Making the best use of ecological and efficiency indicators to guide flood risk project management

Christine Poulard, Pascal Breil, A. Evette, M. Lafont, L. Schmitt, R. Vivien, M. Laluc

MAKING THE BEST USE OF ECOLOGICAL AND EFFICIENCY INDICATORS TO GUIDE FLOOD RISK PROJECT MANAGEMENT POSTER 1: USING IMPROVED RIVERSCAPE CONCEPT FOR DESIGN STAGES ; POSTER 2: EVOLUTION OF INDICATORS FOR DECISION MAKING AT DIFFERENT STAGES

Christine Poulard, Pascal Breil: Irstea**,** UR HHLY, 5 rue de la Doua CS 70077, F-69626 Villeurbanne Cedex, France (firstname.lastname@irstea.fr)
Michel Lafont, formerly Irstea / Les Jardins d'Artémis, F-69100 Villeurbanne, michel.lafont33@sfr.fr
André Evette, Irstea, F-38402 Saint Martin d'Hères Cedex, France ; andre.evette@irstea.fr
Laurent Schmitt, Université de Strasbourg, Faculté de Géographie et d'Aménagement, Laboratoire Image Ville Environnement UMR 7362 Unistra-CNRS-ENGEES ; 3 rue de l'Argonne, 67083 Strasbourg cedex Strasbourg, France ; laurent.schmitt@unistra.fr
Régis Vivien, Swiss Centre for Applied Ecotoxicology (Ecotox Centre), Eawag/EPFL, 1015 Lausanne, Switzerland ; regis.vivien@centreecotox.ch
Mélanie Laluc, BURGEAP, 19 Rue Villette, F-69003 Lyon , France ; m.laluc@burgeap.fr

Key words

Flood mitigation, multiobjective strategy, MCA, co-conception, riverscapes

Subtopics [1.1] [1.3]

Introduction

"Flood control" policies have now shifted to "integrated flood risk management", which should also blend nicely within "water management" and "sustainable development". Thus, flood risk reduction strategies are one element to define in coordination with others in a broader picture. From a practical point of view, the relevance of flood management projects must now be examined under several angles.

This is where Multi-Criteria Analysis is useful: they assess objectively the impact of projects through different indicators, either to guide decision-making by the project manager, or even to obtain final authorizations and/or funding. Here, we advocate that it could be used as guidance throughout all the stages of the project, to ensure informed decisions at each step, from the definition of the project broad lines to the choices of technical details. This means that we need tools and indicators to help people with different backgrounds and objectives, not necessarily used to working together (e.g. hydrologists, ecologists, geomorphologists, planning managers including urban planning, citizens...), to define common objective and improve collectively technical solutions. We propose here a practical method to define the best compromise between the different disciplines involved by the project, and all along the process.

Material and methods

The first step was a feed-back analysis of dry dams (Poulard *et al*., 2009), which showed a great diversity of technical solutions for the same objective (dam mitigation), and led to the question of the respective impact of each design on the river aquatic ecosystems. From this material, we tried to define a metrics of the impact of anthropization on the river biodiversity and ecological functions in a Polish catchment (Poulard *et al*., 2010). For this, we used a pragmatic typology based on riverscapes (Malard, 2006), summarizing relevant information for all possible types -natural and artificial: we suggested to measure the impact of structures by the shift in riverscape type: from the riverscapes before the project, to the riverscapes once the dam built. This metrics, even if only qualitative, can guide technical choices. To facilitate the emergence of good technical solutions, we suggested a way towards a compromise: for each part of the dam, the riverscape shift due to different variants is assessed: the solution that meets civil engineering and hydrologic requirements and causes the lesser shift is the best . However, this first application in a homogeneous context (similar rivers, little diversity of structures) led to a well-hierarchized, simple typology: obviously further developments were required for more complicated cases.

We then proposed to generalize the approach from dry dams to any other feature modifying a river, for flood mitigation or restoration (Poulard *et al*., 2011). Lafont (2011) suggested using Functional Units to define riverscapes in more details (Table 1). Poulard *et al*. (2013) proposed to enrich the description of the riverscapes with features of the adjacent terrestrial ecosystems (presence/absence of riparian zone…) and to complete the individual diagnostics for each projected modification with a global diagnostic at the scale of the whole studied domain, in terms of diversity and spatial coherence.

POSTER 1 presents further improvements to this approach: we now consider the terrestrial ecosystems, where relevant, as independent entities ; we propose to coin the word "terrascape" on the model of our riverscapes descriptions. Riparian ecosystems show a high level of biodiversity, partly controlled by flood regime through disturbance and flow of diaspores (Junk *et al.* 1989, Merritt *et al*. 2010). Works from Cavaillé *et al*. (2013) on riverbank protections could serve as basis to define riparian terrascapes. Even fully terrestrial ecosystems can be integrated in the study when impacted by floods, sometimes severely (e.g. Koutecký and Prach 2005), or by flood mitigations structures. For instance, the water level upstream dry dams rises dramatically during floods, which damages the terrestrial ecosystems in dry dam bowls.

POSTER 2 presents a framework to place this approach in a coherent process, from specification writing to assessment. Indeed, our previous works were focused on the design stage, after the type of actions is already chosen (dry dams), and only variant of technical solutions are examined, within the same range of costs and efficiency. In a context of integrated management, it appears now necessary to start co-conception earlier. This second poster therefore presents a framework to guide decision-making at all stages, using Multi-Criteria Analyses.

Theory

Rethinking the approach to better fit it in the context of actual project led us to:

1) **Poster 1:** Refine the principles of our approach and improve description of riverscape types:
- we propose, as support for discussions, synthetic descriptions of every natural and artificialized conditions in the form of "riverscapes" and "generalized -scapes" where relevant, understandable by everyone involved. Riverscapes with a code "0" are (near-)natural types present in the studied domain ; they constitute a reference, whether ecologically good or poor. Riverscapes derived from a reference type are named after it, with a code increasing with the level of degradation.
- The measure of impacts of proposed actions is the subsequent shift of types;
- each implementation will lead to a different description of types and of evolution indicators, depending on the natural context, the objectives of the project and the types of actions to be assessed. They must be tailor-made in concertation to help people understand each other, define common solutions and collect and integrate suggestions from different specialists ;

2) **Poster 2:** Link the indicators with those of the MultiCriteria Analyses assessing the final project.
- the discussions are to take place throughout the project, from the choice of the general orientations to the design of each action, including technical details when relevant. The idea is to define for each stage an adapted MCA, suitable for discussions, while ensuring coherence between the stages, always keeping in sight the final MCA, requested by the project manager or external authorities. In this framework, poster 1 corresponds to one of the stages of the process.

Results

Poster 1: Table 1 shows a riverscape described by Lafont (2011) using Functional Units. We sketch in table 2 how "terrascapes" could be defined. Features which discriminate a riverscape reference type from the others, or a degraded form from the others, must be put forward ; common features can be omitted (e.g., the soil type is not detailed here, but could be relevant in other cases). To prepare the assessment of local modifications, the possible shifts from the natural type (P0) to more degraded types are described, whether by hydraulic works (P1) or human activity (A). To help the global assessment, positive and negative interactions with other "scapes" are also very important, whether with adjacent areas or beyond (for instance, dry dam modify the flood regimes and subsequently sediment transport over a long reach downstream).

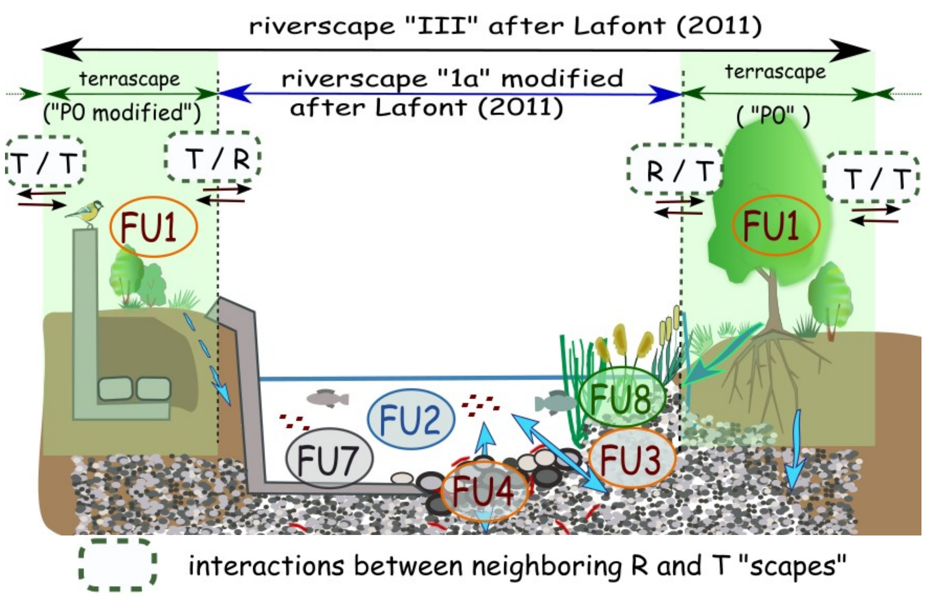
Physical characteristics	*semi-natural conditions 1a: 30 to 50% artificial ; 1b: 50 to 70 % artif.* *Surface Water / Ground Water (SW/GW) connections partially restored*
processes	*Metabolic processes of increasing diversity compared to type 2 (100% impervious, no SW/GW exchanges). The porous matrix fully acts as a filter (FU3, FU4).* ***Type 1b*** *with sandy or fine sediment deposits (FU5, FU6)* ***Type 1a*** *has better SW/GW exchanges, and macrophyte assemblages (FU8)*
Biomonitoring indices suited to this type (here, French indices)	*Biomonitoring may be performed using diatom indices, oligochaete Functional Traits, macrophyte indices, IOBS index and harmonization system. Traditional invertebrate indices and fish index can be used, but mainly in* ***type 1a*** *which is coming closer to a "natural" system. The use of geomorphological reference types (Schmitt et al. 2006; 2011) might be indispensable when the physical restoration from a type 1 to type 0 (near natural or natural) is planned.*
Schematic cross-section with Functional Units: example of ***1a*** *FU1: interactions terrestrial / aquatic environments; FU2: water mass; FU3: coarse sediments; FU4: hyporheic porous matrix; FU7: flat system (boulders, impervious material); FU8: macrophytes*	

Table 1: new description of a riverscape, based on functional units, where terrestrial units (FU1) are excluded to be addressed separately as "terrascapes" ; modified after Lafont (2011), Differences with better type (0) and more degraded (2) are explicitly mentioned and described.

Physical characteristics of "P" type	***P0*** *(natural riverine habitat)**: simple description:** "characterized by patches of habitats, trees + bushes + grassed areas" ;* ***finer specialized description (…)*** *,* ***P1:*** *natural landscape like P0 but located within a dam bowl: subjected to enhanced flood hazard (water stored for a longer time and with high water depth ;*

(and subtypes)	*possible sediment deposit…).* ***Possible shifts**: P0 <=> P1(construction/removal of a dry dam) ; P0, P1 <=> **A** (A= agricultural area outside dam bowl, Ab =within dam bowl…)*
Links with other "scapes"	***Positive interaction** of P0 and P1:* • *(+) with the other nearby natural patches (connected better than isolated)* • *To the river: (+) P0 and P1: input of organic matter, shade ; (-) Ab: possible pollution of cultivated land by chemicals or fine sediments* • *(+) From the river to types P: water, food for birds*
Representative photos	 *P1 in normal state vs flooded conditions*  *P1: blocks deposited after flood event*
Table 2: Possible description of "terrascape" type and sub-types suited for a dry dam bowl	

Poster 2: Our previous works focused on dry dams, and concertation consisted in choosing the "best attainable riverscapes", to reduce the negative impacts on the river. Poster 2 proposes to generalize the concertation process, from earlier stages (choice of action) and ensure compatibility with the final multi-criteria assessment. Our working hypothesis is that multi-criteria analysis can provide a good framework for decision-making at all stages. To improve a project, the scores for every criterion are useful: a total score would hide the specificities. Radar graphs appear very appropriate to display these results in a synthetic way, and thus discuss and compare solutions (e.g. Edjossan-Sossou *et al.,* 2014.). Table 3 gives an idea of how MCA could be used and adapted throughout a project, from to definition of the project to the design stages. The prerequisite is an explicit list of the project manager's objectives (stage1). They should be compatible with the local and national policies when relevant, and comply with the requirement from authorities or funding institutions. In the early stages, we need a very pragmatic and simplified form of MCA. As the project progresses from one stage to another, criteria are refined, other are removed because they are insensitive to the remaining choices, but always in good agreement with the other stages, in particular with the MCA used to assess the final project (for internal decision-making and/or to obtain authorizations or funds). Table 3 tackles practical problems: how to define the minimum and maximum for each criterion (absolute or relative values ? how to account for uncertainty ?…) ; the examples shown here illustrate the issue but of course in each case the choices have to be made by the people involved in the project. Poster 1 deals with stage 3, after the actions are chosen (dry dams, in our case); the impact of individual actions are measured by the shifts in riverscapes. We added here an indicator of the overall impact at the scale of the catchment, based on the respect of green and blue networks

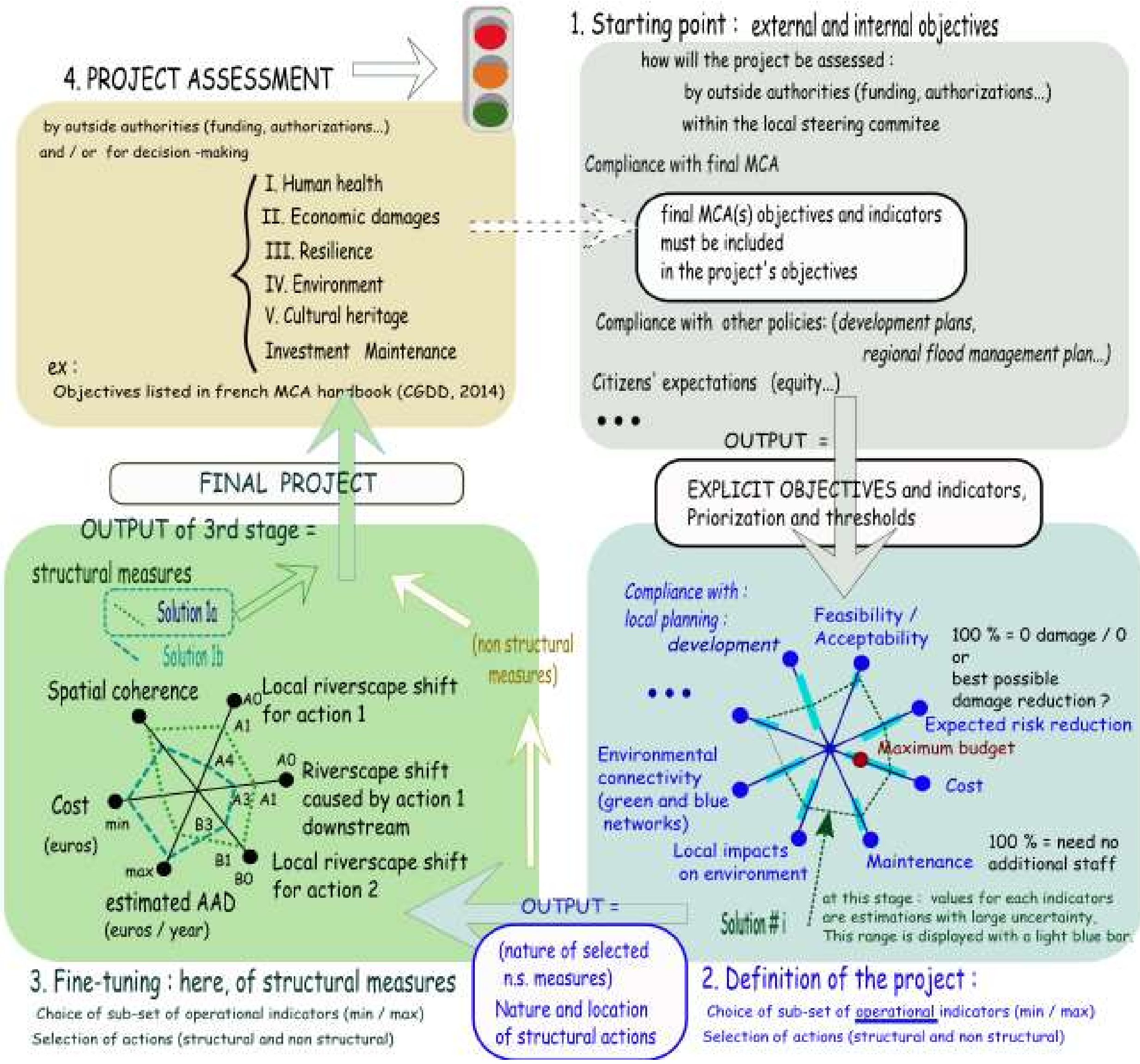


Table 3: Possible evolution of criteria displayed on radar graphs from early to final stages

Discussion

Although explicit objectives seem a prerequisite to any project, obtaining an exhaustive list of all the decision criteria that will be used might remain difficult. We also need an idea of the priorities, i.e. weights given to reach indicator, and thresholds (for a given criterion, can "poor" be tolerable if the other criteria are excellent, or not). Furthermore, there is no standard method to define synthetic "environmental indicators". In France, the national guidelines on MCA for flood risk mitigation projects list as "environmental indicators" only accidental pollutions of the environment caused by flooded facilities (CGDD, 2014). However, they announce on-going works, and "standard" environmental indicators should be given in a near future. Finally, to draft a project, we should not forget common-sense criteria like "feasibility" – including time-scale, acceptability, partnerships…- can also be very determining.

Another major difficulty is the assessment of indicators in early stages: only estimations can be reasonably provided. Table 3 suggests a "best situation" be defined, thus the score could be a percentage of this optimum. Similarly, the reliability of assessment is an interesting information: therefore, an expected score can be usefully completed by a range of uncertainty.

All these objectives remain theoretical and cannot be achieved if not supported by a transdisciplinary team, including in particular end-users from public and/or private organisms (Lafont, 2011; Lafont *et al.,* 2010; 2012; Tixier *et al,.* 2012; Vivien *et al.,* 2014). Practitioners who will be in charge of technical achievement or maintenance should also bring their expertise throughout the project: they can be aware of what is feasible and what is not, and of technical alternatives. Concerning public participation, we suggest it should take place in the early stages, and in particular in the definition of objectives to ensure public acceptance.

We insist on the necessity for the transdisciplinary team to follow and share the same conceptual and operational approaches, for example the riverscape typology, and that aslo includes guides for end-users (Lafont, 2011). Conceptual and operational phases are linked approaches, and have to be accepted and shared by the team. The triad [project/approaches/team] seems in our opinion a key to the success, because it constitutes the indispensable cement for the complete development of a given project. The triad differs from a project to another: other concepts, teams and end-users (Gaillard, 1997).

Conclusions

The idea is to make the best use of the competences of each involved person, including technical staffs. Co-conception implies the active participation of all. Therefore, our approach insists that first the objectives have to be explicit and shared, and that solutions must be found to discuss and compare the means of action, using common conceptual and operational views.

Our approach still has to be implemented for full-scale studies, in real and varied contexts, to test and improve the method to a fully operational stage. Only then can "guidelines' be written, but always allowing much freedom in the implementation. Future implementations should be followed closely, certainly not to control the process, but to capitalize on the experience. Social sciences should be closely associated to the project, to analyze the paths towards solutions: how different specialists collaborate, which were the expected and unexpected misunderstandings at the beginning, how they were identified and solved, how compromises were made, how each specialist around the table really influenced the final version of the project. Of course, each project is different, but feed-back analysis can always bring insight to the delicate art of project management and help identify obstacles and solutions for fruitful co-conception (Lafont 2011; Richard-Ferroudji, 2014).

Acknowledgements

This study started in collaboration between Irstea and Cracow University of Technology thanks to funding from PHC bilateral projects and EcoNet 3-partner projects.

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