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ANALYSIS

Participatory decision-making in land use planning: An application in Costa Rica

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ABSTRACT

The economic, social and environmental implications of electricity generation for land use planning are a significant and complex problem in many countries. One reason for this complexity is the existence of several stakeholders with very different views or perceptions of the different criteria underlying the decision-making process. Therefore, the aggregation of individual stakeholder preferences into a single collective preference is a crucial problem. In this paper, this type of problem is addressed with the help of a methodology based upon the definition of a consensus within a distance-based framework. The methodology is applied to a case study in Costa Rica at two levels: at a national level and at a river basin level. The River Birrís was chosen because the conflict of interests between agricultural production and electricity generation are especially significant in this basin.

1. Introduction

Electricity generation and land use planning are very often interlaced. Dealing with the two problems together is a realistic but at the same time complex approach. There are two different grounds for this complexity. First, the process involves a host of very different criteria (economic, environmental, social, etc.) and, second, there is more than one stakeholder with different views or perceptions of these criteria (e.g., Georgopoulou et al., 1998; Hobbs, 1995). The search for a solution to this type of problem calls for the development of a participatory decision-making process within a context of multiple criteria.

The need to deal with electricity generation and land use planning jointly is especially significant in Costa Rica. In fact, Costa Rica's electricity system is composed of three subsystems: generation, transmission and distribution. Fig. 1 illustrates the current generation mix, clearly showing that the hydroelectric component is the main source of electricity generation (around 73%). It is interesting to note that non-renewable energy represents only 16% of total generation, and its source is thermal (ICE, 2000). There is no nuclear electricity generation in the country, nor are there any plans for this in the short term. Within this scenario the problem of electricity planning depends mainly on a rational land use planning strategy focused primarily on the main energy-producing river basins.

The Birrís River Basin is located on the southern slopes of the Irazú Volcano, a 3400 m high volcanic cone located in central Costa Rica. The Birrís River Basin is part of the Reventazón River District draining to the Atlantic Ocean (see Fig. 2). The hydrographic network is dense due to newly formed geology

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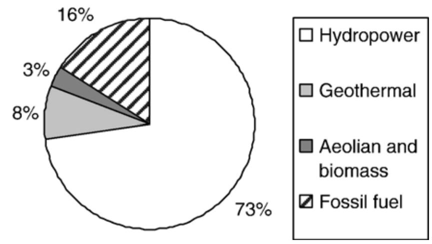

Fig. 1 – Share of each energy type in Costa Rica's electricity generation.

and steep slopes. There are two main streams: the Birrís River and Quebrada Pacayas, its major tributary. The Reventazón River Basin is the primary electricity-producing basin in Costa Rica, accounting for 32% of total hydropower (Jaubert, 2001).

The intensive land use (arable and cattle farming) in the Birrís River Basin is threatening the future sustainability of the hydropower production. This power is produced by the provincial electricity supplier, the state-owned Junta Administrativa del Servicio Eléctrico de Cartago (JASEC) company, followed by the also state-owned Costa Rican Institute of Electricity (ICE), which operates a huge hydroelectric dam downstream from the mouth of the River Birrís. Consequently, the Birrís River Basin is considered a high-priority river basin in the Land Use Plan for the Reventazón River Basin (law in Costa Rica). Additionally, the Tropical Agricultural Research and Higher Education Centre CATIE (2003) drafted a specific Land Use Plan for the Birrís River Basin as a means to allocate economic resources that will be produced by the internalization of environmental costs in JASEC's electricity bill. Its application is pending final approval by the Public Services Authority (ARESEP).

This paper presents a participatory decision-making process, involving relevant stakeholders, to support the electricity production process nationally, as well as at the level of resources allocation for land use planning in a high-priority electricity-producing river basin. The paper has two concerns. First, it addresses a very significant economic and environmental problem for Costa Rica and, second, it proposes a methodological framework that could be applied to other similar situations.

2. The problem

2.1. *Energy planning in Costa Rica*

At the present time the Costa Rican electrical sector is mainly state-owned, but it faces a future of partial privatizations pursuant to free trade agreements. Private companies generate 13.2% of the country's energy (Álvarez, 2003), mainly at small hydroelectric plants. Costa Rica reckons with an immense potential for hydroelectric generation. The theoretical and projected hydroelectric potential is 37,891 MW and 9776 MW, respectively. The installed capacity is now 1427 MW, which means that there is still a huge usable potential for hydroelectric generation. This has triggered a speculative process as regards Costa Rica's potential for satisfying the increasing power demand in the Central American region. Generators argue that Costa Rica should increase generation by clean power plants using water, wind and geothermal energy sources. Nevertheless, environmentalists condemn the overdevelopment of hydroelectric power as compared with other clean sources, as well as the absence of water resources planning and integral management (FECON, 2003).

According to the national electrical expansion plan, the infrastructure capacity for electricity production needs to be doubled every twelve years. Environmentalists denounce the export slant and that this power model overestimates demand (Durán, 2003). This problem has important political

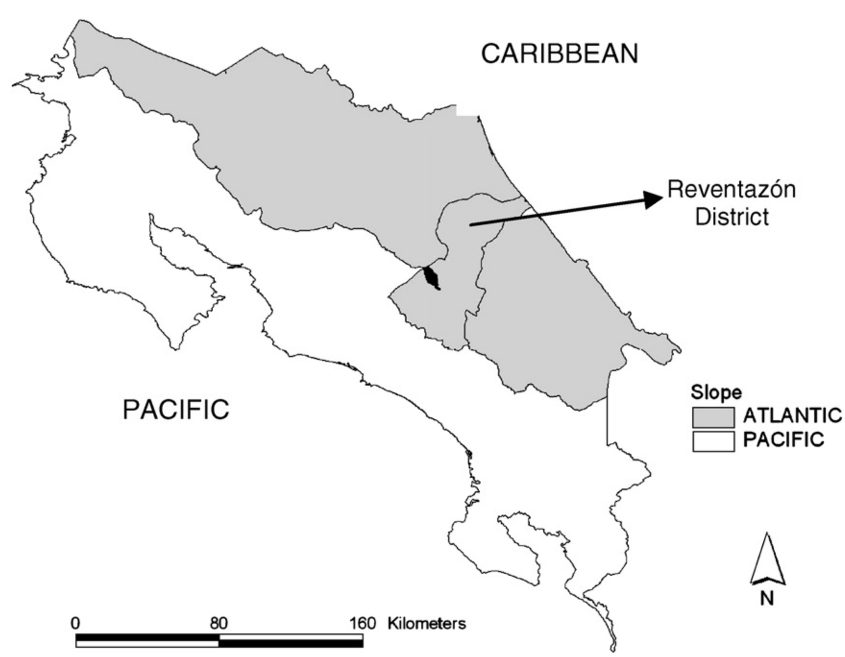

Fig. 2 – Spatial location of the Birrís River Basin (black) in the Reventazón District (Costa Rica).

Table 1 – Criteria and social groups involved in Costa Rica's energy planning

Problem	Criteria	Social groups
Energy planning in Costa Rica	Cost	Generators
	Percentage of renewable energy	Academics
	Wildlife conservation	Environmentalists
	Power self-sufficiency	–
Number	4	3

connotations, as it implies changes to the structure of the Costa Rican state as a result of globalization.

There are two main strategies for power expansion: an "internal or self-sufficiency" policy and an "external" policy, based on local power and global market demands, respectively. The signature of the Central America Free Trade Agreement with the USA and the progress of the Plan Puebla-Panama is now increasing speculation about Costa Rica's key role as the region's main potential electricity exporter. Recent analyses demonstrate that the country's future hydroelectric infrastructure will not be able to meet the predicted electricity demand for the year 2026 within a scenario where the construction of dams in Costa Rica's Protected Areas (National Parks and Reserves and Refuges) or Indigenous Reserves is prohibited (Portilla, 2002). The increasing opposition among indigenous and non-indigenous communities to the construction of new dams raises numerous questions about Costa Rica's future power development. Critical factors in the near future are: satisfying the increasing power demand, honouring the international power commitments subscribed by Costa Rica (SIEPAC at the regional level and the Kyoto Protocol at the international level), increasing the country's renewable energy potential, the viability of future hydroelectric projects, wildlife conservation and the budget available for the expansion.

This study evaluates policies based on the preferences of different stakeholders. The following four criteria have been chosen to characterize and assess future potential electricity generation policies in Costa Rica:

A) *Cost* criterion. The maintenance of the current low cost and accessibility of the electrical energy in the country. At present, Costa Rica enjoys cheap and comparatively accessible electrical energy. If this is to continue, the country will have to increase its own generating capacity in the coming years, as well as select the most profitable and efficient projects.
B) *Percentage of renewable energy* criterion. Even though renewable energy sources now have a comparatively large share in electricity generation in Costa Rica (see Fig. 1), the sizeable predicted growth in future demand without a long-term planning might lead to an increase of polluting thermal generation as a short term solution. On the other hand, a long-term planning may be based on the investment on aeolian, solar, geothermal and hydropower plants. This option would involve a policy of heavy investment in the development of this type of energy.
C) *Conservation of wildlife* (National Parks, Biological and Indigenous Reserves) criterion. This is one of Costa Rica's environmental policy flagships and the main cause of this country's reputation as a tourist destination. According to several international agreements, however, many of these territories could be opened up to hydroelectric operation in the near future in order to meet domestic and Central American electricity demand. In short, the conservation of this type of protected areas would imply a sizeable increase in the cost of energy generation, as well as the implementation of responsible consumption programs.
D) *Power self-sufficiency* criterion. According to this criterion, electricity generation would be completely subordinated to domestic demand. Hence, any type of project aimed primarily at generating electricity for exportation or importing energy from other countries would be ruled out despite its potential economic benefits.

Table 2 – Criteria and social groups involved in River Birrís Land use plan in Costa Rica

Problem	Criteria	Social groups
Evaluation of alternatives for land use planning of Birrís River basin	Farmer's income	Generators
	Quantity and continuity of water resources	Land use planners
	Physical quality of water resources. Erosion-sedimentation	Farmers
	Chemical and biological quality of available water resources	Academics
	–	Environmentalists
Number	4	5

Table 3 – A summary of Saaty's fundamental scale (Saaty, 1977)

Intensity of importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective.
3	Moderate importance	Experience and judgement slightly favor one activity over another.
5	Strong importance	Experience and judgement strongly favor one activity over another.
7	Very strong or demonstrated importance	One activity is favored very strongly over another, and its dominance is demonstrated in practice.
9	Extreme importance	The evidence favoring one activity over another is irrefutable.

2.2. *Land use planning in a high-priority electricity-production river basin*

One of the major low impact strategies to solve the generation challenge in Costa Rica is to increase the efficiency of the existing hydropower systems. Some of these systems are affected by sedimentation as a result of severe erosion in the headwaters and adjacent slopes. Erosion is a national problem in Costa Rica that, among other effects, reduces its generation potential and increases costs, mainly because of the frequent sedimentation-induced work stoppages and maintenance costs. During these stoppages generation shortages are backed with

Table 4 – Individual preferences and degree of inconsistency (IR) for each criterion of energy planning in Costa Rica

Stakeholder	Criteria				IR
	Cost	Conservation	Renewable energy	Self-sufficiency	
Generator no. 1	0.081	0.074	0.441	0.404	0.01
Generator no. 2	0.599	0.098	0.044	0.259	0.04
Generator no. 3	0.661	0.038	0.155	0.146	0.10
Academic no. 1	0.115	0.049	0.380	0.456	0.13
Academic no. 2	0.074	0.284	0.321	0.321	0.01
Academic no. 3	0.344	0.311	0.278	0.067	0.03
Environmentalist no. 1	0.059	0.444	0.444	0.053	0.00
Environmentalist no. 2	0.078	0.635	0.200	0.087	0.05
Environmentalist no. 3	0.036	0.607	0.255	0.102	0.17

fuel thermal generation, what increases energy costs and affects national commercial balance. According to the points discussed above, the problem of sustainable electricity planning in Costa Rica depends greatly on a rational land use planning strategy focused specially on the main energy-producing river basins.

The Birrís River Basin is part of the Reventazón River District draining into the Atlantic Ocean (see Fig. 2). The basin extends over 4800 ha from the heights of the Irazú Volcano (3400 m) down towards the Reventazón River Valley (1250 m) across pastures and intensive agricultural farms developed upon volcanic soils (andosols). The Reventazón River District produces up to 32% of all electricity nationwide, whereas the Birrís Hydropower System (SHB), run by the state-owned JASEC, produces 20 MW to supply the Cartago province with energy. The quantity and quality of electricity generation in the SHB has fallen due to high sedimentation rates in dams and the impact of spates on structures. This destabilization is related to the intense land use conflicts and the decrease of forest cover in tributaries flowing into the Birrís Hydropower System. This has increased Cartago province's energetic dependency and raised the price of energy. On the other hand, the Birrís River Basin is the source of half the vegetables produced nationwide. There is an intense production of potatoes, carrots and other vegetables (Fam. Brassicaceae) and dairy products (milk and cheese) supporting a dense population of 161 inhabitants/km^2 (the average Costa Rican population density is 78 inhabitants/km^2) (INEC, 2001) and high employment in agriculture (61% of the total labor force).

For all these reasons, the Birrís River Basin was declared a high-priority basin in the Reventazón River Land Use Plan (Costa Rican Law 8023) and the River Birrís Land Use Plan (CATIE, 2003) is pending application pursuant to the internalization of environmental costs into the electricity bill in the Cartago province.

From a diagnosis of the Birrís River Basin, four strategic lines of work and a traversal scheme have been proposed as a guide for the implementation of the River Birrís Land Use Plan. Each one of these lines represents a land use planning criterion or policy for the river basin:

1) *Farmer's income* criterion. This criterion will consist of generating sustainable technological agriculture and cattle farming alternatives for soil and water conservation in the SHB tributary river basins. Investments in sustainable projects within this line of work are aimed at improving farmer's income in harmony with the environment. This line promotes various sustainable technological alternatives like precision agriculture, greenhouses, organic production, gas production through integrated waste management, production of fruit, intensification of cattle farming and conservation agriculture with a heavy training and technical assistance component for producers.
2) *Quantity and continuity of water resources* criterion. The purpose of this criterion is to improve the amount and continuity of the water resources, especially in dry periods, while reducing flood vulnerability during the wet season. These objectives are to be achieved via the restoration and enhancement of the vegetal canopy as an element regulating the hydrologic cycle, including the conservation of existing forest and re-vegetation. The measures to be applied within this plan range from Payments for Environmental Services (PES) for forest land owners to Socio-Environmental Compensation Measures for owners of non-forested high priority lands for re-vegetation.
3) *Physical quality of the water resources (erosion-sedimentation)* criterion. The purpose of this criterion is to reduce the erosion and sedimentation processes that have a negative effect on electricity generation. This line will cover activities like soil conservation projects, drainage design, run-off control on farms and road infrastructure improvement.
4) *Chemical and biological quality of available water resources* criterion. The purpose of this criterion is to improve the physical, chemical, bacteriological and ecological quality of the Birrís River Basin water. The activities covered by this line

Table 5 – Group preference weights and social consensus for each energy planning criterion in Costa Rica

Social groups	Criteria				SUM
	Cost	Conservation	Renewable energy	Self-sufficiency	
Generators	0.599	0.038	0.104	0.259	1.00
Academics	0.115	0.284	0.280	0.321	1.00
Environmentalists	0.059	0.607	0.247	0.087	1.00
Social consensus	0.148	0.284	0.247	0.321	1.00

Table 6 – Index of heterogeneity for each energy planning criterion and social group in Costa Rica

Social groups	Index of heterogeneity				IHA
	Cost	Conservation	Renewable energy	Self-sufficiency	
Generators	0.369	0.049	0.245	0.130	0.20
Academics	0.165	0.167	0.076	0.203	0.15
Environmentalists	0.021	0.117	0.143	0.026	0.08

of work are logically urban and farm solid waste management, residual water treatment and river restoration projects.

As a traversal line of action, we have the "Education, Environmental Training and Institutional Coordination Support Program" that aims at promoting participation in and social awareness of the rational management of the River Birrís Land Use Plan.

3. Analytical procedure

In this paper, we present the foundations for a participatory decision-making process at two different levels: national electricity planning and land use planning for a high-priority river basin. The methodological scheme includes a number of consecutive phases for each level of analysis. Thus, we have:

3.1. *Identification of social groups (stakeholders), criteria and constraints involved*

The social groups and criteria were identified from the information provided by experts in Costa Rica and taken from existing publications (e.g., FECON, 2003). The four criteria specified in the last section to evaluate Costa Rica's power policy were assessed by three selected social groups (see Table 1). In this case, the problem constraints are available budget, future electricity demand, legislation on protected areas, the limitations of the country's renewable energy sources, external obligations and the economic, social and environmental feasibility of future hydroelectric projects.

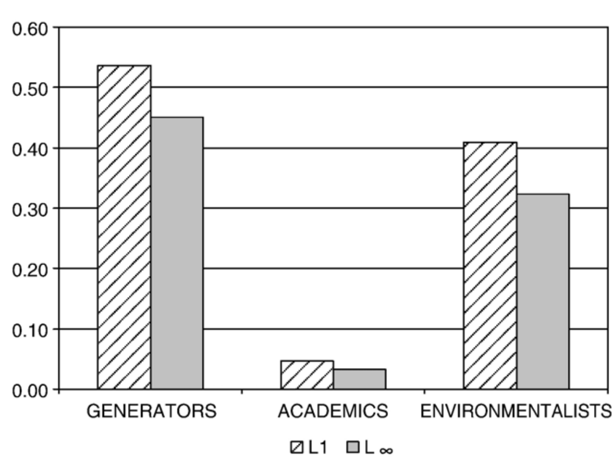

Fig. 3 – Euclidean (L_1) and Chebyshev (L_∞) distances: degree of disagreement for each social group with respect to the social consensus for Costa Rican electricity planning.

For the social evaluation of the Birrís River Basin Land Use Plan alternatives, the four criteria introduced in the last section were assessed by the five social groups considered to have an interest in this problem (see Table 2). In this case, the problem constraints are hydrological supply, budget, agricultural market dynamics, power demand, legislation on protected areas and opposition to the change in land use.

3.2. *Determination of individual preferences (questionnaires by "pairwise" comparisons of criteria)*

Three people representative of each social group were selected for the preferences survey. Twenty-two farmers were interviewed due to the importance and size of the social group. We made use of a "pairwise" comparison approach in all cases. Within this approach the following question was used to elicit the decision-maker's judgment on the relative importance of the ith criterion over jth criterion: "between the ith and jth criteria which one is more important and by what ratio? The questions were formulated with the help of the Saaty's fundamental scale (Saaty, 1977, 1980), which has been widely tested in practice. See Table 3 for a summary of this scale.

This yields the ratio values a_{ij}^k. These values represent the quantification of the assessment or judgment made by the kth stakeholder when the ith criterion is compared with the jth criterion. From these values, a square matrix $m \times m$ is built, m being the number of criteria considered (four in our exercise). Within this context, elements are normally assumed to be reciprocal (i.e., $a_{ij}=1/a_{ji}$). Hence $m(m-1)/2$ judgments by each interviewed person are required for n criteria (i.e., six pieces of information in our case). The preference values can be obtained from these ratio values by making use of any of the procedures proposed in the literature (for instance, a technique for finding the maximum eigenvalue). This outputs the preference weight attached to the ith criterion by the kth member of the lth group, s_i^{kl}.

3.3. *Aggregation of individual preferences*

The problem now is to derive group weights from the individual preference weights s_i^{kl}, and then the final or "social" weights from the group weights. To do this, we have used a new methodology proposed by Linares and Romero (2002). We adapted this methodology to our problem using the following notation:

i	number of criteria involved $(1,2,\ldots,m)$
l	number of social groups involved $(1,2,\ldots,q)$
N_l	number of members of the lth social group $(l=1,2,\ldots q)$
W_i^l	preference (group) weight attached to the ith criterion by the lth social group $(l=1,2,\ldots q)$

Table 7 – Individual preferences and degree of inconsistency (IR) for each criterion for River Birrís Land Use Plan

Stakeholder	Criteria				IR
	Farmers' income	Water quantity and availability	Erosion	Water quality	
Generator no. 1	0.043	0.429	0.427	0.101	0.13
Generator no. 2	0.051	0.643	0.209	0.097	0.09
Generator no. 3	0.036	0.133	0.632	0.199	0.13
Land use planner no. 1	0.598	0.111	0.063	0.228	0.06
Land use planner no. 2	0.058	0.234	0.608	0.100	0.16
Land use planner no. 3	0.085	0.035	0.648	0.232	0.17
Academic no. 1	0.052	0.210	0.210	0.528	0.03
Academic no. 2	0.082	0.170	0.524	0.224	0.14
Academic no. 3	0.250	0.250	0.250	0.250	0.00
Environmentalist no. 1	0.065	0.700	0.091	0.144	0.15
Environmentalist no. 2	0.087	0.533	0.232	0.148	0.19
Environmentalist no. 3	0.204	0.105	0.105	0.586	0.19
Farmers (*)	–	–	–	–	–

(*) 22 farmers were interviewed to evaluate the opinion of this group.

W_i^S preference (social) weight attached to the ith criterion by society as a whole (aggregate weight)

To determine the W_i^l preference (group) weights attached to the ith criterion by the lth social group, the following weighted goal programming (WGP) model was formulated (Romero, 1991; Linares and Romero, 2002):

Achievement function:

$$\mathrm{MIN} \sum_{i=1}^{m} \sum_{k=1}^{N_l} (n_{ik} + p_{ik})^{\pi}$$

s.t.

Goals: (1)

$$W_i^l + n_{ik} - p_{ik} = s_i^{kl} \qquad i \in \{1, \ldots, m\}, k \in \{1, \ldots, N_l\}$$

where n_{ik} and p_{ik} are the negative and the positive deviation variables, respectively. These variables measure the under-achievement and the over-achievement, between the preference group weight attached to the ith criterion by the lth social group and the weight attached to this criterion by the kth member of the lth group. π is a parameter representing a topological metric. As π increases, more importance is given to the greater deviation, that is to say, to the minority group (Linares and Romero, 2002). In our case we chose $\pi=1$, according to which the preferences structure represents a solution for which the sum of individual disagreements is minimized (principle of the majority rule). For $\pi=1$ the achievement function of model (1) can be interpreted as an additive group utility function leading to the "best group optimum" from the point of view of the majority (i.e., the Benthamite or utilitarian point; see González-Pachón and Romero, 1999).

The main advantage of the proposed method is the clear meaning in utility terms underlying to the achievement function of model (1). Thus, if in a particular case a consensus respectful towards the interest of the minority is searched for, then the model should be particularized for a large value of metric π. Thus, for $\pi=\infty$, the disagreement of the most displaced individual with respect to the consensus obtained is minimized (Yu, 1973). By formulating and solving q similar models, we get the $(m \times q)$ W_i^l weights assigned to each criterion by each social group. Finally, the W_i^l weights were normalized to add up to 1.

It should be pointed out that this type of model can lead to alternative optimal solutions. In our context, that means that more than a set of weights can lead to same degree of consensus. This is not a surprising fact, since it is well-known that different utility functional forms in many cases yield the same optimum solution (Köksalan and Sagala, 1995).

At the end of this phase, we calculated the degree of heterogeneity of preferences inside each group as the standard deviation of internal opinion with respect to the group value for each criterion. The index of heterogeneity for each social group with respect to the group consensus for a given criterion was calculated as follows:

$$\mathrm{IH}_i^l = \sqrt{\frac{\sum_{k=1}^{N_l} (S_i^{kl} - W_i^l)^2}{N_l - 1}} \quad i \in \{1, \ldots, m\},\ k \in \{1, \ldots, N_l\},\ l \in \{1, \ldots, q\} \tag{2}$$

The aggregate index of heterogeneity (IHA) for each social group was calculated as an average of the IH_i^l indices for all the criteria.

Table 8 – Index of heterogeneity for each criterion and social group for River Birrís Land Use Plan

Social groups	Index of heterogeneity				IHA
	Farmers' income	Water quantity and availability	Erosion	Water quality	
Generators	0.008	0.258	0.212	0.069	0.14
Land use planners	0.363	0.102	0.367	0.091	0.23
Academics	0.121	0.040	0.196	0.227	0.15
Environmentalists	0.084	0.325	0.090	0.255	0.19
Farmers	0.231	0.198	0.126	0.130	0.17

Table 9 – Group preference weights and social consensus for each criterion for River Birrís Land Use Plan

Social groups	Criteria				SUM
	Farmers' income	Water quantity and availability	Erosion	Water quality	
Generators	0.043	0.429	0.427	0.101	1.00
Land use planners	0.085	0.111	0.576	0.228	1.00
Academics	0.082	0.210	0.250	0.458	1.00
Environmentalists	0.087	0.533	0.105	0.275	1.00
Farmers	0.417	0.161	0.250	0.172	1.00
Social consensus	0.085	0.390	0.250	0.275	1.00

In the second phase of the procedure, the social weights, W_i^S, were obtained from the group weights, W_i^l. To do this, another WGP model was formulated:

Achievement function:

$$\text{MIN} \sum_{i=1}^{m} \sum_{l=1}^{q} (\bar{n}_{il} + \bar{p}_{il})^{\pi}$$

s.t.

Goals: (3)

$$W_i^S + \bar{n}_{il} - \bar{p}_{il} = W_i^l \qquad i \in \{1, \ldots, m\}, l \in \{1, \ldots, q\}$$

where $\bar{n}_{il}$ and $\bar{p}_{il}$ are again the negative and the positive deviation variables of the goal programming model. These variables measure now the under-achievement and the over-achievement, between the social weight attached to the ith criterion and the weight attached to this criterion by the lth social group. It should be noted that the W_i^S social weights were normalized to add up to 1. These social weights represent the consensus solution obtained by maximizing aggregate agreement (i.e., the principle of the majority rule that satisfies the metric $\pi=1$ as was commented above).

3.4. *Analysis of disagreement*

Finally, the degree of disagreement of each social group with respect to the social consensus was calculated. To do this, we applied two well-known metrics like the Euclidean distance ($\pi=1$) and the Chebyshev distance ($\pi=\infty$) as follows (González-Pachón and Romero, 1999):

$$L_{1l} = \sqrt{\sum_{i=1}^{m} (W_i^l - W_i^S)^2} \quad i \in \{1, \ldots, m\} \tag{4}$$

$$L_{\infty l} = \text{Max}(|(W_i^l - W_i^s)|) \quad i \in \{1, \ldots, m\} \tag{5}$$

The L_1 and L_∞ distances provide two measures of the degree of disagreement between group and social judgments (consensus). The greater this distance is, the greater the degree of disagreement between the group and the social consensus will be.

4. Results

4.1. *Energy planning in Costa Rica*

Individual preferences for the electrical planning of Costa Rica are presented in Table 4. Only individuals with a degree of inconsistency of less than 0.20 according to Saaty's consistency index were considered.

Group preference weights are listed in Table 5. The bottom line shows the final social weights output at the end of the process.

Table 6 shows the values of the index of heterogeneity for each group and criterion, as well as the aggregate index of heterogeneity (IHA) for each social group.

Finally, the global disagreement of each social group with respect to the consensus reached is presented in Fig. 3.

4.2. *Land use planning in a high-priority electricity-producing river basin*

As for the above case study, individual preferences for the River Birrís Land Use Plan are shown in Table 7.

Table 8 shows the results for the indices of heterogeneity (IH) for the social groups, as well as the aggregate index of heterogeneity (IHA).

Table 9 presents the results of the group and social weights assigned to each criterion for the River Birrís Land Use Plan.

Finally, the global disagreement of each social group with the proposed consensus is presented in Fig. 4.

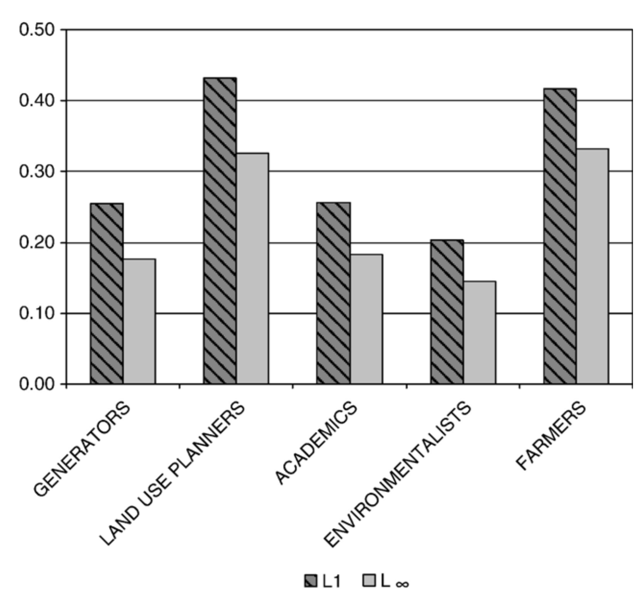

Fig. 4 – Euclidean (L_1) and Chebysev (L_α) distances: degree of disagreement for each social group with respect to the social consensus for the River Birrís Land Use Plan.

5. Discussion

5.1. *Energy planning in Costa Rica*

From the interaction with the interviewed stakeholders, we were able to evaluate of their preferences, which were expressed numerically as normalized weights. The degree of inconsistency of the individual stakeholders was under 0.20 according to Saaty's index. Therefore, all judgments could be considered for the aggregation of group and social preferences. Sizeable differences in the expressed preferences were recorded at group level. Generators ranked the cost (0.599) and the power self-sufficiency (0.259) criteria highly, as opposed to the percentage of renewable energies and the conservation. Academics rated self-sufficiency, the percentage of renewable energies and conservation similarly, downgrading cost. Environmentalists expressed their clear preference for conservation (0.607) and the percentage of renewable energies (0.247), attaching very little importance to cost and power self-sufficiency.

Generators were the most heterogeneous group, followed by academics and environmentalists. The rankings given by environmentalists proved to be highly homogenous for all criteria. The social consensus was positioned very close to the academic's judgment, with which there was minimal disagreement. Generators' and environmentalists' positions were further away from the social consensus, as they prioritized cost and the conservation of protected areas, respectively. According to these results, generators and environmentalists can be said to have held viewpoints that were furthest apart. Each of these two groups supports opposing models for developing power in Costa Rica. On the one hand, generators defend a model of low cost energy and high generating performance, which implies the extension of installed hydroelectric power generating capacity. On the other hand, environmentalists are in favour of production based on renewable, non-hydroelectric sources, enabling the conservation of protected areas and indigenous reserves at the cost of an increase in the price of the energy. Generally, the social consensus emphasizes the preference for an endogenous power strategy, prioritizing self-sufficiency to cover national demand.

5.2. *Land use planning in the River Birrís Basin*

With respect to the allocation of investment in the River Birrís Land Use Plan, generators expressed a preference for improving the quantity and continuity of water supply and reducing erosion. The improvement of hydrologic regulation is a general concern in the generating sector because of its positive effect on the availability of the hydrologic resources during dry periods. The reduction of erosion is an extremely important criterion for reducing economic and material damages to the generation infrastructure. Water quality and sustainable technological alternatives in agriculture are not a high-priority for the generating sector.

Land use planners attach the highest weights to erosion control and water quality improvement. Academics distributed their preferences more equitably, water quality being the main target, followed by water quantity and continuity and erosion control. Environmentalists expressed a clear preference for the improvement of water quantity and continuity through projects designed to increase the vegetal cover and protect existing forest. Farmers indicated their preference for investment in sustainable production projects that could increase family income, followed by erosion control.

The greater degrees of heterogeneity occurred in the group of land use planners, whose members are public employees and local politicians. Local politicians expressed preferences similar to farmers (their main source of votes), supporting investment in projects that are likely to improve farmers' income. Land use planners from the Ministries of Agriculture and the Environment, however, attached greater weight to the erosion control criterion. The other groups showed similar lower indices of heterogeneity.

The proposed social consensus attaches maximum importance to the water quantity and continuity criterion, followed by the erosion control and improvement of water quality criteria. The increase in farmers' income through sustainable production projects is weakly accounted for in the social consensus. Farmers and land use planners showed greater disagreement with the proposed consensus, as they prioritize the increase of the farmers' income and erosion control, respectively. Generators, academics and environmentalists showed a similar degree of disagreement. In this case study, generators and environmentalists share the same preference because of their common interest in forest conservation projects designed to increase the vegetal canopy, albeit on different grounds. In the case of the generators, the group's primary concern is sufficient water provision (in terms of quantity and supply continuity) to maintain generation during dry periods. Environmentalists, on the other hand, defend the recovery of the extension and diversity of the wooded canopy. The difference of opinion between the two groups is based on the fact that generators attach greater importance to erosion control than to water quality improvement. These preferences are opposed to the concerns of the environmentalists' group.

6. Conclusions and further research

This paper has shown how to structure the aggregation of preferences within a participatory decision-making process in a context of natural resources planning. Once the preferences structure has been processed and satisfactorily characterized for several social groups, the consensus solutions are calculated. The proposed calculation procedure is remarkably simple, since it involves just solving a limited number of linear programming problems. Social consensus solutions have been reached assuming that all the groups have the same decision-making power; that is, each individual (within a group) and each group is judged as equally important. More detailed analyses would be called for to account for each group's political power by attaching different weights to the respective deviation variables in models (1) and (3) (see Linares and Romero, 2002).

It is important to remark that the analysis undertaken in this paper is able to quantify the heterogeneity of opinion within each group and the groups' deviation from the consensus solution. This has important implications for natural resources planning processes, since the points of conflict and harmony between social groups can be identified, leading to a process of negotiation to reach a real accepted social consensus.

Finally, it should be pointed out that even though the paper has a methodological orientation, the results derived from the case study might be a useful source of information to support the implementation of major economic and environmental policies related to land use issues in Costa Rica.

Further applications of this method are: a) analysis of the opinion of relevant stakeholders in the formulation of projects, plans or laws that imply a certain degree of social conflict; b) resource allocation among different policies, and c) to use the proposed method as a tool for the implementation of a negotiation process between stakeholders at any level; i.e., from an international to a local level.

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