Spatial information fusion

Application to expertise and management of natural risks in mountains

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RÉSUMÉ. *L'expertise des risques naturels en montagne, dépend de la qualité de l'information spatiale disponible. Une méthode dénommée* ER-MCDA Spatiale *(Aide multicritères à la décision, raisonnement crédibiliste) est proposée pour représenter l'influence de ces imperfections sur les résultats d'expertise. Elle associe l'analyse multicritères et les théories des ensembles flous, des possibilités et des fonctions de croyance en relation avec un environnement SIG.*

ABSTRACT. *Expertise of natural risks in mountains depends on more or less imperfect spatial information. A method called* Spatial ER-MCDA *is proposed to figure how these imperfections influence expertise results. It mixes multicriteria decision making, fuzzy logics and evidence theory in relation with a GIS environment.*

MOTS-CLÉS : *risques naturels, montagne, expertise, aide multicritères à la décision, SIG, fusion d'information, logique floue, théorie des fonctions de croyance, DST, DSmT*

KEYWORDS: *Mountain natural hazards, expertise, multicriteria decision making, GIS, information fusion, fuzzy logics, evidence theory, DST, DSmT*

1. General context : expertise, decision and natural risks management

Natural phenomena in mountains put people and material assets at risks with dramatic consequences. Risk level is often described as a combination of hazard and vulnerability. Hazard relates to the intensity and frequency of a phenomenon while vulnerability concerns damage consequences and values assessment. One one hand, risk management implies to combine those two components to assess risk level and, on the other hand, to define and choose between the different risk reduction measures.

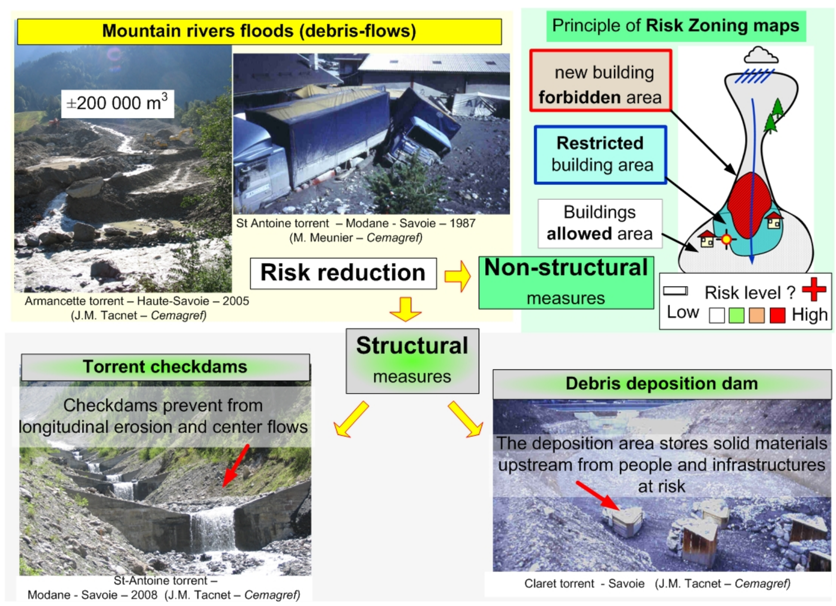

Figure 1. *Torrential floodrisks and risk reduction measures*

Expertise is almost always required to take decisions related to prevention, crisis and recovery steps of the risk management process. Risk managers, local authorities, infrastructures managers have, for example to choose to implement structural measures such as civil engineering protection works and/or non structural measures such as land-use and building controls (figure 1). Expertise is based on quantitative, qualitative but also spatial description of natural phenomena. Due to partial knowledge and variable reliability of the sources, available information about natural phenomena often remain imperfect. This can lead to many imperfect experts evaluations such as : "we are certain that this avalanche or torrential flood has reached this point, area . . . " or "it is possible that the flood deposit was between 1.5 m and 2.5m . . . ". An expert can also estimates that "the debris flows volume is up to 15000 m^3" but we know that he is not fully reliable (a beginner, expertise conditions). . . An important issue consists in determining risk limits in zoning maps applications : how far can we be confident in expertise results and take a decision when both spatial extents, intensity and consequences of the phenomena may be assessed imprecisely ?

Expertise can be considered as a decision problem based on imperfect and heterogeneous information provided by more or less reliable and possibly conflicting sources. Ad-hoc and specific decision support systems are therefore needed to help decisions in this context of imperfect information. To be efficient, they have to take into account and trace information quality, including attribute and spatial values, in the global risk assessment decision process.

2. Information fusion to manage spatial information imperfections and heterogeneity

Fuzzy Sets (Zadeh, 1965), Possibility (Zadeh, 1978; Dubois *et al.*, 1988) and Belief Function Theories are able to consider altogether all kinds of information imperfections such as vagueness, imprecision, conflict and uncertainty. Our methodology extends the *ER-MCDA* approach (Evidential Reasoning and Multicriteria Decision Analysis) (Tacnet *et al.*, 2010) to spatial information with an application to natural risks management problems as proposed in (Tacnet *et al.*, 2009; Tacnet, 2009). The new methodology presented in this paper allows to consider in the same framework both uncertainty and imprecision of the spatial extent of information (e.g. debris-flows, avalanche extent) but also its attribute values such as quantitative values (height, speed, volume, . . .) or qualitative indexes (reached, not reached . . .).

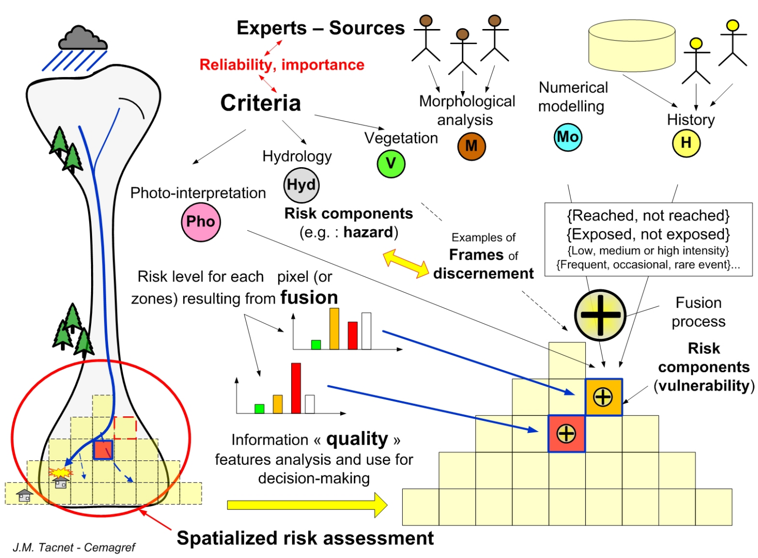

Figure 2. *Risk level results from fusion of available heterogeneous information*

Imperfect information (spatial extent and/or attribute values) are first represented in a G.I.S (Geographic Information System). For example, we aim to determine an hazard level using the extent and intensity of a debris-flows event. Information comes from sources such as an historical database (imprecise, not fully reliable), expert field analysis (based on an expert judgment) or numerical modeling results (whose uncertainty depend on input data quality)(figure 2).

Information is represented through vector and raster approaches. Geographic information (spatial and attribute values) are processed to be introduced in fusion calculation routines using the Dempster-Shafer theory (DST)(Shafer, 1976) and the Dezert-Smarandache Theory (DSmT)(Dezert *et al.*, 2009). Advanced fusion rules (PCR rules, partial conflict redistribution rules)(Dezert *et al.*, 2006) are used instead of the classic Dempster fusion rule to take decisions. At the end, we can spatially represent not only hazard (or risk) level but also a confidence level based on the information quality used to take decisions.

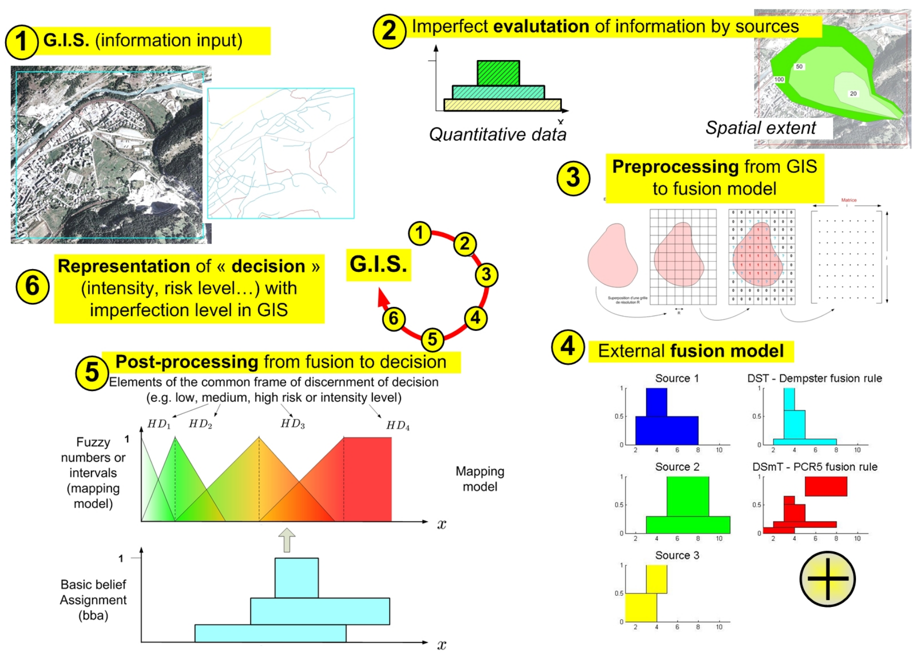

Figure 3. *Principles of the* Spatial ER-MCDA *methodology*

3. Conclusion - Discussion

Using both multicriteria decision analysis, fuzzy sets, possibility and belief function theories allows to consider any kind of information including its imperfection and the sources heterogeneity. On one hand, the spatial *ER-MCDA* methodology allows to trace and combine spatial information imperfection (on extent and attributes) from sources to the final decision and, on the other hand, to represent the result in a G.I.S.

These developments are partially founded by the project *ADAGE* founded by the *ECCOREV* research consortium program [1] 2010 of Provence,Alpes, Côte-d'Azur Region (PACA) and the *PARAmount* Project [2] of the European InterReg Alpine Space program.

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