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Position paper

Environmental conflict analysis using an integrated grey clustering and entropy-weight method: A case study of a mining project in Peru

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ABSTRACT

Environmental conflict analysis (henceforth ECA) has become a key factor for the viability of projects and welfare of affected populations. In this study, we propose an approach for ECA using an integrated grey clustering and entropy-weight method (The IGCEW method). The case study considered a mining project in northern Peru. Three stakeholder groups and seven criteria were identified. The data were gathered by conducting field interviews. The results revealed that for the groups urban population, rural population and specialists, the project would have a positive, negative and normal social impact, respectively. We also noted that the criteria most likely to generate environmental conflicts in order of importance were: access to drinking water, poverty, GDP per capita and employment. These results could help regional and central governments to seek appropriate measures to prevent environmental conflicts. The proposed method showed practical results and a potential for application to other types of projects.

1. Introduction

Environmental conflicts often accompany the planning and implementation of projects and programs, as evidenced by studies of conflicts related to water management (Bolin et al., 2008; Saqalli et al., 2010), energy (Fontaine, 2010; Karjalainen and Järvikoski, 2010), exploitation of natural resources (Correia, 2007; Warnaars, 2012; Madani et al., 2014) or ecological tourism (Yang et al., 2013). Therefore, organizations and governments require techniques enabling them to assess social impact and then, given this information, to propose measures for preventing environmental conflicts (Barrow, 2010; Prenzel and Vanclay, 2014). Organizations have obligation as part of their corporate social responsibility to evaluate their social impact to prevent possible conflicts within the affected communities (Kemper et al., 2013). Furthermore, governments are obligated to improve population welfare to achieve sustainable development of countries; therefore, they must measure social impact of their programs and state policies to prevent possible conflicts (Franks and Vanclay, 2013). In addition, stakeholders are a dimension of integrated assessment (Hamilton et al., 2015), and environmental conflicts are generated between stakeholder groups within communities, due to the differences in the assessment of industrial projects (Arun, 2008; Luyet et al., 2012). For this reason, social impact assessment must first be performed for each stakeholder group and then the gap between the groups must be determined in order to predict and prevent possible environmental conflicts.

Thus far, ECA has been mostly carried out using qualitative methods such as those described by Prenzel and Vanclay (2014), (based on game theory), who address environmental conflict from an infrastructure development project, or by Griewald and Rauschmayer (2014), (based on a capability perspective), who consider environmental conflict in a protected nature area. In addition, there are also quantitative methods for ECA, found, for example, in the study by Al-Mutairi et al. (2008), (based on fuzzy logic) of environmental conflict over aquifer contamination caused by a chemical company. In this article, we apply a method for ECA combining the grey clustering method and the entropy-weight method (The IGCEW method), as an extension to the qualitative and quantitative methods.

The grey clustering method enables quantification of qualitative information and classification of observed objects into definable classes, as well as verification of whether the observed objects belong to predetermined classes – as shown by the studies of

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Zhang et al. (2013), who analysed a water rights allocation system, or by Zhang et al. (2014), who classified innovation strategic alliances. It can be argued that the grey clustering method is likely to benefit the first stage of ECA in that it helps assess social impact by quantifying the qualitative information obtained from stakeholder groups involved in a given environmental conflict.

In turn, the entropy-weight method is used to calculate objective weights of criteria. If there is a large difference between the objects for a criterion determined, this criterion can be regarded as an important factor for the analysis of alternatives, as shown by the study of Wang and Lee (2009), who resolved a software selection problem, or by Kou et al. (2011), who assessed a case of environmental pollution. In our view, the entropy-weight method would benefit the final stage of ECA, as it allows researchers to determine the criteria for which there is divergence between the stakeholder groups involved in a conflict. The combination of both methods would be beneficial for ECA because it integrates social impact assessment and divergent criteria identification. To illustrate the method we propose, a case study was conducted assessing the exploitation plans of a poly-metallic mine in northern Peru. Three stakeholder groups were identified and a set of seven criteria for ECA were established in the mining project.

The specific objectives of this article are to:

1. Apply the IGCEW method for ECA to the concrete context of the exploitation plans of the poly-metallic mine in Peru.
2. Explore if the IGCEW method exhibits potential for other ECA contexts.

In section 2 the literature review is described. Section 3 provides the details of the IGCEW method for ECA. In Section 4 the case study is described, followed by the results and discussion in Section 5. Conclusions are provided in Section 6.

2. Literature review

Environmental conflicts are characterized by the interaction between (1) ecological and (2) social complexity (Wittmer et al., 2006).

(1) One central feature of environmental conflicts is the complexity of the ecological system which is the natural base of the conflicts. Even if its understanding is accompanied by a high degree of scientific sophistication, there remains substantial uncertainty and ignorance. Therefore, the process leading to the resolution of environmental conflicts should take into account scientific and idiosyncratic knowledge and should cope with unavoidable uncertainty and ignorance. Certain forms of multi-criteria decision aid could satisfy this demand (Wittmer et al., 2006).

(2) Another central feature of environmental conflicts is social complexity. Some stakeholders are also actors who may impede the implementation of a decision, or, put positively, their agreement is necessary for a successful implementation of the decision. Social complexity calls for stakeholder participation. Decision structuring tools offer the possibility to make participatory decision processes more transparent (Wittmer et al., 2006).

The resolution of environmental conflicts should concentrate on both aspects, social and ecological complexity. Wittmer et al. (2006) suggest approaching both aspects by an intensive integration of stakeholders and multi-criteria analysis. However, environmental conflict is a social issue and has high level of uncertainty. In addition, in classical multi-criteria analysis methods, the importance degrees of criteria and the performance scores of alternatives are assumed to be known precisely. Moreover, the practical constraints of the real world hinder the use of crisp values. The problems faced in practice occur in such an environment that the goals, constraints and consequences of alternatives are not precise. Furthermore, the ambiguities, uncertainties and vagueness inherent in decision makers' evaluations necessitate the use of methods to model uncertainty in decision problems (Baykasoglu and Gölcük, 2015). There are many methods used to model uncertainty in decision problems. Probabilistic approaches (Augustsson et al., 2011), fuzzy logic (Zadeh, 1965), and grey systems (Liu and Lin, 2010) are some examples of the options used to model uncertainty.

The grey systems theory is a methodology for studying uncertainty problems (Deng, 1985), in which there are limited information and small samples (Liu and Lin, 2010). In order to explore the differences, we compare grey systems with other main approaches, below.

2.1. Comparison between grey systems and probabilistic approaches

A comparison study between grey systems and probabilistic approaches was performed in 1994 by (1) Jiangping Qiu and (2) Xisheng Hua respectively, who established a theoretically delicate statistical regression model and relatively coarse grey model based on the deformation and leakage data of a certain large scale hydraulic dam. Their work shows that their grey model provided a better fit than the statistical regression model. When comparing the errors between the predictions of the two models with the actual observations, it is found that the prediction accuracy of the grey model is generally better than that of the regression model, for more details see Table 1 (Liu and Lin, 2010).

As shown in Table 1, we believe that a model based on grey system could be more accurate than a statistical model. In addition, considering that environmental conflict is a social issue and a very inconstant and subjective topic, which requires a permanent analysis, and that one of the criteria for evaluating methods for ECA is the cost (Wittmer et al., 2006), in this aspect an approach based in grey systems would have a lower cost with respect to a statistical approach, due to the fact that sample size influences the cost of field research.

2.2. Comparison between grey systems and fuzzy logic approaches

Fuzzy mathematics emphasizes the investigation of problems with cognitive uncertainty, where the research objects possess the characteristic of clear intention and unclear extension. For example, the instance, “young man” is a fuzzy concept, because everybody understands the idea of “young man”. However, if you are going to determine the exact range within which everybody is young and outside which everybody is not young, then you will find yourself in difficulty. This is because the concept of young man does not have a clear extension. For this kind of problem of cognitive uncertainty with clear intention and unclear extension, the situation is dealt with in fuzzy mathematics by making use of experience and the so-called membership function (Liu and Lin, 2010).

The focus of grey systems theory is on the uncertainty problems of small samples and limited information which are difficult to handle for probability and fuzzy mathematics. One of its characteristics is construct models with small amounts of data. What is clearly different of fuzzy mathematics is that grey systems theory emphasizes the investigation of such objects which process clear extension and unclear intention. A summary of the differences between these approaches is shown in Table 2 (Liu and Lin, 2010).