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Stakeholder Analysis for Sharing Agro-environment Issues Towards Concerted Action: A Case Study on Diffuse Nitrate Pollution

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Abstract

There is increasing need for participatory approaches to support the development of sustainable farming systems, based on the active involvement of stakeholders in the definition of research objectives and priorities. This paper reports the experience of a team of agronomy researchers involved in the SLIM project (http://slim.open.ac.uk), around a case study of nitrate pollution. The agro-ecosystem analysis included biophysical processes at microcatchment scale and the stakeholders' perceptions, interests and practices related to the nitrate issue (stakeholders analysis). The conceptual SLIM framework model supported new interactions among stakeholders, that were facilitated by researchers, using dialogical tools to enable them to use scientific data and to integrate their own knowledge on the farming system. The agro-environment policies, based on compulsory prescriptions, revealed weak assumptions and insufficient integration of scientific knowledge. The stakeholder analysis contributed to the identification of priorities both for scientific research and agro-environment policies. Researchers provided the site-specific scientific knowledge, in a way that enabled stakeholders to identify the relationships between agricultural practices, landscape values and the nitrate pollution issue and to elaborate shared strategies to develop concerted actions. New spaces for interaction between researchers and stakeholders should be created to face complex agro-environment issues at catchment scale, such as the nitrate pollution of groundwater. The implication for agronomy research is that the experiments should be designed to produce suitable results to facilitate participatory sessions and that it is worthwhile to invest in specific skills of communication science and group dynamics management within the agronomy researchers' community, in order to integrate agronomy knowledge into high quality participatory processes.

Key-words: agronomy research, participatory approaches, social learning, sustainable farming systems, water quality.

1. Introduction

The integration of know-how from other disciplines in agronomy research practice has required investments in the development of specific skills in statistics, modelling and informatics within the scientific community of agronomy researchers, which have developed and applied with full knowledge powerful integrated decision support tools (DSS) for experimental research and management at different levels (Giupponi et al., 2004; Bazzani, 2005). The outcomes of these investments cover a wide range of valuable scientific results on the understanding of the biophysical processes controlling agro-ecosystems. However, the application of DSS and their underlying assumptions, have failed so far their main declared objectives of actually supporting management decisions even at the farming system and administrative level (Keating and McCown, 2001; McCown, 2002a). Furthermore, there are many experiences of failures at local and global scale of reaching significant improvements around complex agro-environment issues such as diffuse water pollution, soil erosion and soil fertility. On this matter, some authors pointed out that despite the apparent objectivity of quantitative systematic approaches, relevant spaces of subjectivity remain in the assumptions made, which are related to the scientists' personal background, and that new approaches should be explored (Ison and Russell, 2000; Jiggins and Röling, 2000; Bouma, 2005).

Recent progresses in social, communication and systems sciences (e.g. Maturana and Varela, 1988; Checkland and Scholes, 1999; Schlindwein and Ison, 2005) are being applied to integrate

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participatory approaches in regulatory policies around environmental decision making (European Parliament and the Council, 2000; Dworak et al., 2005; Quevauviller et al., 2005) and are becoming a common denominator of interdisciplinary research projects dealing with sustainable development (e.g. www.harmoniCOP.info). However, interdisciplinary and participatory practices are difficult to implement and the underlying conceptual issues are often not fully appreciated by agronomy researchers (Bawden and Ison, 1992). Furthermore, the achievement of objectives through the implementation of the norms incorporating participatory approaches is critical, as it can be observed from the current difficulties in meeting the deadlines set by the water framework directive (Oenema et al., 2005).

The development of participatory research approaches in agro-ecology relies on the fundamental distinction between well defined technical problems and complex issues, and on the methodological implications of dealing with the complexity, uncertainties, interdependencies and controversies that characterize the biophysical and socio-economic dimensions of agro-environmental issues at catchment scale. This distinction has been developed for field crop ecosystems by Bawden and Ison (1992), between systems which have an imposed goal, which they then seek to achieve (*purposive systems*) and those systems which are able to set goals as well as seek them (*purposeful systems*). Goal setting or purposeful systems are able to change their goals even under environmental conditions which are constant. Furthermore, they can pursue the same goal in different environments by following different behaviours. This view of agroecosystems has relevant implications on research practice (Bawden and Ison, 1992):

- the problem solving approach is replaced by an iterative and interactive process of problem de-constructing and re-definition, which is focused on the mutual learning process among researchers and their clients (in the sense of Checkland, 1981);
- the research process is focused on the transformation of the joint learning of multiple agents into action (Kemmis and McTaggart, 1988), which means that problem solving, research and learning are equated;
- the identification of the problem situation is made by the participants (e.g. farmer, researcher, consultant etc) with the researcher acting also as a facilitator of the learning process;
- the underlying model of research links systemic, systematic and reductionist approaches to problem solving, but rarely is reductionist experimentation the starting point in the problem solving process;
- improvements in field crop ecosystems will come from paradigm shifts in those who choose to attempt to improve these systems, particularly agricultural, biological, social and economic researchers and administrators, through learning activities which involve the clients of such improvements.

The same authors conclude that there is utility in looking at field crop ecosystems as if they were "learning systems", which means that both observers (e.g. researchers) and actors (e.g. farmers) are considered essential components of field crop ecosystems. This perspective reveals an underlying holistic-constructivist view of agroecosystems, according to which there is no objective system: there are only the various distinctions that different observers draw (Dell, 1985). These are some of the key conceptual bases of the interdisciplinary research project "SLIM" (http://slim.open.ac.uk), which explored and developed an analytic framework to approach complex agro-environment issues at catchment scale (SLIM, 2004a).

In this paper, we report the experience of a team of agronomy researchers within the SLIM project, built around a case study on diffuse water nitrate pollution of agricultural origin in a hilly area of the Marche (Central Italy), which was one of the twelve case studies in four EU countries analysed by the SLIM project. In this case study, nitrates were considered one undesirable outcome of certain agricultural practices, and not just an output of bio-physical processes, and hence the agro-ecosystem analysis has necessarily integrated the analysis of biophysical processes at catchment scale with the analysis of the stakeholders'[1]

[1] Stakeholders are those who have a 'stake' – a real, material interest, from their perspective – in the situation or in the resource under consideration. A person's stake can be formed in any number of ways: for example, as a resident, domestic water user, angler, farmer, professional water manager, or government official. Stakes may also overlap. Stakeholders can be concerned, for in-

perceptions, interests and practices (stakeholder analysis) related to the nitrate issue.

2. Methods

The analyses reported in this paper have been framed in the "SLIM framework" (SLIM, 2004a), which provides an heuristic to support participatory research activities and fits the second order Research and Development approach (Ison and Russell, 2000). The SLIM framework is based around four main "variables", emerging from a dynamic iterative and interactive participatory process between researchers and stakeholders, after the boundaries of the system of interest have been defined (Figure 1): (i) the identification of a sub-set of ecological factors underlying bio-physical process dynamics controlling the cause-effect relationships between agricultural practices and nitrate pollution of groundwater (ecological constraints); (ii) the normative system and public policies that frame the current practices (institutional constraints); (iii) the stakeholders and stakeholding related to competing claims in the use of resources (stakeholder analysis); (iv) the facilitation processes supporting the interactive and iterative participatory learning.

Each component of the proposed framework is relevant to the others, but the identification of the stakeholders actively involved in the participatory process (stakeholder analysis) is a crucial phase to the whole process outcomes. In this paper, we focus particularly on the stakeholder analysis (Appendix 1).

2.1 Case study overview

The starting point from the researchers' perspective was a "nitrate emergency" following the implementation of the nitrate directive (91/676/EC) in the Marche region, in 1994. The waterworks water of fifty municipalities in the region was polluted by nitrates and hence declared undrinkable. Nitrogen fertilisers were

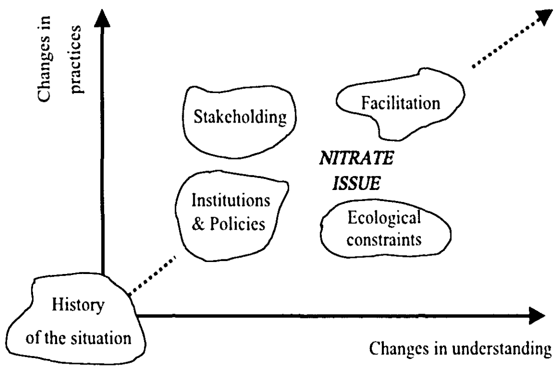

Figure 1. A graphic representation of the "Slim" model that has been used to frame the nitrate case study (Slim, 2004a).

identified as main cause of the pollution. The contingent availability of EU funds from the agro-environment program (reg. CE 2078/1992) created the opportunity for the regional government to adopt in 1996 a special measure (action D3), applicable to contiguous areas greater than 1,000 ha, consisting of a set of low-input farming prescriptions and subsidies to compensate farmers for expected lower yields, to prevent the diffuse nitrate pollution of water. This measure was implemented by the Mayors of seven municipalities located upstream or in the polluted catchments. In 1997, an experiment was established at microcatchment scale in one of the seven areas that adopted the D3 measure, Serra de' Conti, to assess the relationships between agricultural practices and nitrate concentration dynamics in surface and ground water. The microcatchment experiments provided scientific evidences that (Roggero and Toderi, 2002):

1) nitrate concentration in surface water was high, despite the implementation of the low-input prescriptions, particularly in the autumn, when most arable land was bare soil and soil water surplus reached its maximum. The high nitrate concentration in surface and sub-surface runoff water was therefore attributed to the unbalance between nitrates made available by organic matter mineralisation and absence of plant absorption;
2) the application of low input prescriptions did not reduce crop yields as expected, as a consequence of a higher nitrogen fertiliser use efficiency, resulting from the prescribed accuracy in the time distribution of fertilisers;
3) the subsidies associated to compulsory pre-

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stance, that farming might result not only in food production, but also in landscape values or changes in water quality. *Stakeholding* expresses the idea that individuals *actively construct*, promote and defend their stake, also by deliberately deciding not to participate in multi-stakeholder events (Slim, 2004b).

scriptions were not considered enough to make a substantial change in cropping systems (e.g. replace annual with perennial crops), which in fact was necessary to reduce nitrate pollution;

4) despite being compulsory for at least 1,000 ha of contiguous agriculture areas, the prescriptions were implemented with a field-based scale rather than a territorial one.

The scientific data provided a knowledge basis for analysing some relevant bio-physical features of the nitrate issue in the specific context. However, while these preliminary results were used as a basis for the *ex-post* impact assessment of the agro-environment measures (1992-1998), they were not used for the design and implementation of the new agro-environment prescriptions (reg. CE 1257/1999; 2000-2006).

At this stage, in 2001, the SLIM framework provided an opportunity for the agronomy research team to reflect on the complex nature of the nitrate issue, recognised as an emerging property of the complex interactions between bio-physical and social processes, according to the view of agroecosystems as learning systems (Ison and Russell, 2000).

The first step of this new participatory analytic process, was reflection around the system of interest's boundaries from the researchers' perspective, and hence the engagement of the identified stakeholders in a participatory process of agro-ecosystem analysis, to surface the uncertainties, interdependencies and controversies embedded in the stakeholder perspectives around the nitrate issue.

The SA was implemented as an open process, in which researchers created new spaces and opportunities for interactions between the identified stakeholders. A series of events were organised, such as public participatory GIS interactive workshops, meetings with farmers and people involved in local tourist activities, focus groups with administrators, semi-structured interviews with farmers' Unions and politicians and a civil theatre event. In these events, researchers played an active role in observation → reflection/assessment → design → implementation → observation (Toderi et al., 2004). Different dialogical tools were used to engage with different stakeholders in different contexts. Attention was paid to the quality of the dialogical process more than to drive it towards a predetermined target. More detailed descriptions of the participatory events designed by the researchers to interact with stakeholders are given in other papers (Seddaiu et al., in preparation; Toderi et al., submitted).

The design, implementation and assessment of each step of the SA process were supported by an interdisciplinary "methodology team" of the SLIM project, that also played the role of external observers and helped the agronomy team in reflecting around assumptions and theoretical framework underlying agronomy research practices (Powell and Toderi, 2003; Arzeni et al., 2004; Toderi et al., 2004; Seddaiu et al., 2004).

The design of each step of the SA was made on the basis of the overall theory framework and of the results obtained in the preceding steps. In this way, SA was considered as an ongoing dynamic process which would evolve together with the dynamic shape of the issue boundaries, as shared by the involved stakeholders.

2.2 The stakeholders analysis of the nitrate case study

The SA applied to the nitrates case study started from the preliminary identification of the relevant stakeholders from the researchers' perspective, on the basis of the experience gained through the field research at plot and micro-catchment scale, and the personal contacts made so far. Stakeholders were clustered using different tools and methods, which served also as heuristic device to share the system boundaries within the research team and hence plan the subsequent analytic steps. Following this step, a meeting was organised in Montecarotto (a town near Serra de' Conti, where the microcatchment experiments were conducted) in which the experimental data collected in two microcatchments in the agricultural area of Serra de' Conti were presented in a conventional way (Roggero and Toderi, 2002). On the basis of the outcomes of this event, over three years, a number of participatory events were organised by the research team, from which the SA was derived. The design, implementation and assessment of the events (Table 1), which will be described in detail elsewhere, provided a richer picture of the system of interest, based on the shared perceptions between researchers and identified stakeholders.

Table 1. Participatory activities and stakeholders involved (more details on Toderi et al., submitted; Seddaiu et al, in preparation).

Activity	Stakeholders involved
3 Public participatory GIS (PP-GIS) sessions	(1) Farmers, (2) agricultural and hydraulic engineers, (3) clients i.e.: inhabitants, school teachers, environmentalists, journalists
"Landscape images" meeting	Hobby farmers, restaurateurs, landscape managers, officers from local tourist agency, a photographer
"Agricultural scenarios" meeting	Participants involved in previous PP-GIS sessions and the landscape images meeting: farmers, clients, , tourist operators, officers from regional government involved in the implementation of agro-environment measures
Semi-structured interviews	President of the Commission for Agriculture of the Regional Council; past Agricultural Councillor, in charge of the implementation of reg. CE 2078/92 in Marche Region; four regional responsibles of Farmers Unions
Focus groups	Regional officers involved in the implementation of agro-environmental measures Schoolchildren, their teachers and local administrators
Theatre event in Serra de' Conti "Il teatro dell'acqua"	People from the catchment area and from elsewhere that visited Serra de' Conti to attend the "Festival of the Chickling" (Festa della Cicerchia) an annual festival during which almost all canteens in town are transformed into wine shops

A final workshop was organised gathering different groups of stakeholders already invited to specific events, in order to share the nitrate issue with multiple perspectives. The meeting responded to the claims of several stakeholders to create a new opportunity for them to analyse and share options and constraints of their practices with other groups of stakeholders which could have an influence on the issue and could depend on others' behaviour.

Results and progress in understandings around the nitrate issue where recorded to benchmark the different steps of the SA. The discussion of results is built around the final outcomes of the whole process and on the implications for further developments in agroecology research.

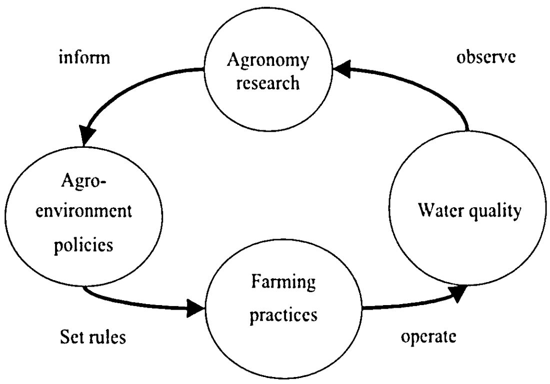

Figure 2. A possible interpretation of the influences of farming practices on water bodies, that inspired the agronomy research team at the starting of the SA, which is coherent to what appear to be assumed in the Nitrates and Water Framework Directive (adapted from Morris et al., submitted).

3. Results

The initial view of the nitrate problem from the researchers' perspective was focused around the bio-physical processes linking agronomic practices and nitrogen leaching, based on the results of the experimental surveys made at microcatchment scale. Therefore, the system's boundary at the beginning of the SA was not far from the interpretation of the relationships between stakeholders and water bodies that is depicted by the water framework directive (Figure 2). In this context, researchers were supposed to provide "objective results" and their authoritative interpretation on the cause-effects relationships between farming practices and water quality, which should ideally support political decisions for the implementation of the EU agro-environment directives.

The identified stakeholders were clustered in different ways (Figure 3 and Table 2) and were involved in the conventional meeting held in Montecarotto.

The outcomes of the meeting held in Montecarotto did not meet the researchers' expectations:

– although almost all identified groups of

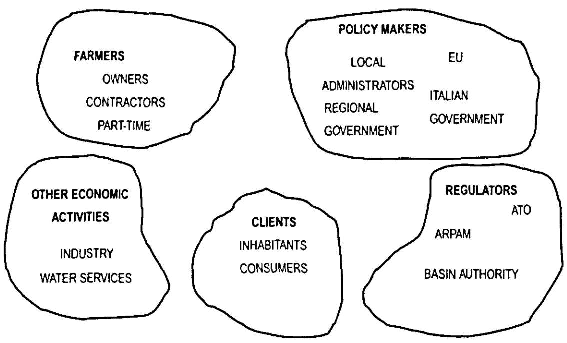

Figure 3. An example of a map of main identified stakeholders in the nitrates case study. ATO is a public organisation coordinating the integrated water cycle (from water extraction to purification) at sub-regional scale. ASSAM is the regional Agro-food Development Agency. ARPAM is the Regional Environmental Agency.

stakeholders showed a certain enthusiasm around the idea of creating a new "agro-environment table", where "institutional" stakeholders (regional officers, engineers from the agencies etc.) could share the results of the experiments to support the implementation of agro-environment policies, in practice, this enterprise was stopped after two sessions, because of lack of funding and probably lack of real interest for a scarce stakeholding platform;

- the meeting in Montecarotto and the subsequent meetings of the agro-environment table did not provide a good opportunity for researchers to analyse the stakes of the identified stakeholders, as most of their positions were constrained and biased by a formal atmosphere;
- the scientific evidences provided by the researchers about the ineffectiveness of the agro-environment measures in reducing nitrate pollution, despite the subsidies and the prescriptions, were interpreted by farmers as they were the main responsible of the pollution, as they subsequently complained when involved in the participatory activities. Moreover, they were frustrated for not understanding the hidden cause-effects relationships between farming practices and nitrate pollution and hence for not being able to find their own way to solve the problem. The farmers' learning was constrained by the language used by researchers for the presentation of the results, illustrated to the varied audience including also experts, policy makers and regional officers.

On the basis of this experience, researchers planned a new process relying on the basic assumption of the SLIM framework, that changes in practices can be only obtained through changes in understandings (SLIM, 2004a). An interactive workshop between researchers and farmers was organised, and a GIS (Geographic information system) learning platform, fed by the scientific data collected by researchers in the two microcatchments in Serra de' Conti, was interactively used with farmers, to enable them to interpret the results of the agro-ecology surveys (Powell and Toderi, 2003; Toderi et al., 2004).

The outcomes of this event went beyond the researchers' expectations: farmers' enthusiasm was revealed by their active participation to a meeting that started at 8 p.m. and ended over 1 a.m. and by the willingness of farmers to or-

Table 2. An example of preliminary stakeholder analysis around the nitrate pollution issue following the CATWOE procedure suggested by Checkland and Scholes (1990).

CATWOE category	*Example*	*Notes*
Customers	Inhabitants, consumers	people using water
Actors	Farmers, industries, managers of wastewater	their practices may have direct effects on water quality
Transformation	To decrease nitrate concentration in water	the desirable transformations imply a radical change of current practices
Worldview	From the researchers and SHs' perspectives	SA is aimed at sharing the different W's in the system of interest
Owners	Land owners, regulators	they have the power to drive changes
Environment	Monitored microcatchments	the area identified by researchers as a representative sub-unit of the whole complexity

Table 3. List of available results of the surveys made to assess the cause-effect relationships of the nitrate pollution of ground and surface water at catchment scale, that have been used by researchers to feed and facilitate the participatory sessions.

Monitoring task	*Materials and methods*	*Outputs*
Weather	Automatic rain gauge, wind and thermometer probe coupled to a data logger.	Rainfall (mm h^{-1}); temperature (daily mean, max and min); daily average wind speed.
Surface and ground water	Area velocity flow meter installed downstream to the main catchment ditch, coupled to a data logger and automatic water sampling device. Manual sampling of well water at 8 sites. Conventional laboratory analytical methods to assess nitrate, soluble phosphorus concentration, and sediment yield.	Continuous monitoring of surface flow output from the microcatchment. Concentration of nitrates, soluble phosphorus, and sediment yield in the surface flow. Concentration of nitrates in the groundwater every 1-3 months; concentration of minerals twice a year.
Soil	Soil profile analysis. Periodical surface soil sampling.	Soil map of the microcatchments (Corti et al., 2006) Soil mineral nitrogen dynamics.
Farming practices	Systematic interviews with farmers Biomass sampling at crop harvest.	Georeferenced map of: - Space-time dynamics of crop rotations and productivity - Nitrogen and phosphorus balance at microcatchment scale - Agricultural practice (fertiliser and chemicals rate and time of application, ploughing time and depth etc.).

ganise new meetings with other stakeholders to share their views and roles around the complex interdependencies and competing claims that arose around the nitrate issues. An emergent outcome of the farmers' involvement was also the identification of substantial gaps between farmers' view of the system complexity and that of regional officers and policy makers, which were taking influent decisions on the implementation of agro-environment policies.

All interactive events were informed by the available results of the surveys on water quality and agricultural practices in the two microcatchments (Table 3). These results were always presented in a way that participants were able to understand, make their own personal interpretation of the data and discuss with others, in an informal context, being each participant at the same level, around the nature of the issue and the possible solutions (Toderi et al., submitted). The results of the participatory activities provided the information used by researchers for the SA (Tables 4 and 5).

Table 4 reports some of the relevant results of the SA made at the beginning and at the end of the participatory processes. The statements in the first column indicate the researchers' views of the roles of the different stakeholders at the start of the process. The final results of the SA reveal a substantial shift of the researchers perceptions around the nitrate issue in the specific context of the Marche, relying on the need, which has been declared by almost all involved stakeholders, of improved relationships and dialogue between stakeholders to approach such complex issues. In the current perspective, public institutions are seen by stakeholders as a constraint to the development of better systems, while in the new perspective, the role that public institutions could play is that of enablers of self-organised communities of practice (Wenger, 1998), in which the various stakeholders interact continuously in facilitated open social spaces, to share issues, objectives and strategies to improve the situation (McCown, 2002b).

In the specific case of nitrates, agronomy researchers played the role of facilitators of the dialogue between interdependent stakeholders. In this context, SA contributed to the identification of priorities both for scientific research and agro-environment policies, with researchers providing the available scientific knowledge, which was essential to give all stakeholders the possibility to use the known cause-effects relationships related to the system of interest to build their own solutions.

Farmers, inhabitants, politicians and policy makers, before the process started, believed that

Table 4. Main outcomes of the SA of the nitrate pollution issue in the Marche, benchmarked on the researchers' view at the beginning and at the end of the participatory process. The table describes how researchers changed their perspective on the potential role of different stakeholders throughout the SLIM project.

Stakeholders	Before the participatory events (benchmark)	After the participatory events (outcomes)
Politicians	Responsible for the implementation of the EU norms on agro-environment. See themselves as *mediators* between knowledge inputs from experts' and local interests.	Stakes are related to a complex network of relationships with electors and vary according to their political interests. See themselves as *enablers*: create and feed new spaces to build a learning network in the local society to enable stakeholders to self-adapt to changes.
Policy makers	Regional officers playing a fundamental role in the design and implementation of the EU norms.	They are questioning their own methods of working, in order to build synergies with colleagues of different departments (e.g. agriculture, environment, planning). Current routine job is constrained by close deadlines and delays of the bureaucracy. Sensitivity to local issues can be enhanced by "ground experience" (i.e. direct contacts with stakeholders) and training opportunities.
Basin authority	Informed by norms, they define the criticalities to face.	Stakeholding of this institution is defined by norms. It could play a fundamental role in coordinating a participatory network of agro-environment monitoring in collaboration with farmers and other institutional organisation (e.g. monitoring relationships between farming practices and water quality).
ASSAM (Local Agro-food Development Agency)	Extension services to inform farmers about innovation in agriculture and norms, using technical and analytic tools for agro-environment assessment.	Advisory services may create an interactive learning platform around innovation in agriculture, involving researchers, farmers and professionals and may provide support to agro-environment assessment through monitoring services (agro-meteo, lab support etc.).
Farmer Unions	Representative of farmers in the institutional tables for negotiation around agro-environment norms.	They are questioning themselves around new possible roles in the framework of moving agricultural subsidies from agricultural to rural development. New methods are under discussion, to build new relationships with the rural society, also because the farmers' population is steadily decreasing.
Professionals	Their technical support to farmers may be relevant in supporting "best" agricultural practices.	Agronomy engineers' job is oriented by clients' needs. They do not express specific stakes in the nitrate issue. New professional skills are needed to develop new learning facilitation platforms around agro-environment issues at catchment scale.
ATO (Ambito Territoriale Ottimale)	Institutional role in coordinating the integrated water cycle at catchment scale.	The stake on water pollution is related to the application of the law. Agriculture is currently almost ignored. A stakeholding process would be necessary to involve them effectively in a learning network.
Farmers	Target of the agro-environment prescriptions. Potential beneficiaries of technological innovations from scientific research, through extension services. Nitrate pollution also related to non-rational farming practices (e.g.	Able to take complex decisions under uncertainty (climate, market, subsidies etc.), on the basis of available knowledge. Open to change through learning and dialogue. Can play a role in agro-environment monitoring.

	fertilisers use, deep ploughing etc.) Innovation constrained by traditions, lack of technical knowledge and cost-benefit analysis.	Ready to integrate the valuable lay knowledge driving their practices into a dialogue with other stakeholders. Choices and practices constrained by a number of different factors, not just cost-benefit balance.
People working in the tourist enterprises	Passive beneficiaries of positive externalities of cropping systems (e.g. landscape beauty). Stakeholders on the nitrate issue because polluted water may damage the tourist reputation of the area.	When involved in interactive sessions with researchers and farmers, proved to be available to share the linkages between sustainable farming activities and landscape and water quality. Interested in developing concerted actions with farmers, when aware of the interdependencies of their own activities and the evolution of the cropping systems.
Researchers	Feed agro-environment policies with DSS relying on scientific data and optimal solutions for resource management.	Share scientific results with stakeholders through participatory processes, playing also the role of facilitator in de-constructing the issue and helping stakeholders to find their own way in identifying sustainable options.
Inhabitants	Suffer the consequences of the nitrate pollution. Negative view of subsidised and polluting farming systems. Not informed about the relationships between agriculture and water quality.	When aware of the complexity of farming activities and of the interdependencies between their own behaviour as consumers and farmers practices impacting on water quality, proved to be available to develop concerted actions towards shared objectives.

Table 5. Main statements of some stakeholders involved in the participatory activities showing a shift in their perspectives around the nitrate issue and the reciprocal interdependencies.

Stakeholders	Main statements (at the start)	Main statements (at the end)
Farmers	The reduction of the fertilizers rates, as prescribed by agro-environmental measures, was effective in solving the nitrate pollution. Some agronomic techniques prescribed by the agro-environmental measures were not feasible in the local context, such as the cover crop between wheat harvest and sunflower seeding.	I did not know that my cropping systems could affect water quality downstream. There are strong economic constraints to change cropping systems, also related to the CAP subsidies. We need new opportunities to meet other SHs like the inhabitants using the groundwater in the catchment, to explain the reasons of the current farming practices that result into pollution.
Clients (e.g. local inhabitants using water, schoolteachers etc.)	The problem of water is solved because the tap water now is drinkable. The nitrate pollution is related to mineral fertilisers: the use of manure could solve the problem.	Consumer choices influence market demand and hence there is shared responsibility of current farmers' practices. New opportunities should be created to interact with farmers to identify alternatives to the current cropping systems. Local agreements between producers and consumers may help to re-build interdependencies.
Tourist operators stakeholders, agro-tourist managers, restaurateurs	Water quality as a problem is solved because the tap water now is drinkable.	We appreciate the interdependencies between landscape values, cropping systems and water quality. Local administrators should be awakened about the importance of an harmonic coexistence between landscape and human activities.

the low-input farming agro-environment prescriptions were sufficient to decrease nitrate concentration in the water below the legal threshold. They also ignored that mineralisation of organic matter played a relevant role in nitrate leaching in the specific ecological condition, since cropping systems in the area relied on the extensive use of summer ploughing and hence on a high proportion of bare soil in the catchment in the autumn-winter period (Table 5). The participatory meetings gave stakeholders the opportunity to de-construct the nitrate problem and to integrate the scientific knowledge and their own experience about the situation, to identify new options, or at least to share the complexity of the issue (Powell and Toderi, 2003). Researchers benefited of this emerging knowledge, in the planning of new research activities and involvement of new stakeholders.

The participatory sessions also provided new conditions to promote stakeholding processes as farmers or as consumers or as beneficiaries of EU subsidies with the other stakeholders, which rarely happen in the routine relationships between stakeholders and that provided valuable data to implement the stakeholder analysis.

4. Concluding remarks

The SA provided useful information to frame the nitrate problem as one undesirable output of a complex and poorly-defined learning system of interest, which includes researchers and stakeholders perspectives, learning facilitation processes, perceived ecological factors and the institutional and policy context framing the actual agricultural practices related to water pollution. From this perspective, stakeholders (including researchers) are also an object of the research process on the nitrate problem and hence specific attention has to be deserved to their analysis.

The following are just some of the outcomes that the agronomy research team directly referred to the integration of agronomic scientific data and the stakeholder analysis described in this paper:

- SA, implemented through the involvement of stakeholders in participatory events in which scientific data are transformed into dialogical tools, made agro-ecological processes affecting water quality visible to most stakeholders, and this surfaced interdependencies (e.g. consumers and farmers behaviour, farming and tourist industry) and constraints to change current practices causing diffuse nitrate pollution;
- the improved relationships between researchers and farmers involved in the participatory processes was beneficial for the reliability of the on-farm field data collection, based on farmers' interviews, that were necessary to identify the causal relationships with nitrate pollution;
- the trust relationships and the networking between researchers and other stakeholders, developed through the stakeholder analysis, opened spaces for the development of a new collaborative research project on sustainable farming practices in protected areas (Toderi et al., 2005), which in the specific catchment included the members involved in the development of a new "eno-gastronomic park";
- the involvement of regional officers in the participatory activities opened new spaces for the integration of knowledge gained from the field monitoring and agronomic experiments into the 2000-2006 impact assessment of the agro-environment prescriptions (reg. CE 1257/1999) on soil and water quality in the Region Marche and the design of future strategies;
- researchers gained a more reflexive attitude in identifying a number of questions about why, what and how to measure relevant agronomic variables driving the recognised ecological processes influencing water quality at catchment scale, that could be integrated into participatory research processes.

The negative experiences made by the same agronomy team in supporting norms and political decisions with agronomic scientific results through interface bodies (e.g. extension services) confirm that some fundamental assumptions around the linear transfer of knowledge from science to practice are weak (Ison and Russell, 2000). On the other hand, the shift from the agronomic analysis of the pure bio-physical system to an integrated analysis of both bio-physical and human behaviours requires a shared analytical framework model to support interdisciplinary research activities. The analytical framework developed by the SLIM project has been used as an explorative "field tested" integrated and participatory approach which proved to be useful to integrate scientific and lay knowledge (e.g. www.corason.hu) to develop concerted actions around the nitrate case study. The experience reported in this paper shows that agronomy researchers can actively contribute to develop a suitable theoretical framework to support a multi-stakeholder learning process fed by scientific results, aimed at changing practices towards more sustainable use of water resources at catchment scale and at managing the complexity of the science-policy interface (Lankford et al., 2004). However, the management of participatory approaches requires specific investments on new skills based on an integrated and comprehensive view, in order to satisfy the needs of multiple stakeholder groups equitably and efficiently (Walker et al., 2001). For these reasons, it is important that investments are also made within the agronomy researchers community dealing with agro-environmental issues, to develop specific skills at least on the basic principles of communication and group discussion dynamics, in order to guarantee a sufficient standard of quality of the participatory processes.

The efficacy of the involvement of stakeholders and their constructive attitude to actively participate, feeding with their own experience the learning process, are related to the quality and quantity of available scientific results and to the quality of the dialogical processes between researchers and stakeholders. The process of design and implementation of agronomic research on the environmental impact of farming systems is also relevant to the possibility that agronomic data can be effectively used to facilitate participatory activities. The availability of a space-time dataset on cropping systems and water nitrate concentration collected at microcatchment scale, designed to allow the interpretation of the relationships between current farming practices and water quality, was a fundamental basis to facilitate the focus of the local stakeholders around their own water and land and to increase their awareness about the consequence of everyday practices.

Researchers and those involved in the participatory process design, have to take decisions on the dialogical tools and scientific data to be used for different situations, to maintain a high level of interest among those involved in the different analytical sessions, while avoiding to bias the process driving it in a pre-determined direction (Toderi et al., 2004). To face this issue, the process should be followed by an interdisciplinary team, including biophysical scientists and experts in communication and learning processes, so that researchers can play an authoritative and transparent role in providing their knowledge in the ongoing learning process.

The ultimate emergent property of such activities is to enhance the development of concerted actions towards the improvement of agricultural practices and water quality in the socio-economic and normative context of an European region (e.g. nitrate or water framework directive).

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Appendix 1

Stakeholder *analysis (SA)*
SA is a participatory process which fits the conceptual constructivist model of agroecosystem described by Bawden and Ison (1992) and the second order R&D approach (Ison and Russell, 2000) to competing claims on the use of resources at catchment scale. The application of SA to resource dilemmas such as water related issues are described by SLIM (2004b).

What to do and why
1. *Identify the boundaries of the system of interest*
If agroecosystems are considered a social construction of purposeful learning systems (Bawden and Ison, 1992; Ison and Russell, 2000), the claims and practices of different stakeholders should be considered as part of the system of interest, hence boundaries become dynamic and less defined, in relation to the evolution of the SA. From this perspective, agronomy knowledge is useful to approach an identified agro-environment problem, even using DSS's, but it may not be sufficient either to support a recognised improvement nor to be effectively integrated in the decision making process at different levels. Participatory SA may help to shape and share the system of interest (i.e. the issue) between interdependent stakeholders, to identify what is collectively desirable in a specific context and which are the priorities for concerted actions. In this process, agronomy researchers may provide crucial information for supporting these processes.

2. *Identify* stakeholders *and stakeholding*
The identification of stakeholders is a dynamic and iterative step-wise process.
A first step may be represented by the preliminary identification of stakeholders (Ramirez, 1999) by a team of researchers, e.g. following the "CATWOE" classification of stakeholders made by Checkland (1981) and described by Checkland and Scholes (1990).
The following questions may help to start the analysis:
- Which are the priorities in the specific system of interest?
- Who are the stakeholders, direct or indirect, active or passive, aware or unaware, around these priorities?
- Why? How? Which are the stakes?

The subsequent steps will be focused on the identification of the roles, stakes and perspectives of different stakeholders or groups of stakeholders around an issue (Grimble et al., 1995). Researchers can play different roles in different situations (e.g. experts providing just data but not solutions; facilitators of learning processes; co-researcher with other stakeholders).
Different strategies can be implemented:
- make just "external" observations on stakeholder behaviours in different contexts (e.g. monitoring practices, participating as observer to self-organised meetings and fora etc.).
- create new opportunities for interaction with and among stakeholders (e.g. organise events such as an interactive workshops between groups of stakeholders, make semi-structured interviews or focus groups).

An important point in both cases is to create an interdisciplinary team of researchers in which different participants play different roles in different situations, so to reduce the risk of misinterpretation or process driving.
At each step of the SA, the specific activities and

strategies can be re-defined according to the results obtained in the previous step.
The first steps may be finalised to set the priorities from different perspectives around a perceived issue and to invite the stakeholders identified by the research team to identify other stakeholders.

3. *Develop tools to engage with* stakeholders
Researchers may use different tools to engage with stakeholders (Powell and Toderi, 2003, Toderi et al., 2004).
The use of these tools require attention to some critical methodological aspects, with a specific care to avoid driving the process towards a pre-defined direction (Freeman, 1984; Ramirez, 1999). Researchers should always be transparent in defining their role and the task of the research process when engaging stakeholders.

4. *Assessing and benchmarking the learning process*
An important point is to benchmark the process start and the subsequent steps, identifying a set of indicators of the evolution of the entire process. Indicators would be defined by researchers according to the declared objectives.
The direct outcomes of the process assessments may be for instance:
1) a list of priorities and weights from different perspectives;
2) a list of stakeholders and related interests;
3) the dynamic boundaries of the system of interest;
4) a network of interdependencies among different stakeholders;
5) the relationships between identified stakeholders and the system of interest.

Indirect outcomes may be:
1) the building of trust relationships between researchers and other stakeholders;
2) an ongoing learning process within the research team around the complex set of social and biophysical processes related to practices at catchment scale;
3) the building of a network providing new opportunities for research and development in the specific context;
4) the integration of scientific knowledge at different levels and the recognition of the role of scientific research to support sustainable practices.

These outcomes can be represented through tools such as two way SHs/priority matrices (Table 6) or systems mapping, which can provide heuristic devices for the ongoing learning process, to share issues and identify relevant processes.

Table 6. An example of a weighted priority/SH matrix that can be either prepared by researchers as an output of SA or used as an heuristic device if co-constructed with stakeholders. The multivariate analysis of the matrix scores can be used to cluster SHs sharing similar views. Weight attribution may also be exploited in a participatory approach: in this case the matrix can become an heuristic device to facilitate social learning among participants.

SHs	SH1	SH2	SH3	SHn	Median
Priorities					
Priority 1	9	2	5	9	7.0
Priority 2	2	5	5	1	3.5
Priority 3	9	9	9	8	9.0
...	...	...	...	...	...