A NEGOTIATION AID SYSTEM FOR THE DEVELOPMENT OF DISTRIBUTED RENEWABLE GENERATION

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Abstract – This paper describes the concepts behind a Negotiation Aid System, developed over a GIS (Geographic Information System) and designed to facilitate reaching compromises among agents such as investors, environmental groups and governmental agencies, when deciding the location and sizing of new renewable energy sources in a region. The concepts are based on the definition of preferences and levels of acceptability by each agent. A fuzzy set model is then built and an outranking method employed to define geographical places of less conflict among the interest groups. An application to the region of La Rioja, in Spain, is described.

Keywords: New Renewable Energies, Decision Aid, Negotiation Aid, Fuzzy Sets, Geographical Information Systems

1. INTRODUCTION

The development of distributed generation is conditioned, especially in developed countries such as in the European Union, by a number of constraints that limit the success of incentives granted by global and local administration, aimed at increasing the penetration of renewables in the generation portfolio of each country or region.

These incentives have several forms, from subsidies to the construction of new generation facilities to guaranteed "green" prices and tariffs for energy from renewables. Therefore, investors place a heavy pressure in searching for places where to build new renewable plants and where to connect them to the grid with the purpose of selling energy.

One source of constraints to this kind of investment derives from supra-national, national or local regulations, creating protected zones, natural or national parks, areas of protected bio-diversity or ecological protected areas, besides zones close to buildings, airports, etc. or related with the military or possibility of radar confusion.

Another source of constraints derives from the opposition of environmental organizations, which sometimes develop a winding reasoning and object to renewables locally while at national level continue to claim for their use. Therefore, Government Energy Directorates or Energy Agencies need to have at hand a comprehensive methodology to try to conciliate the interests of different agents (investors, environmentalists, state agents) in order to organize regional plans for the development of distributed renewable generation. [1]

This paper presents one Negotiation Aid platform for such purpose [2][3][4]. It is built over a GIS – Geographical Information System[5], and it allows the identification, over a map of a region, of the zones or areas where the conflicting interests of several actors may best be conciliated. In order to reach such compromise sets of emplacements for distributed renewable generation, the criteria for each actor are identified and their relative importance is ranked. These criteria may range from costs or expected energy generated to land occupation or bird disturbing.

This ranking allows one to determine, for each type of actor and land area, the level of interest or opposition to its use for generation. Then, a combination of the preferences and rankings of each actor finally allows one to determine the location of compromise geographical areas and to rank them according to the strength of compromise achieved. All these manipulations of criteria and ranking scales are carried out adopting a linguistic model of expressing variables and declarations and by applying fuzzy set operators to such variables.

The work described has been applied in a joint project developed for the region of La Rioja, Spain, by INESC Porto and the University of La Rioja, and some results are displayed in the paper, under the form of maps and graphs.

2. BUILDING THE CONCEPT

A Negotiation Aid System (NAS) is different from a Decision Aid System (DAS) in the following basic aspects:

- a NAS targets a set of agents or Actors, instead of a single Decision Maker, as in the case of a DAS
- in a NAS, each Actor defines his own interests and objectives and measures alternatives based on attributes and criteria, independently of the attitude of the other agents
- the criteria adopted by an Actor are not necessarily the same nor in the same number as the criteria adopted by any other agent.

This means that one cannot directly transport for a NAS environment the techniques usually employed in DAS where a single Decision Maker is present. For instance, if the actors do not share the same criteria, it is not possible to define a set of alternatives with the property of Pareto Optimality.

In order to build a NAS, we have therefore proceeded to take two successive steps: 1) to develop a model for each Actor; and 2) to apply a model for the interaction among actors.

3. MODEL FOR AN INDIVIDUAL ACTOR

3.1. General model

In order to be able to establish communication among actors, we need to pass from a level where criteria are explicit to a level where preferences are expressed, regardless of the criteria.

We need therefore to take in account the preferences of an Actor, depending on each criterion, and then define a way to aggregate or combine such individual preferences into a single preference index.

Let us take a criterion k under which an Actor evaluates a solution or alternative, leading to a value $C_k(x)$ with $x \in \mathbf{D}_k$, where $\mathbf{D}_k$ is a domain of definition for x; then, $C_k()$ is defined in a domain $\mathbf{CD}_k$; we now define a membership function

$$\mu_k: \mathbf{D}_k \rightarrow [0,1]$$

expressing a linguistic concept of "preference" for a solution taking values in $\mathbf{CD}_k$.

When taking in consideration two criteria at the same time, the Actor must consider the distinct degrees of "attraction" or "rejection" that a solution has over him when considered under different lights (criteria). This "attraction effect" is represented by applying a modifier to the preference value expressed by μ_k in criterion k.

The application of modifiers is a well-known technique in a linguistic manipulation of concepts. If the modifiers form a set of discrete linguistic labels, each may be represented by a fuzzy set and its membership function.

The application of a modifier is done by a composition of functions. If the membership function of the modifier applied to criterion k is m_k: $[0,1] \rightarrow [0,1]$, then we have the preference, modified by the attractiveness, as a function g_k

$$g_k: \mathbf{D}_k \rightarrow [0,1] \;\;, \qquad g_k = m_k \circ \mu_k$$

This membership function g_k is associated with a fuzzy set $\mathbf{G}_k$ denoting the "weighted preference" of criterion k.

Because an Actor must consider at the same time several criteria "weighted" by their relative attractiveness, a final preference is given by the intersection of the fuzzy sets of the individual preferences.

We have defined for Actor j an aggregated fuzzy set $\mathbf{\Pi}_j$ with membership function π_j representing his "preference for an alternative". We have, for the nj criteria being considered by Actor j

$$\mathbf{\Pi}_j = G_1 \cap G_2 \cap \ldots \cap G_{nj}$$

One must therefore select a t-norm to represent this intersection of fuzzy sets. An adequate choice must be a compensatory operator, so that a good preference induced by a criterion is not totally erased by a less good evaluation in another criterion. This explains why we have rejected the *min* operator and have adopted instead the *product* operator for the intersection of fuzzy sets. Then,

$$\pi_j(x) = g_1(x) \,.\, g_2(x) \,.\, \ldots \,.\, g_{nj}(x)$$

The membership value may be interpreted as a "tolerance index".

3.2. Application in the GIS environment: preference definition

In a GIS environment, the domain of decision is discrete: it is constituted by "Map", the set of cells defined to represent the region at a given level of geographical resolution.

The membership functions μ_k cannot easily be defined by an analytical expression. However, it is possible to define a set of ranges for the values of $C_k(x)$, with x being any cell in the map, and allow the Actor to define values of preference, in the interval [0,1], which become a discrete representation of the membership function μ_k.

For instance, let's admit a criterion such as "distance to an urban center". Imagine that, for some reason, places located at the distance of 1 km are preferred by an Actor. Each cell in the map could be classified according to

Distance	Preference index (μ_k)
0 – 200 m	0.1
200 – 500 m	0.4
500 – 900 m	0.7
900 – 1200 m	0.95
1200 – 1600 m	0.3
> 1600 m	0.1

3.3. Application in the GIS environment: attractiveness of criteria

The concept of "being acceptable" is associated with the concept of "being rejectable". If these concepts are represented by fuzzy sets, we may define them as constituting a fuzzy partition. Having m as the membership function associated with the former concept and r as the membership function associated with the latter, we will have

$$m(x) + r(x) = 1, \quad \forall x$$

We can therefore say that the solutions form 2 fuzzy clusters; each solution belongs to the set "acceptable" with a certain degree m of membership and to the set "rejectable" with another degree r, obeying to the equation above. A membership value of 0.5 denotes, therefore, a case of indifference. Values below 0.5 in the set "acceptable" denote opposition, while values above 0.5 express acceptability. A value of zero (0) expresses a veto. Of course, it is always possible to implement a veto threshold in a practical application, by setting all values below such threshold as equal to zero.

A membership function adequate to represent the set "acceptable" is

$$m_w(p) = \left(1 + e^{10w(1-2p)}\right)^{-1}$$

A representation of this function and its complement $r_w(p)$ is represented in Figure 1. The shape of this function depends on a parameter p. The influence of p is represented in Figure 2.

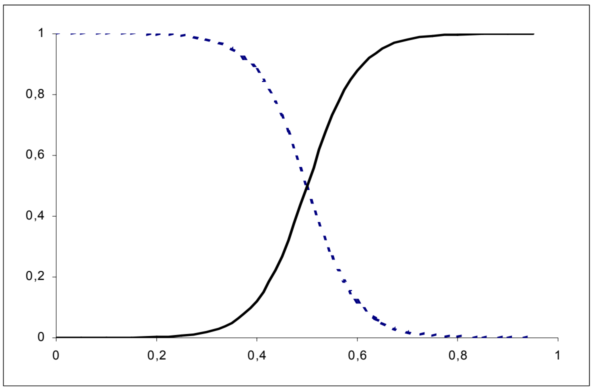

Figure 1 – Membership function for the modifier “acceptable” (full line) and “rejectable” (dashed line)

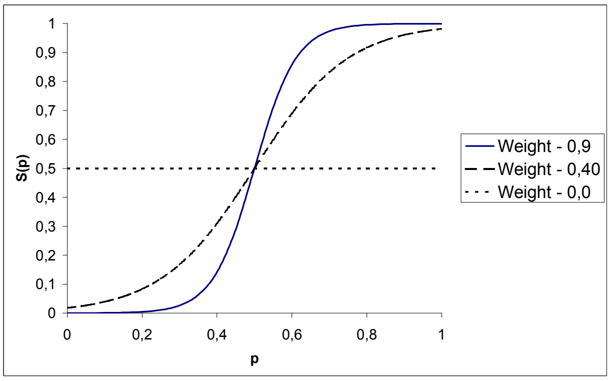

Figure 2 – Variation of the modifier membership function with tolerance parameter p

It is through the manipulation of “w” that an Actor may place more or less weight in the acceptability of a criterion. Instead of defining a discrete set of modifiers, we allow the Actor to select a value for w and build his own modifiers adequate to express the relative importance that he associates with each criterion.

The model may consider *veto* and *absolute preference* thresholds, which may be useful in describing conditions imposed by any Actor. Their definition is as follows:

<u>Veto threshold</u>: $vt = 0.5 - \dfrac{1}{10w}$

<u>Absolute preference threshold</u>: $ap = 0.5 - \dfrac{1}{10w}$

3.4. Ranking locations in GIS

Having calculated π_j for all cells in a map, one may proceed to establish a ranking by counting, for each cell, how many are considered preferable to it or how many outrank it in the preference concept of Actor j. If Map is the set of cells,

$\text{OutrankA}_j(x) = \text{Count}\{\pi_j(y) > \pi_j(x),\ \forall y \in \text{Map}\}$

This allows a (geo)graphic displaying of the aggregated preference, usually translated into colored maps that illustrate the preference structure for the particular Actor j.

4. MODEL FOR SEVERAL ACTORS

4.1. Renormalization

In order to consider several actors, it may be useful to establish a basis for comparison of the strengths of preferences for each one. This cannot be done directly from comparing membership values π_j for each Actor j in a set of T actors (j = 1 to T): the application of the *min* t-norm leads to smaller and smaller membership values with increasing number nj of criteria and it is likely that each Actor considers a different number of criteria.

Therefore, we must apply a process of *renormalization* of the membership values in order to make the preferences of all actors *comparable*.

The renormalized preference set $\overline{\Pi}_j$ is determined by transforming the membership function π_j into

$$\overline{\pi}_j(x) = \sqrt[nj]{\pi_j(x)}$$

recalling that nj is the number of criteria that Actor j takes in consideration.

The effect of the renormalization process is simple to observe. For instance, an alternative seen as “indifferent” by an Actor “a” under the perspective of a single criterion and with a membership value of 0.5, receives the same normalized preference value (0.5) as this alternative seen by Actor “b” under the combined effect of two criteria that deserve both a membership value of 0.5 (which leads to a non-normalized preference value of 0.25).

One must notice that the renormalization process does not affect the relation of order within the fuzzy set, relative to membership values; therefore, rankings of solutions are not changed.

4.2. Compromise ranking

To allow a (geo)graphic display of the areas of compromise among any subset of Actors, usually translated into colored maps, one proceeds, for each cell in the map, to count how many cells are simultaneously preferred to it by the Actors. For instance, for Actors j and k

$\text{OutrkC}_{jk}(x) = \text{Count}\{\pi_j(y) > \pi_j(x) \wedge \pi_k(y) > \pi_k(x),\ \forall y \in \text{Map}\}$

Notice that for this process one does not need the renormalization operation. Maps based on this ranking will help to identify areas of lesser and of greater conflict.

4.3. Maps of equal preference

With the help of the renormalized preferences, it is also possible to identify areas of the map where several actors have the same "preference strength" and find map intersections among Actors for these same value levels. Namely, it is possible for each actor to understand the levels of opposition of any other actor against the use of any cell, referenced in terms similar to the way he has expressed his own perceptions and preferences.

4.4. The negotiation process

All the maps mentioned above have informative value. In a negotiation process, it is important that each Actor becomes aware of the way others see the problem and of his own and each other's margins of flexibility.

The negotiation process must be conducted by a broker or facilitator, who will help the Actors in becoming aware of the consequences of slightly changing criteria or preferences. This is a phase of possible intense simulation, from which Actors will progressively become aware of the feasible negotiation margins and the resulting "geographical trade-offs". As a Negotiation Aid System, one does not expect the system to point out any solution.

5. APPLICATION

This Negotiation Aid model has been applied to the region of La Rioja, Spain. The objective is to identify areas in the territory where the potential for conflict is low. This identification may help the local Autonomic Government and its Agencies for Economic Development in defining policies for the use of renewables and for licensing new generation facilities.

The problem under modeling has been the definition of locations to allow investment in new renewable energy generation. One of the most well known conflicts of the present days, in the European Union, is the one associated with the installation of new wind parks. There is a classical conflict between investors or economic interest groups that wish to build generating facilities and environmental interest groups that oppose to such investments. Besides these two groups of actors, a third group of Actors is easily identified, corresponding to governmental Agencies or departments.

Investors may express their preferences for locations near the existing electric grid, or with the highest economic efficiency in generating electricity. Environmentalists will express their opposition to places located in the path of bird migration or too close to villages or invading protected zones. The government will try to impose its own criteria on the use of the land, or to enforce protection plans defined at national or European Union level.

The following figures illustrate some of the results obtained. The system was developed with ArcInfo and ArcView tools and is one of the modules of a much more complex set of applications. The database of the GIS has been filled up with data from La Rioja and modules defining the economic efficiency of renewable energies have been developed; these modules may be used to help defining some of the data necessary to be considered by the Negotiation Aid System.

The simulations represent a Negotiation process between a Group of Investors in Wind Parks and an Environmentally Oriented Group.

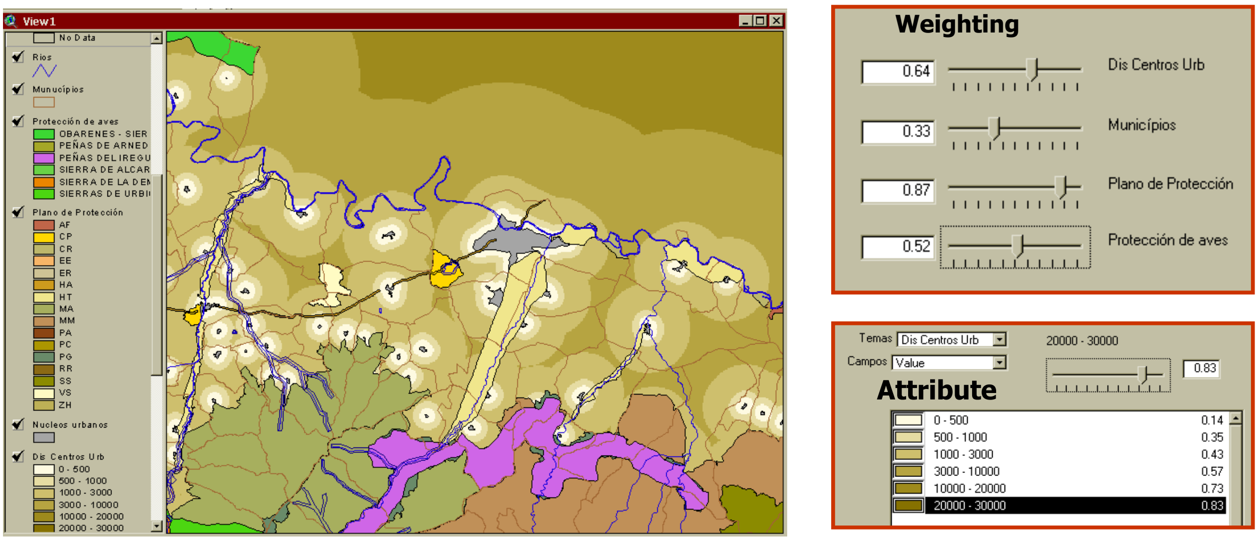

Figure 3 – City of Logroño and surrounding area: map identifying coverages related with distinct criteria and interface allowing an Actor to define his preferences and weights in several criteria (the criteria in the figure are: distance to urban centers, municipalities, nature protection plan, bird protection – output from the actual application).

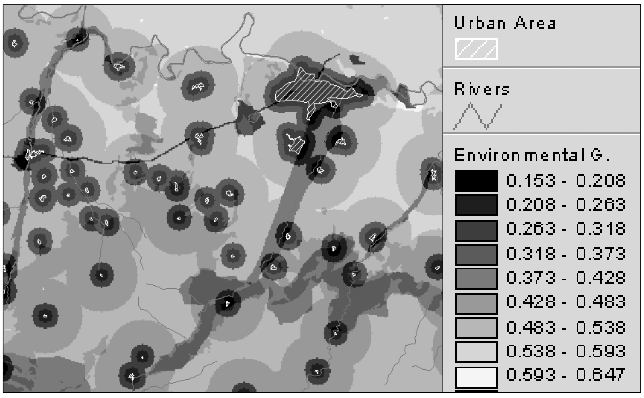

Figure 3 – Tolerance index maps for the environment interest group. The dark zones represent sites with lower tolerance. We can observe less tolerable zones near urban centers and in some environmental protected areas.

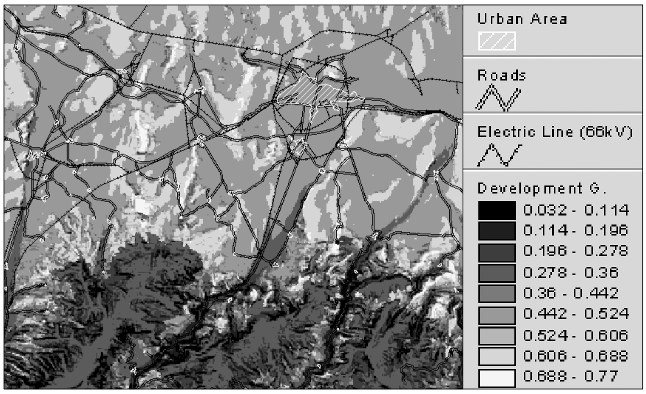

Figure 4 – Tolerance index maps for the wind farm development interest group. The dark zones represent sites with lower tolerance. We can observe better interest areas in some locations with high potential resources and technically acceptable sites.

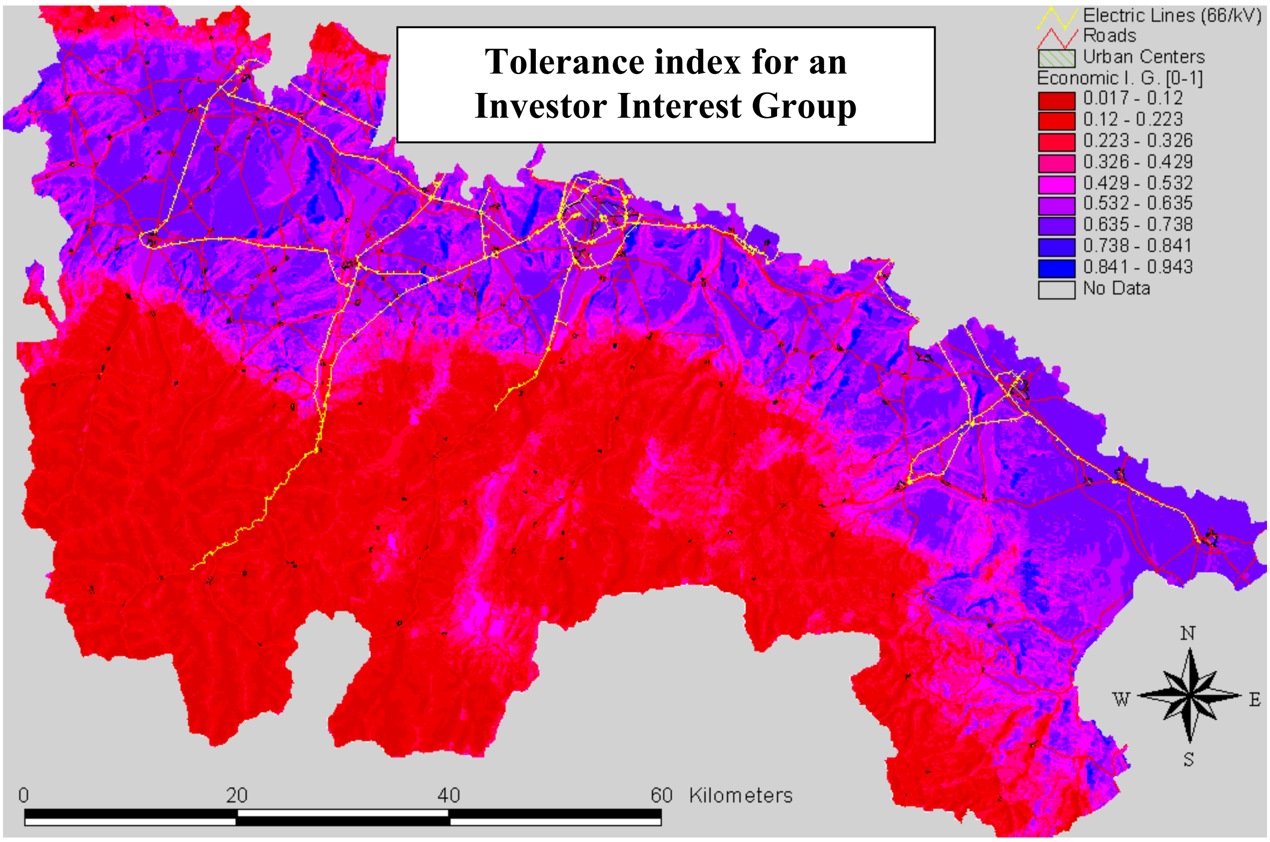

Figure 4 – Region of La Rioja. Simulation of outranking results for a single Actor, representing an Interest Group of investors.

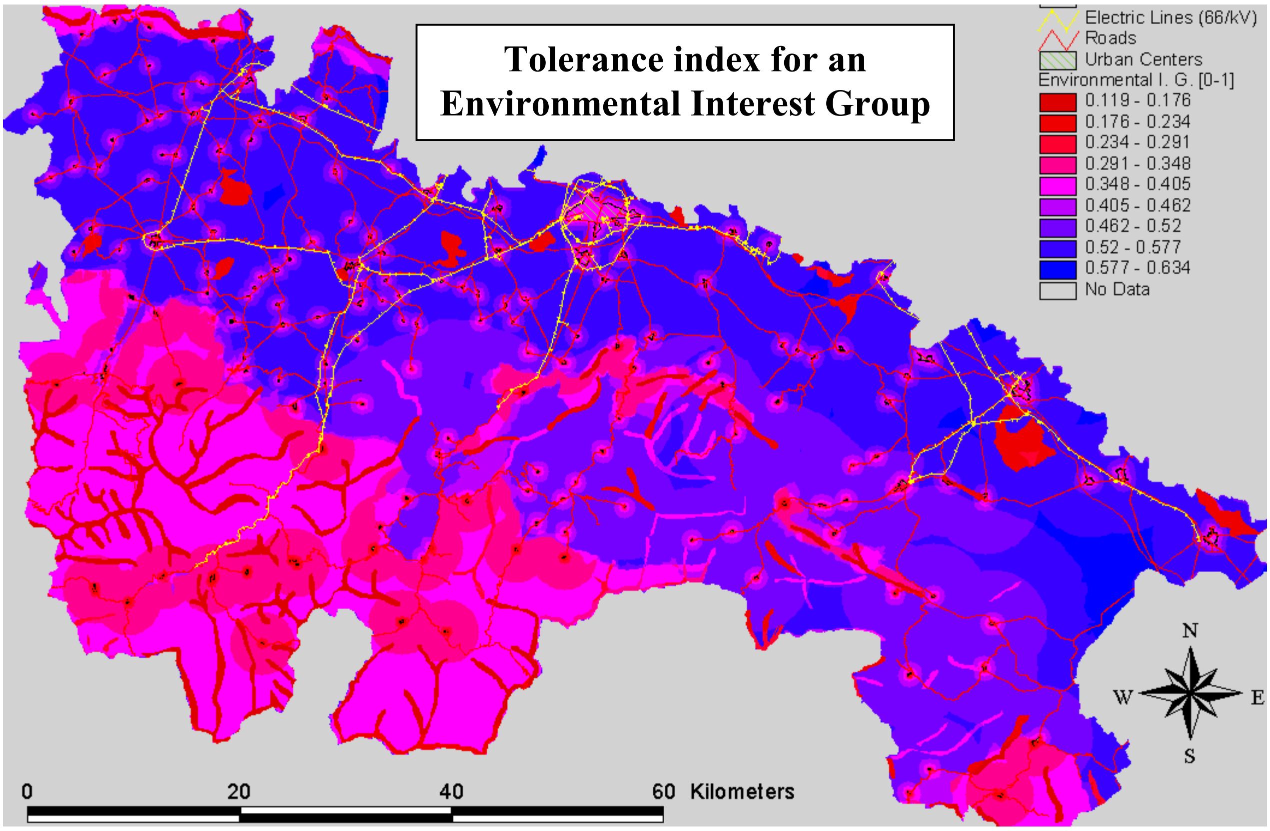

Figure 5 – Region of La Rioja. Simulation of outranking results for a Single Actor, representing an Environmental Interest Group. Notice how the definition of regions of interest, in this case, is different from the definition produced by the interaction with the investing concerned Actor.

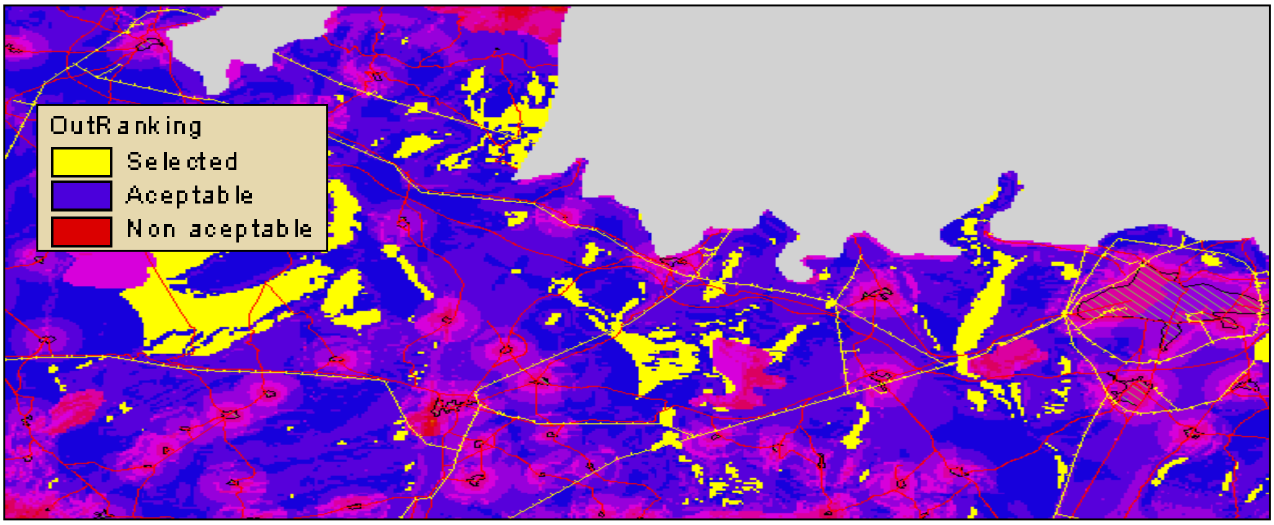

Figure 6 – Region in La Rioja. Simulation of a conciliation process between two Actors, representing a Group of Investors and an Environmentally Concerned Group: identification of areas of coincidence of choice and areas of no agreement, for the development of wind parks of 220 MW.

6. CONCLUSIONS

This paper offers the following contributions:

a) a model that allows the comparison of preferences among several Actors in a negotiation framework

b) a fuzzy set model that allows each Actor to express his own criteria independently of the criteria defined by the other actors

c) a model that allows the identification of alternatives with the smallest possible potential for conflict among Actors

d) the implementation of the model over a GIS platform to help negotiations in order to explore new renewable energy resources

e) an implementation that allows Actors to experiment with the importance of their criteria and to test distinct scenarios, in order to discover compromise solutions

f) the application of such model to the Autonomic Region of La Rioja, in Spain.

The development of Negotiation Aid Systems is one important step into generating coherent and feasible plans for using the energy resources of a region, given that there is a liberalization of the generation activity, promoting the increase of dispersed generation.

This pressure for building new facilities, owned and operated by private entities, leads to conflicts that may even paralyze the predicted and desired development.

A Negotiation Aid System that allows flexibility during the negotiation process or allows the simulation of such a process is, on the contrary, a tool to promote development within the limits of respect for the interests of all actors in the society.

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