

SYRAH-CE : SYstème Relationnel d'Audit de l'Hydromorphologie des Cours d'Eau

A relational, multi-scale system for auditing the hydro-morphology of running waters: diagnostic tool to help the WFD implementation in France

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The context

The implementation of the European Water Framework Directive (WFD) requires a practical tool for the analysis of the hydro-morphological functioning of the running water ecosystems, in order to implement the relevant restoration measures. The "Good" ecological status, which is the common objective assigned to all waterbodies, is based upon the assessment of the biological elements (fish, invertebrates, macrophytes and phytobenthos) and of the supporting chemical parameters.

The assessment of the physical characteristics is only required to qualify the "High" ecological status, but must be taken into account through the impacts on the aquatic habitats, which influences all the biota and thus the ecological status.

Audit principles

The primary determinants at a regional scale (topography, geology, climate) define the hydromorphological control variables (hydrological and sediment regimes, width and gradient of the valley bottoms). The key factors of the ecological functioning (physical habitat, aquatic "climate", food webs) rely on these variables, as well as on the structure of the riparian vegetation and the correct state of the lateral and vertical connectivity. To understand and diagnose the ecological dysfunctions driven by hydro-morphological alterations, we must necessarily take account of this hierarchical and multi-scale organisation of the hydrosystems.

The "top down" approach proposed in the SYRAH-CE audit relies on the assessment, at large scale, of the "damage risk", which allows to focus the analytical work on a lower level if a high probability of damage is evidenced. For technical and economical reasons (short deadline, limited budget), the assessment of the hydromorphological alterations, in the context of the natural physical functioning driven by the primary determinants, has been given precedence over a more conventional approach involving a description of the "status" confined solely to the station level.

The deterioration of the processes (particularly water and sediment fluxes) and related structures (river morphology) are at the heart of the assessment because:

- they are closely linked to the intensity of anthropogenic pressures in a given geomorphological context (at the reach or segment scale),
- they are clearly at the root of the direct and indirect disturbances of the aquatic habitats, but also of their regeneration processes.

Fourteen types of hydromorphological damage have been identified. These are the most common and the most likely to be the cause of impairment of the rivers' ecological status. The audit process relies on an evaluation of the layers of geographical data, existing databases, and on cross references between this information and the data required for management, programming, decision-making and assessment of restoration actions.

Principle

We direct our first scale of analysis of hydromorphological dysfunctions at the level of a higher compartment called "Land cover and activities" (urbanization, agriculture, transport, energy). These

activities and land use interact, according to their nature, with the physical functioning of running waters at several different spatial, lateral and longitudinal scales (watershed, floodplain, river channel). They are set out in concrete terms in "Engineering works and uses", which are identifiable and often quantifiable objects, with direct and indirect effects on the river functioning. These effects translate into "damage to processes" (modification of water and sediment fluxes, stream erosion processes, hydrodynamic components) and "structural alterations" (bed morphology, longitudinal and transversal geometry, morphological units, substrate) of the physical environment (figure 1).

These different types of damage are in fact modifications (detrimental) of natural forms of running waters and consequently of their habitats.

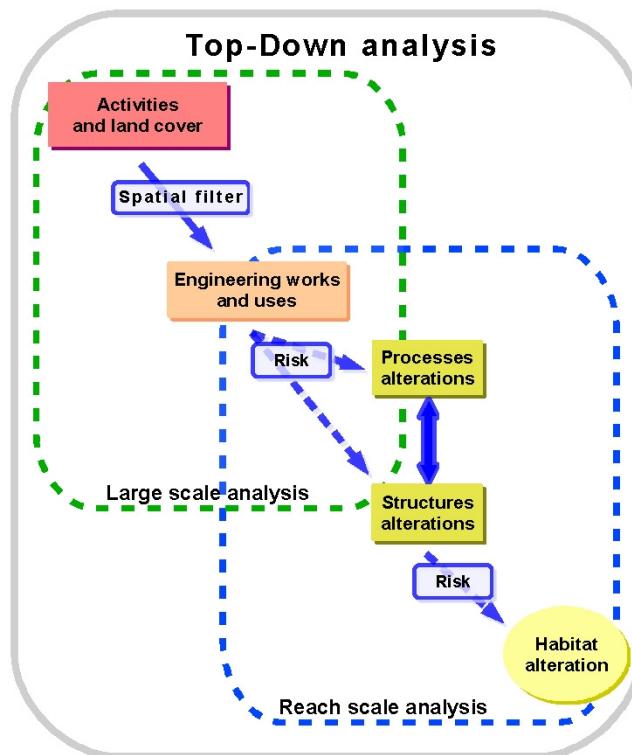


Figure 1 - SYRAH-CE conceptual framework

Types of damage: disturbance of physical structures and functioning

The main aim of the audit is to detect hydromorphological damage of a "non-natural origin" which can be clearly linked to deterioration of the "ecological status", particularly through a deterioration of the aquatic and riparian habitats (figure 2).

Structural damage (mainly morphological) is generally evidenced by a modification of the "fluvial forms" (main channel and secondary channels, succession of morphological units, river channel geometry, substrate). This necessitates descriptions or measurements taken by direct observation in the field. As regards damage to processes (flow and sediment fluxes), we must factor in a notion of time, which requires the use of time series.

It is difficult to assess the damage directly, especially in terms of structural damage (it is necessary to carry out measurements in the field on the entire river system), and perhaps even impossible (complicated and voluminous database systems to be set up and kept up to date). It has therefore been necessary to propose an indirect assessment method.

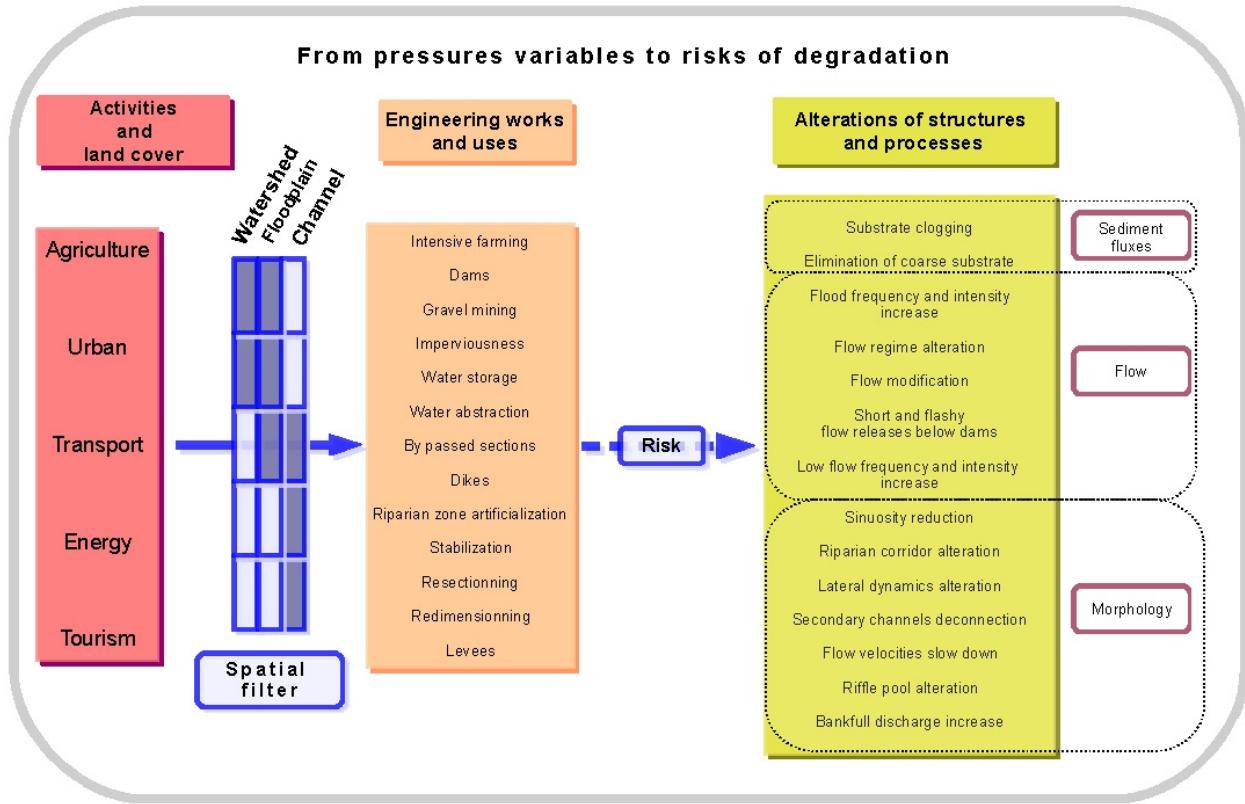


Figure 2 - Pressure and physical damage risk variables

Artificial features and uses

The final aim of the audit is to foster the implementation of measures designed to rectify, if possible at source, the ecological damages. It seemed appropriate to propose audit methods starting "upstream" in the causal chain, and thus at the level of "Engineering works and Uses".

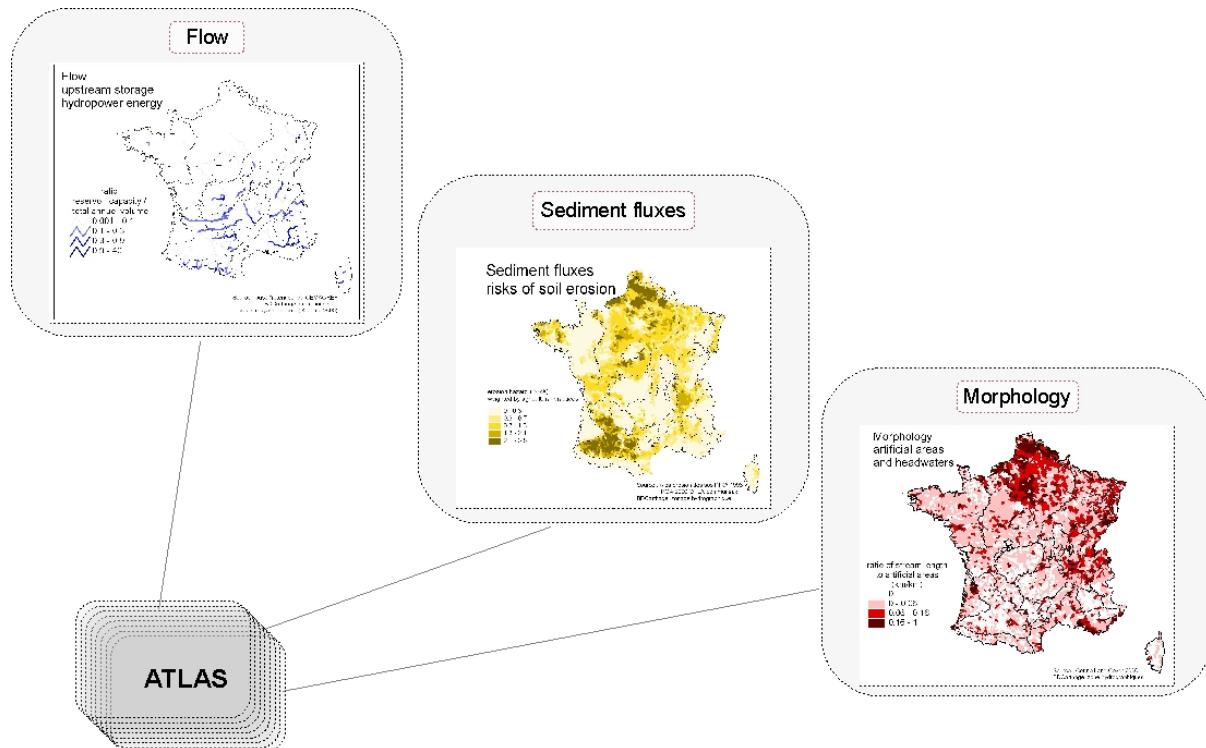


Figure 3 - Examples of maps taken from the large-scale analysis of engineering works and uses

A list of works and uses likely to cause hydromorphological damage has been drawn up, taking account of the various spatial scales involved: basin (agriculture, urban area), floodplain (agriculture, urban area, transport), river channel (agriculture, transport, energy, sometimes tourism) (figure 2).

It is possible to identify and analyse at a large scale all these features in using national geographical databases (figure 3). The resulting maps can be used for management and programming purposes but their precision is limited, particularly regarding "local" morphological aspects. This scale of analysis is therefore inadequate to enable a precise diagnosis of the dysfunctions and to design restoration measures, but does nevertheless provide us with an overview of a large area (i.e. to see the forest before the tree...).

The analysis at the scale of geomorphological reaches provides a description of these "engineering works and uses" at a level of precision compatible with the search for causes of deterioration of the ecological status. This level of precision in the analysis is made possible by the existence of precise geographical databases such as BDTOPO IGN® (figure 4).

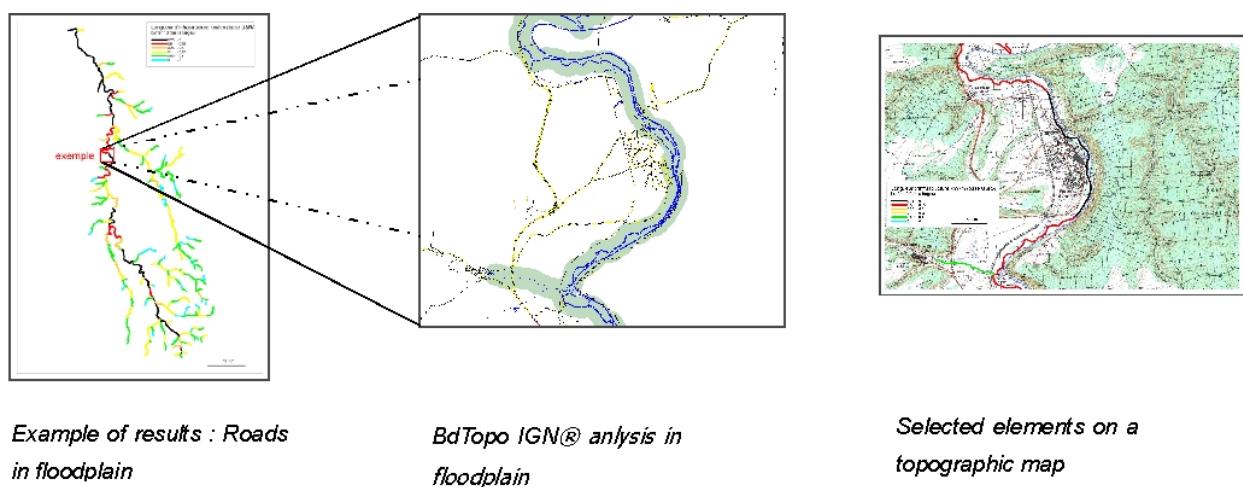


Figure 4 - Example of an analysis at the scale of a section using BDTOPO IGN®: communication infrastructures in floodplain

Results

We obtain raw indicator values for the identified "engineering works and uses" of each analytical unit (geomorphological section). These results can be stored in georeferenced databases, and mapped (figure 5). A further step will be necessary to reinterpret these results according to the geomorphological characteristics of the section in which they were collected.

For example, an identical density of thresholds does not have the same consequences in a fast-flowing mountain torrent as in a lowland river with a gentle slope. Another example: infrastructures in the floodplain close to the river channel will have really negative consequences only on dynamically active rivers.

Potential uses of the audit

Apart from mapping the risks of hydromorphological deteriorations undergone by rivers, the SYRAH-CE¹ audit provides aid for management decision and functional restoration.

The raw results of the audit allow an easy identification of the parts of the river network that are undergoing limited pressure. This information, combined with the knowledge of the chemical

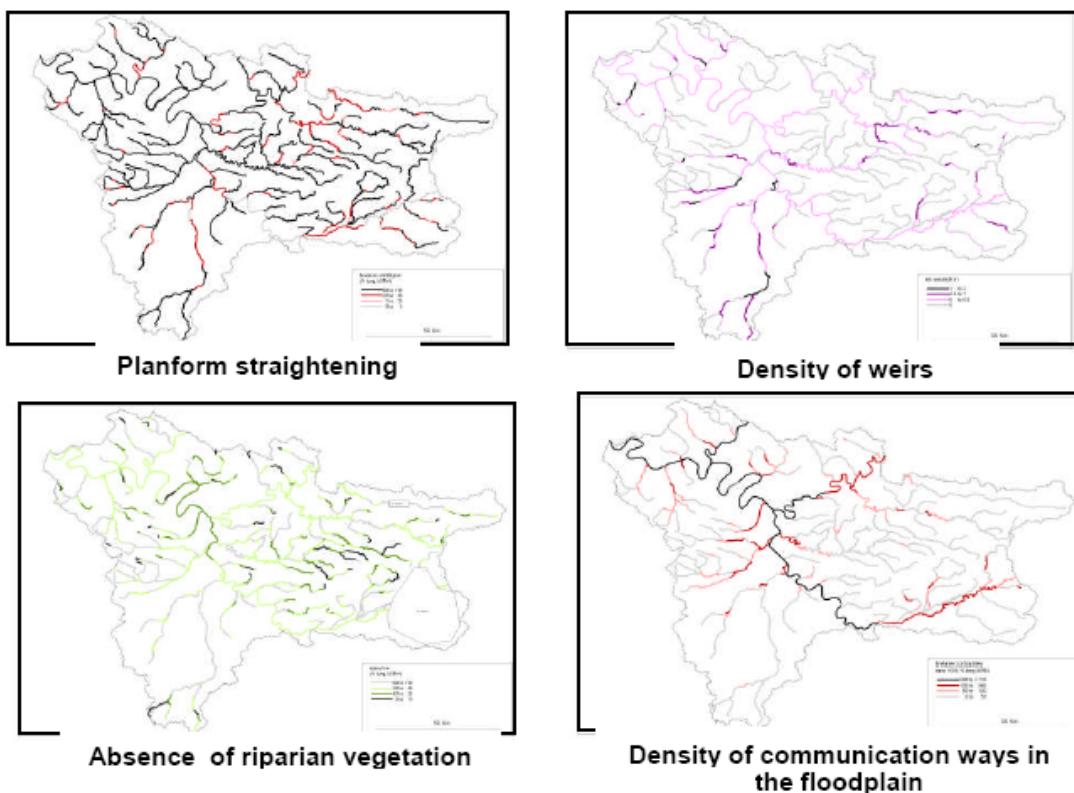
¹ Chandesris A., Malavoi J.R., Souchon Y., Wasson J.G. & Mengin N., 2007 a. Le système relationnel d'audit de l'hydromorphologie des cours d'eau (SYRAH CE): un outil multi-échelles d'aide à la décision pour la gestion des cours d'eau. Ingénieries - Eau Agriculture & Territoires, n° 50, p. 77-80.

quality of the water, is necessary to delineate the sectors likely to be classified in "High status" according to the WFD, which are thus a priority for conservation.

The method used allows the rivers analysed to be considered in a more general context, and focuses the analysis on the hydromorphological functioning, considered on a scale that exceeds the site of investigation.

Mapping the indicators that represent the pressures causing geomorphological dysfunction allows to identify the most prevailing ones; the problems can be located, and even categorized in a ranking order.

An analysis of this set of information could provide support for the establishment of management plans to be considered on several scales, with an easier identification of desirable restoration actions, and help for the decision-makers.



**Figure 5 - Examples of results of the analysis of engineering works and uses
(AESN –DRIF Malavoi, 2007).**