Farmers, policy makers, and researchers faced to the search of innovative alternatives for water quality preservation: three French case studies.

Fabienne Barataud, Marc Benoit, Florence Hellec, Laura Martin

INRA – SAD, UR ASTER (Agrosystèmes Territoires Ressources), 662 av. Louis Buffet, 88500 Mirecourt, France

Abstract

Admitting that the stakeholders have shared and distributed cognition about the relations between activities and water quality, the question is that of mobilization of this heterogeneous knowledge of complex territories. Therefore, it is expected from researchers to analyze and produce efficient methods of expression, acquisition, and sharing of knowledge, to allow coordinated evolutions of farmers' practices.
The study of three French watersheds (Harol, Lons-le-Saunier, Vittel) with a common problem of agricultural diffuse pollution enables us to identify two main stakes, with regard to:
- the management of these territories: period of time let to the actors to evolve, possibility given -or not- of getting feedbacks, and capacity of innovation related to the kind of relationships between the partners.
- the research contribution: level of interdisciplinarity used and quality of the tools (mapping of local knowledge, modelling).

Key-words : catchment management – stakeholders – landscape agronomy

Introduction

In spite of measures taken since more than twenty years to reduce water pollution by urban and agricultural activities, nitrate contamination of ground and surface water remains a matter of concern in many European regions as officially revealed by a report of the European Commission (2010) taking stock of the application of the Nitrate Directive of 1991. In France in particular, many regulatory and incentive actions have been conducted to reduce diffuse nitrogen sources from agriculture, including manure management plan, agro-environmental measures, or advices, but it clearly appears that the results obtained so far are not satisfactory in view of the objectives set by public authorities (European_Commission, 2002 ; rapport de la Cour des Comptes, 2009).
The key objective of the European Water Framework Directive (WFD 2000/60/CE) is to achieve by 2015 a "good water status" for all European surface and underground waters.
Clearly more drastic changes beyond the simple marginal adjustment of current agricultural practices will be required on a long term basis in nitrate vulnerable areas. Hence, the Grenelle-2 Law, which is the French translation of the WFD, aims to strengthen and orient the actions: "By 2012, action plans will be implemented to assure the protection of 500 drinking water wells (at the national scale) the most threatened by the diffuse pollutions, in particular nitrates and phytosanitary products. On these catchment areas, priority will be given to the surfaces of organic farming [...] in order to protect the water resource and reduce its costs of treatments."
In this strongly forcing context, the local stakeholders - water agencies, municipalities, farmers' associations, unions of exploitation of waters - are in search of local methods and solutions to answer these objectives on these watersheds of utmost importance.
We have to admit that at individual scale already designing a system with the aim of supporting decision making is a complex process with multiple connections between the various dimensions of a decision: between technical operations competing for resources, between temporal and spatial scales, between biophysical, technical, organizational, and economic processes. Separating the complex system in subsidiary sub-systems as decision sub-system, technical sub-system and bio-physical sub-system (Le Gal *et al.*, 2010) is one option to better understand the interrelations between these various dimensions. Different actors won't mobilize the same sub-systems; depending on situations and their specific goals, one or other sub-system should become central or on the contrary ignored.
So it's a common point that the exchange of points of view could serve in the analysis of a problem, its modelling and the definition and evaluation of alternative scenarios; complex issues (and catchment management is obviously one of them) can be better resolved taking into account the diversity of interests and mental frames, and relying on disseminated information and knowledge (Maurel *et al.*, 2007). This conclusion is formulated by many authors who point out that there are advantages of involving stakeholders in the design process of tools and innovations (Le Gal *et al.*, 2010; Reed, 2008); furthermore better decisions are then implemented with less conflict and more success when they are driven by stakeholders (Voinov and Bousquet, 2010).
According to these observations WFD (Article 14) states that public participation is one of the five main instruments to reach the environmental objectives: "Members States shall encourage the active involvement

of all interested parties in the implementation of this Directive, in particular in the production, review and updating of the river basin management plans."

But on the basis of this report, and to avoid a quite nominal or reduced engagement of stakeholders, many questions are arising: how to organize this exchange (it is the question of the various stakeholders processes), with which tools can we support the decision making (it is the question of the Information and Communication tools), what is the place of technical information, and the role of researchers within collectives in charge with these environmental, human and practical challenges?

Methods

Our paradigmatic basis

Territories are systems impacted by anthropogenic influences (and more specifically agricultural practices), thus they are relevant to the notion of bio-complexity; this term has emerged as a description of the rich patterns of interactions and behaviours in human and natural systems (Bolte *et al.*, 2006). Territory (an appropriated and managed piece of land) and farmer practices are joined in a double bind (in reference to Gregory Bateson works): territory is a result of farming practices and territory is a factor of farmer practices.
Water is then a product of this interaction between territory and farmer practices.

Scientists can be asked to mobilize the knowledge acquired on the interactions between activities and resources, or to improve management and planning of these systems. The role of technical information in shaping the discussions is central as all sides in the debate are employing scientists and scientific assessments (Gasteyer, 2008). Scientific contributions are expected to join many advantages: they should facilitate understanding by stakeholders of physical phenomena and environmental consequences; they also should offer a good compromise between simplicity and reliability. However this compromise is not easy to achieve; the simplification of one dimension (biophysical or technical dimensions, decision rules) increases the risk of working on representations that are divorced from reality; in an inverse way the use of too complex representations techniques for processes under study (dynamic models, rule-based models) may prove to be counterproductive by rendering the proposed model difficult for the users or the targeted populations to understand and validate. Scientific information and analysis should certainly inform stakeholders' deliberation, but unless carefully balanced such information may bias decisions. That's why scientific knowledge should be thought in combination with local knowledge in order to contribute to a more comprehensive understanding of these complex and dynamic systems and processes.
By triangulating different local and scientific knowledge sources it may be possible to investigate uncertainties and assumptions and develop a more rigorous understanding as well (Reed, 2008). The joint production of knowledge presents the advantage to be able to evaluate the appropriateness of potential technical and local solutions to environmental problems.

In those situations, we have to distinguish two types of innovative processes, as proposed by Le Masson *et al.* (2006):

- Rule-based design whose goals are clearly defined in advance and reached throw gradual modifications of products or existing technologies; skills and validation processes are unchanged from one innovation to another.
- Innovative design whose frame is called into question, whose goals take shape during the design and for which it is not possible to specify in advance the required skills and the validation methods.

For our purpose we make the choice of "innovative design "way to solve those questions of water resources protection.

Reasons of case study choices

Vittel is a typical case of mineral water catchment. In these situations, manager of water resources have to use preventive solution, because curative one with treatment of water are forbidden. Another reason of this choice is the high quality of aquifer delineation and modelling.

The Lons-Le-Saunier catchment was chosen because public action in order preserve public water quality was specifically developed here at the beginning of the 1990s and so constitutes a particularly interesting and "historical" case for the French context. It is often cited as a success story (like Münich in Germany); due to its strategic character (it provides drinking water for a huge population – 25 000 inhabitants - and no neighbouring substituting resource does exist), this catchment was designed as one of the 500 Grenelle areas.

The catchment of Harol, our third case study, belongs to the Grenelle's list too; the problem here is a high nitrate concentration clearly due to agricultural diffuse pollution. The collective is faced in this particular case to a dualism: it is the place for a participatory process that has to compose with the policy constraint that imposes short term results. Its interest lies in the possibility to go with a living process on a small territory subjected to a strong legal constraint and that is supposed to serve as a reference for the others contaminated catchments.

Methods of investigations, place of the research

For the two first study cases (Vittel and Lons-Le-Saunier) we can perform an ex-post analysis of the water management; on the contrary, Harol is at the beginning of its management (or participation) process.
Vittel Research has been associated throw a contract between Vittel mineral manager, Rhin-Meuse Water Agency and the research teams. We can distinguish five steps corresponding to five diverse aims for researchers:

- 1989-1993: diagnostic of the main agricultural practices related to water quality risk
- 1992-1996: propositions for new cropping and farming systems
- 1996-1998: analysis of the changes in the farming systems
- 1998-2001: evaluation of the effects of theses changes
- 2002-2004: elaboration of management tools for the farming system

In Lons-Le-Saunier a total of 30 interviews were carried out (in 2010) with the leading actors, farmers, and with stakeholder representatives, local authorities. They aimed to reconstruct the history of the collective action for 30 years and to confront the different perceptions about the water resource. These interviews, added to our participative observation in meetings, and the review of local public and private archives are the basement of our work in Lons-Le-Saunier. Research was hence not directly associated in the past on this territory.
In Harol we are implicated since 2009 (i.e. the beginning of the Grenelle procedure) in the meetings of the collective constituted by various state organisms, a representative of the regional agency in charge of water preservation that supports local management actions, members of municipal council – mayor and aldermen - that includes one of the concerned farmers, an engineering consulting firm in hydrogeology, a technical advertiser from the local agricultural chamber. We performed interviews too with the eight farmers concerned in association with the local agricultural chamber. We are also at the initiative of a participatory process (including farmers) in this territory.

Thus we will begin with a brief overview of political and historical context of our three study cases (whose main characteristics are synthesized table 1).

Findings and discussion

Description of the history of the three study cases

- Vittel : the example of a mineral water private society

The Mineral Water Society of Vittel (SGEMV) decided in 1987 to protect the aquifer area. This decision was important for two reasons: they have to insure on the long terme the water quality (mainly through nitrate concentrations) and to maintain a high level of employment (1300 workers in a very rural region).

The main actors concerned were the farmers. The agricultural land use represented 78 % of the surface (woodlands are 16%, and the suburban area 6 % of the total surfaces). The main production was the milk production with maize, and the cereals for bread and beer (wheat and barley).

In 1988, the research team of INRA Mirecourt and eight other research teams began to work on this challenge: how to change the local agriculture to protect water quality and to improve in the same time farmers' incomes? (Deffontaines *et al.*, 1993)
The first phase (1989-1993) aimed to diagnose the main agricultural practices related to water quality risk; this was achieved by building an on – farm observatory that recorded farming practices (Benoît, 1992), by conducting surveys, by setting up 19 ceramic cups sites in farmers' fields to obtain in-situ nitrate leaching measurements (Benoît *et al.*, 1995), by mapping the diversity of soils, and by building a common research GIS (Gaury, 1992).
By transforming these elements of diagnostic in practical proposals for farmers (1992-1996), propositions of new cropping and farming systems were made; the main changes were to transform the fresh farm yard manure into compost, and to decrease its amount per hectare (Benoît *et al.*, 1997), to transform the cows feeding system from a maize one to a hay and permanent grassland one (Benoit and Simon, 2004), to build new crop sequences (from short ones: Maize- wheat, to long ones: 3 years alfalfa/wheat/barley/2 years temporary grassland/wheat/barley), to stop definitively the pesticids' use by farmers and other inhabitants.

Changes in the farming systems were then analyzed (1996-1998) in terms of economical, social and technical conditions for these changes and in terms of learning about new cropping and feeding techniques. Effects of these changes in terms of water quality and evolution of technical systems were evaluated too (1998-2001). A society was finally constituted (2002-2004) to assist farmers throw technical advices and financial compensations.
The main innovations created in this situation were a kit of technical changes for farmers (moving from a maize system to a grassland system, moving from fresh to a composted management of farm yard manure, moving from a chemical to an organic farming system, moving from short cropping systems to long cropping systems) and a new method to monitor water quality (ceramic cups sites in farmers' fields). These modifications of most of farmers' practices let obtain great results (i.e. really weak nitrate concentrations).

- Lons-Le-Saunier: a French success story?

Lons-Le-Saunier is located in east France (Jura Region); the catchment consists of six water wells, and the area covers 15 km^2. In the 1980s, the municipality faced to an important sanitary degradation of its drinking water (mainly due to nitrates and atrazine content), when this one was leading innovative and environmental projects in its city. In this context, municipality closed some wells and decided to introduce a preventive policy management against agricultural pollutions.
At that moment, land acquisition plan and land use change project decided by Lons-le-Saunier municipality (as arable crops suppression and grassing area replacement) afraid farmers. Therefore, land use and land ownership conflicts emerged.
To solve the problem a contractual agreement had been hardly negotiated between both parts and was established in 1993, i.e. three years after the starting policy management process. This agreement based on practices' change was contracted with about ten voluntary farmers who owned fields located into a protected area surrounding wells (70 ha) where they were committed to renounce to maize production and to reduce fertilization and chemicals treatments.
From 1991 to 1993, terms of the agreement were the main topic points of the negotiation.
In 1991, overlapping to the starting discussion process (much more established by land use conflict than by water quality issues), a second stage to water policy management consisted to convince farmers of change practices interests to protect water, introducing by this way a local dynamism of friendlier environmental practices development. In Lons-le-Saunier case, this stage knew a high dynamism thanks to a participatory approach between engineers of local agricultural institution and local farmers.
From 1991 to 2001 (corresponding to the working period of the leading engineer), agronomic experimentations were established with voluntary farmers to explore and to perform local knowledge about groundwater hydrological functioning and farming practices effects over nitrogen transfers. Local knowledge acquisition was the support to awareness campaign provided through various trainings and focus group between all farmers committed to the contractual agreement and some other farmers who felt concerned with this issue.
Combined to local agronomic advices investigation (by farming institutions), this process led to a major collective participation of farmers to change practices in accordance to their know-how practices and to the results of local experimentations. In 1995, local dynamism resulted to the establishment of spreading environmental practices over a larger area than the city agreement one (180 ha) trough a collective voluntary contractibility of environmental policy; this financial added compensation enabled committed farmers of the city agreement, to extend their new practices over their entire farm.
In 2001, when friendlier environmental practices were well experienced and integrated to farming activities, Lons-le-Saunier municipality worked over water protection reinforcement by encouraging organic conversion in wells countryside. The reinforcement of water protection corresponds to farmers' involvement rupture in Lons-le-Saunier water management. Indeed, in 2010 despite current high political willingness and financial supports for farmers, this new perspective of device is always in stage of project: farmers refuse to introduce organic practices and conflicts between farmers and the municipality prevent them to find an agreement.
National water rules reinforcement has implemented major roles to some protagonists whose were previously discrete in Lons-le-Saunier device and whose power decisions were weak before that event. For instance, national subsidies which have been focusing to organic conversion plan, has engendered a new strong relationship between city and a water financial institution. Under those circumstances, relationships between stakeholders have changed: they have become much more complexes that previous one characterised by a binomial relation "city-farmers" and tensions appeared between both parts.
Furthermore, the integration to the Grenelle plan caused the current conflict between farmers, the municipality and its partnerships, as far as farmers have been feeling disappointed that their previously efforts to change practices, were not judged by national institutions as weighted criteria to avoid them a reinforcement of water protection.

- Harol: a small catchment with high constraints and expectative

Our third case study is a spring (so called 'Rochotte') contributing to the drinkable water supply of the village of Harol (670 inhabitants, east France in Vosges region) which states in the Grenelle's list too; concentrations in nitrates (NO_3) are closed in a constant way to the legal limit of 50mg/l.

Grounds situated on this part of Vosges are very essentially agricultural ones (mixed livestock farming) but forests represent a small part too.

The studied catchment is of restricted extent (55 ha concerning the Perimeter of closer Protection and the complete area whose limits are yet not well established should not exceed 100 ha). Nine farmers (polyculture-dairing farms) are concerned by the program; some of them for a small part (one or two plots corresponding to a few hectares) whereas the main part of the cultivated plots of his farm are engaged in the area for a particular farmer.

Drinkable water is a mix of four springs: three of them are located in the forest (with low level of nitrates hence); the last one (Rochotte spring), located in the agricultural zone, is the most important in terms of flow; before 2008, there was a confusion between the total distributed water and this particular Rochotte spring (this error was made by the legal services in charge of monitoring) and the problem of pollution was revealed suddenly to the mayor who did not expect such complications.

An official collective was constituted; the first step of the process was the delimitation of the catchment: but many difficulties occurred and today the ways for water transfers are still not well understood. Despite this, a limit was fixed for the action. Farmers were not associated to the discussions of this collective during this first step consisting in determining the limits of the perimeter; results were presented to them at the end of the study of the engineering consulting firm. But the research associated them to another approach: in order to stimulate scenario construction, we proposed to analyze the territory in terms of actors, resources and dynamics of interactions. The diagram we obtained collectively (Barataud *et al.*, 2010) let us observe many points: the lack of certain actors in the collaborative decision or information process, the need of a better understanding of the system and of water transfer mechanisms, the different meaning of the notion of 'resource' following the actors: farmlands, grasslands, are resources for farmers; water appears not as a resource for farmers as far as it is sufficient for cultures.

This participatory modelling underlined the repercussions on the farms in the whole of the demarcation of the basin while this one is uncertain: this uncertainty should be considered when elaborating the measures to protect the water resource.

Farmers are now invited to participate to the debate of the institutional collective. The aim of this second step is to establish a program of agricultural practices and land use modifications in order to obtain significant results for the water resource. Permanent grassland could be promoted, exchange of plots and optimization of organic fertilization are options that are discussed too.

	Vittel	**Lons-Le-Saunier**	**Harol**
	Mineral water (groundwater)	Drinking water (groundwater)	Drinking water (groundwater)
Agricultural systems	polyculture-dairing farms	cash crops, dairy farms, wine growing, truck farming	polyculture-dairing farms
Evolution of the nitrate concentrations at the beginning of the action/ objectives [NO_3]	increase / below 10 mg/l	increase / below 25 mg/l	Increase / below 50 mg/l
Leader for environmental concern	Private firm	Municipality	State
Anticipation of the environmental problem before legal constraint?	yes	yes	no
Specific actions	- Meetings in each concerned village - Creation of a consulting society - Common walks around the watershed - Porous cups implementation	- Contractual agreements - Local agronomic experimentations	- Data monitoring (nitrate concentrations in surrounding wells, characterization of soils) - Companion modelling

Table 1- Characteristics of the three study cases.

Awareness of the environmental problem and temporal scales for action

Lons-Le-Saunier appears clearly as an original experience. The elected representatives have chosen in an early time to promote a positive and ambitious attitude. Problem was anticipated, no waiting a legal constraint. A preventive logic determined the public action, whereas in many cases palliative solutions are preferred. Legal norms are not sufficient from the point of view of the municipality: its aim is to reach concentrations behind the European guide value of 25 mg/l, to come back to the prior value of 5 mg/l corresponding at those that existed before the intensification of the agriculture. Contrarily to this position, most of municipalities attempt to minimize the importance of diffuse pollution assimilating them to an ordinary risk (Becerra and Roussary, 2008).

From this point of view (anticipation and ambition) Vittel presents common characteristics with Lons-Le-Saunier. But the person who gives the alert and engages the action in case of Vittel is a private firm. 1987s there is collusion between the local political power and the economical interests in the way that the mayor of the city is director of the firm in the same time. The initiative of action is thus economically based when it is policy and sanitary based in Lons-Le-Saunier where the aim is to comfort an environmental leadership and reduce the most as possible risks for the population.

Context of Harol is fundamentally different: municipality's awareness results from a legal policy constraint. The knowledge of the existence of a diffuse pollution came out suddenly and late. That led the mayor to feel himself unprepared: his questions were: "how to organize the process? How to receive technical and financial helps to support the necessary reforms of agriculture". He felt first as "a culprit forced to justify himself".

Today, this elected representative expresses his strong will to develop a logic of partnership; he also underlines the importance of the prevention and companion processes (this help should be provided by the state services for example during land consolidation operations whose environmental repercussions were not enough evaluated at the moment); he underlines so indirectly the fundamental role of the knowledge and the need to understanding of the stakes and the physical phenomena.

In Harol case we explained how the emergence of the crisis' situation came suddenly; because of the national context (Grenelle) and international context (WFD), in most cases actions must be engaged and results obtained in a short time. In this context, analysis, experimentations, and even collaborative decision making can difficultly be conducted because they are procedures that imply sufficiently long term perspectives. Environmental systems are open in time and space; it means that they constantly evolve and decisions should never be taken once and for all; exogenous changes (new policies, climate change) and endogenous changes (new data about the system, new involved actors, new priorities or values) might occur that require adaptive decision making.

In a participatory process outcomes are necessarily uncertain, goals should be negociated and participation should be considered as early as possible in the process (Reed, 2008). The French Grenelle law context does not seem to offer such opportunities. An integrated management (imposed by the existing conflicts between different goals) should impose a broad perspective that take al potential trade-offs and different scales in space and time into account. But the temptation to reduce complexity and dimensions of a problem (Pahl-Wostl, 2007) leads to compress a messy problem situation into a well-defined problem with simple cause-effects relationships.

Participation and Information tools

It was proved in Lons-Le-Saunier that farmers' participation throw local experiments is a great factor of successful engagement and modifications of agricultural practices. On the contrary a predefined protocol or procedure could lead to demotivate stakeholders (Voinov and Bousquet, 2010).

Focusing on the nature rather than the degree of engagement (Rowe and Frewer, 2000) lets identify different types of local stakeholders' engagement by the direction that communication flows between parties. According to this view, three types of engagement can be distinguished:

- information dissemination to passive recipients constitutes 'communication';
- gathering, extracting information from participants (farmers in our study cases) for the need of other stakeholders (scientists or administrators) is 'consultation';
- 'participation' is conceptualised as two-way communication between participants: either participation serves to support (promote and articulate) the decisions, or it is an interactive participation where stakeholders share the diagnostic and analytical methods and tools or results.

This grid of analysis lets us classify different phases of processes for our three cases (table 2).

	Vittel	Lons-Le-Saunier	Harol
information	- Delimitation of watershed - Modelling of water dynamic	- Delimitation of the area - Contractual agreements	- Delimitation of the area - Results of soil analyses
consultation	On farm experiments		Diagnostic about agricultural practices
participation		Technical experimentations	- Elaboration of an actions' program - Companion modelling

Table 2- types of engagement during the various phases of the processes studied.

The levels or types of engagement we just described need various tools to be developed (table 3): we usually used maps, experimental field's results and questionnaire. More original is the recourse to common "walking around the watershed" experimented in Vittel's case that let the stakeholders confront their perceptions by giving a central place to farmers who have a concrete experience of this territory. The conceptual model built in Harol is another way to share different visions of a territory and its resources.

	Information and Communication tools
Vittel	Graphs of soil water quality on experimental farm fields Maps Duestionnaire Common "walking around the watershed"
Lons-Le-Saunier	Maps Questionnaire
Harol	Maps Graphs Questionnaire Conceptuel model

Table 3- Information and Communication tools used by the research and/or the collectives

Conclusions: Role of knowledge and specific place for the researchers

Any transition to a new management regime requires collective learning processes (Pahl-Wostl, 2007). In these study cases our role was either to help the stakeholders to build a common view (on the problem, the critical way, the diagnosis, the possible futures) or to provide analysis for policy makers to take into account the point of view of others stakeholders. In this way, we focused on some common main key points:

i) status of empirical data, fields measurements, and models

Farmers are demanding for local measurements to better understand physical mechanisms and to comfort the decisions that are taken: it appeared clearly in our three study cases concerning the water transfer (tracers were thus employed) or the impacts of agricultural practices (porous cups measurements were performed). In a first approach finding agreement seems to be easier for empirical data than finding agreement for results derived from simulation models (that contain assumptions that may be questioned) and such a demand for field data should be taken into account by research. But fields measurements can also be unsuccessful and not provide the expected results (this was the case with tracers in Harol that never allowed to understand the water pathways). Besides the farmers always point out the specificity of their own fields to claim measures in each plot which seems to be unrealisable. Research has to deal with these strong expectations.

Farmers and administrators are finally often favourable to a hard system approach (Pahl-Wostl, 2007) that emphasizes factual knowledge and the role of the analyst as external observer; following this approach, models are expected to represent the relationships of variables in the real world. As researchers we would better trust a soft system approach that emphasizes subjective perception; from this point of view the analyst is seen as participant in a process of social learning and models serve above all to structure the debate. To evaluate a diagnostic about water quality, nature of debates and exchanges between stakeholders seems to be a better indicator than the precision of scientific measurements (Mormont, 1996).

ii) identification of the main driving factors of the current states,

As water is a result of many constraints, a product of various interactions between territory and farmer practices, we have to provide methods to favour the expression of these constraints or interactions.

Farmers have "good reasons" to do what they do. Our question as researcher is to find and explain these reasons, to help them and the other stakeholders to find a common way of land changes for the future of the

watershed. For example, we can explain the use of the land for a farm with two main variables: the spatial constraints of the fields and a physical constraint, i.e. the status of water. This can be formalized throw a constraints/use diagram.
Another option is to construct, in a collaborative way, a diagram that represents the actors, the resources and the dynamics of their interactions (Etienne, 2007).

iii) facilitation of knowledges' sharing between stakeholders

Discourse is an important mechanism for schema modification, and thus for behaviour change. "Through discourse groups of people construct a shared story that is a collective model; this model is useful for predicting likely outcomes of actions and events […] Good stories are models that filter and organize distributed knowledge about complex situations and relationships in ways that are readily absorbed by human cognitive processes." (Beratan, 2007).
The topic of the information sharing can be improved through local Community Information System (Le Ber *et al.*, 2011) or companion modelling (ComMod, 2005); anyway faced to an environmental problem (intrisically complex and dynamic) we have to construct a flexible and transparent decision. For this purpose a diversity of knowledges and values should be embraced, and the idea should be accepted that outcomes of the process are necessarily uncertain and goals negociated. The quality of decisions is strongly dependant on the nature and the quality of the participatory process leading to them. Therefore local and scientific knowledges should be integrated, on one hand to evaluate the appropriatness of potential technical and local solutions and on the other hand to provide a more comprehensive understanding of these complex systems and processes.

Supprimé : ¶
¶
¶
----------Saut de page----------

References

Barataud, F., Rolland, V., Kung-Benoit, A., Benoit, M., 2011. Construire des coordinations d'activités agricoles sur un BAC : Une problématique nitrate sous la contrainte du Grenelle à résoudre par un petit collectif d'acteurs : les captages d'Harol. Rencontres du GIS GCHP2E, Protection des aires d'alimentation de captage vis-à-vis des pollutions diffuses, Paris, 3 février 2011, 67-70.

Becerra, S., Roussary, A., 2008. Gérer la vulnérabilité de l'eau potable : une action publique désengagée ? Natures Sciences, Sociétés 16 (3), 220-231.

Benoit, M., 1992. Un indicateur des risques de pollution azotée nommé "BASCULE"(Balance Azotée Spatialisée des systèmesde CULture de l'exploitation), Fourrages 129, 95-110.

Benoît M., Saintôt D., Gaury F., 1995. Mesures en parcelles d'agriculteurs des pertes en nitrates. Variabilité sous divers systèmes de culture et modélisation de la qualité de l'eau d'un bassin d'alimentation. C.R. Acad. Agric., 81(4), 175-188.

Benoît M., Deffontaines J. P., Gras F., Bienaimé E., Riela-Cosserat R., 1997. Agriculture et qualité de l'eau. Une approche interdisciplinaire de la pollution par les nitrates d'un bassin d'alimentation. Cahiers Agriculture 6, 97-105.

Benoît, M., Simon, J.C., 2004. Grassland and water resources: recent findings and challenges in Europe. IN : Lüscher A., Jeangros B., Kessler W., Huguenin O., Lobsiger M., Millar N., Suter D. Land use systems in grassland dominated regions, Grassland Science in Europe, vol.9; 20. General meeting of the European Grassland Federation, Luzern (CHE); 2004/06/21-24, 117-128.

Beratan, K.K., 2007. A cognition-based view of decision processes in complex social-ecological systems, Ecology and Society 12(1), 27.

Bolte, J.P., Hulse, D.W., Gregory, S.V., Smith, C., 2006. Modeling biocomplexity – actors, landscapes and alternative futures, Environmental Modelling & Software 22, 570-579.

Collectif ComMod, 2005. La modélisation comme outil d'accompagnement, Natures Sciences Sociétés 13, 165-168.

Deffontaines J-P., Benoît M., Brossier J., Chia E., Gras F., Roux M. (Ed.), 1993. Agriculture et qualité des eaux ; diagnostic et propositions pour un périmètre de protection. INRA-SAD, 334 pages.

Etienne, M., 2007. Co-construction d'un modèle d'accompagnement selon la méthode ARDI : guide méthodologique, ANR-05-PADD-007.

European Commission, 2002. Implementation of Council Directive 91/676/EEC concerning the protection of water against pollution caused by nitrates from agricultural sources. Synthesis from year 2000 Member States reports. COM (2002) 407 fin. European Commission, Brussels.

European Commission, 2010. Report from the Commission to the Council and the European Parliament on implementation of Council Directive 91/676/EEC concerning the protection of waters against pollution caused by nitrates from agricultural sources based on Member State reports for the period 2004-2007 SEC(2010)118/* COM/2010/0047 final */

Gasteyer, S.P., 2008. Agricultural transitions in the context of growing environmental pressure over water, Agricultural Human Values 25, 469-486.

Gaury F., 1992. Systèmes de culture et teneurs en nitrates des eaux souterraines. Dynamique passée et actuelle en région de polyculture-élevage sur le périmètre d'un gîte hydrominéral. Thèse de Doctorat de l'ENSA de Rennes, 229 pages + annexes

Le Ber, F., Nogry, S., Brassac, C., Benoit, M., 2011. Capitalisation d'expériences pour la mise en place d'observatoires de pratiques agricoles – Une approche fondée sur l'exploitation de narrations, Revue internationale de géomatique 21 (1), 101-120.

Le Gal, P.-Y., Merot, A., Moulin, C.-H., Navarette, M., Wery, J ., 2010. A modelling framework to support farmers in designing agricultural production systems, Environmental Modelling & Software 25, 258-268.

Maurel, P., Craps, M., Cernesson, F., Raymond, R., Valkering, P., Ferrand, N., 2007. Concepts and methods for analysing the role of Information and Communictaion tools (IC-tools) in Social Learning processes for River Basin Management, Environmental Modelling & Software 22, 630-639.

Mormont, M., 1996. Agriculture et environnement : pour une sociologie des dispositifs, Economie rurale 236, 28-36.

Pahl-Wostl, C., 2007. The implications of complexity for integrated resources management, Environmental Modelling & Software 22, 561-569.

Reed, M.S., 2008. Stakeholder participation for environmental management: a literature review, Biological conservation 141, 2417-2431.

Rowe, G., Frewer, L., 2000. Public particpation methods: a framework for evaluation in science, Technology and Human Values 25, 3-29.

Toussaint Soulard, C., Compagnone, C., Lémery, B., 2007. La recherche en partenariat : entre fiction et friction, Natures, Sciences, Sociétés 15, 13-22.

Voinov, A., Bousquet, F., 2010. Modelling with stakeholders, Environmental Modelling & Software 25, 1268-1281.