the most typical phisiographic site
- as generally there is not enough number of samples, it will be difficult to do an statistical analysis, and consequently there is no error associated to the prediccion.

2. If we want to quantify the risk of prediction of land evaluation units and we are going to do additional sampling, then we suggest the two following approaches:

- The use of Transects. In this case what is proposed it to use a simple adaptation of the method developed by Johnson (10) to determine the composition of cartographic units. This has been used and readapted by several authors (2,15).

In this case, as shown in Fig 1, we select a given land evaluation unit in which we have interest in quantifiyng the risk of prediction, and we draw transects in the direction of maximum variability. We then select at random a number of transects, depending on to the maximun error that we want to allow. In each transect we will select 10 equally spaced sites in which we do the specific land evaluation and obtain the suitability class for each point. These results can be organized in a way as shown in Table 1, and using t distribution and a level of probability selected, for instance 90%, we can calculate the proportion of each class and its confidence limits.

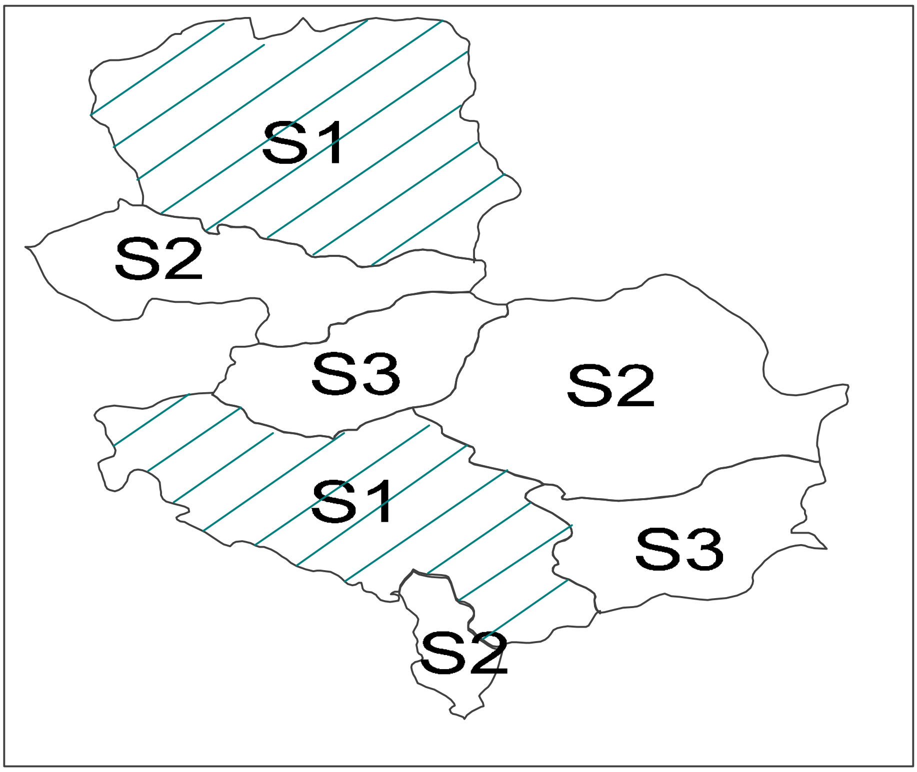


Figure 1. A land evaluation unit showing transect lines.

The main disadvantage of this method is that, eventhough we know the risk of prediction of that unit, we do not know where does it occur within it.

- The use of Indicator Kriging. This is a type of non-parametric kriging in which the data of proportion, interval, ordinal, or nominal are transformed into a boolean algebra, to be subjected to a geostatistical analysis and interpolation by kriging (11). This approach can be used for two different situations: for land evaluation delineation or for the whole study area.

As shown in Fig 2, we select a given land evaluation delineation (2a) in which we will do a systematic sampling, in the order of 50 to 60 points (2b), and obtain the land evaluation class for each point. For the ones that coincide with the suitability of the delineation will assign a value of 1, for the others a value of 0. With the transformed data will do a geostatistical analysis and indicator kriging, obtaining a map showing the geographical distribution of the probability of ocurrence of the suitability class (2c).

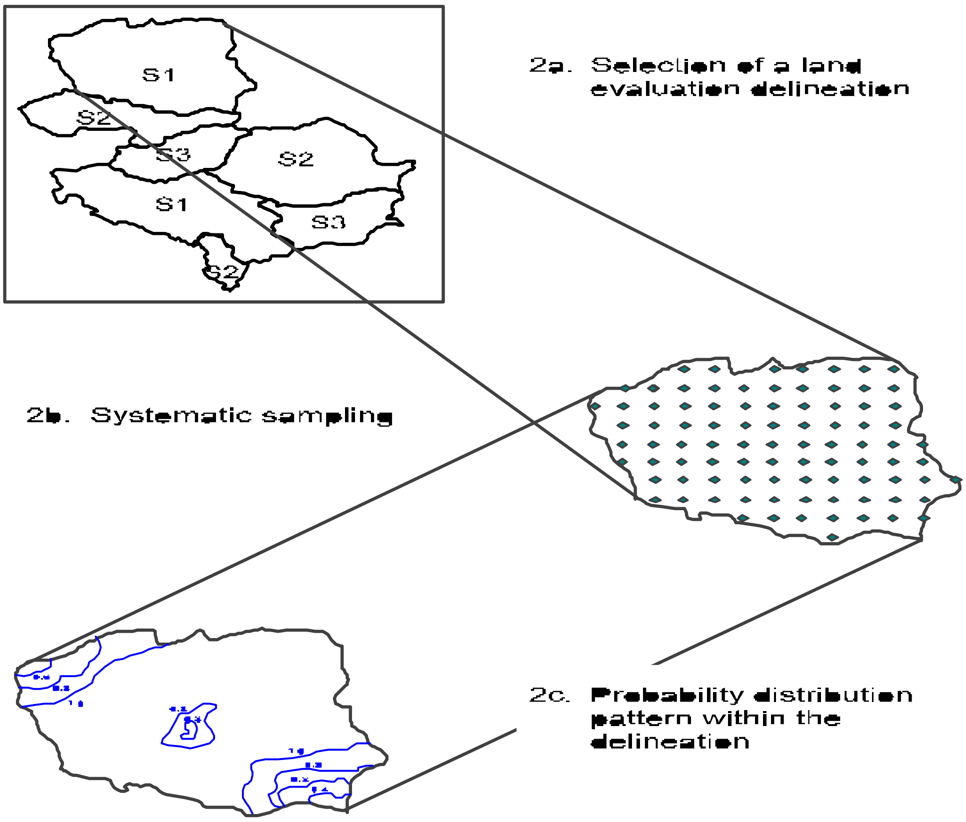
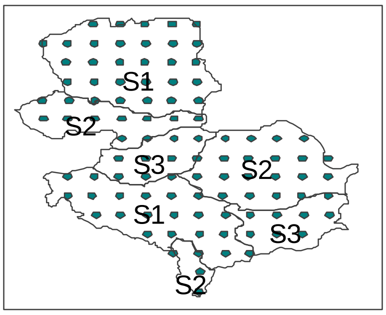


Figure 2. Example of the indicator kriging for a selected land evaluation delineation.

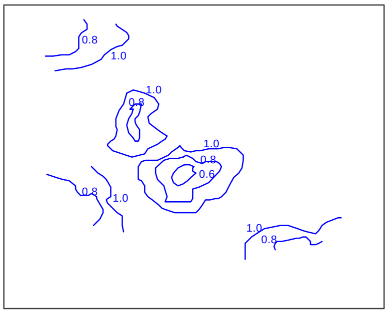
The case of its application to the whole area of study is shown in Fig 3. Again, a systematic sampling is done, superimposing a net that contains around 80 points to the whole area, independently of scale (3a). We then obtain the suitability class for each point, and check if it coincides with the suitability of the delineation where it belongs, in that case we value it 1, if not 0. With the transformed data, will do a geostatistical analysis and indicator kriging, obtaining a map showing the geographical distribution of the probability of the accuracy of the whole land evaluation map (3b). Through the use of GIS, we can superimpose the probability map on the land evaluation map, and obtain a geographical distribution of the risk of prediction for the whole area (3c).

In summary, the transect will tell us the proportion of classes that a given land evaluation unit will have, but we do not know where these classes occur. On the contrary, the indicator kriging will give the geographical distribution of the probabilities of a given class, but will not tell us about the kind and proportion of the other classes of suitability present in the land evaluation unit. In relation to the effort associated with sampling, the transect as well as the indicator kriging applied to a delineation will be much larger than the case of indicator kriging for the whole area.

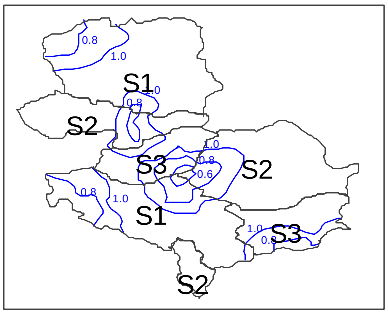
In conclusion, depending on the case and objective we will select one of these methods to express more precisely our predictions and improve the sustainability of the user.



3a. Systematic sampling



3b.Geographical distribution of probability



3c. Geographical distribution of the risk of prediction

Figure 3. Example of the use of indicator kriging for the whole study.

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