Using spatial information to improve collective understanding of shared environmental problems at watershed level

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Abstract

The decrease in stream water quality due to intensive agriculture is an environmental problem of concern in various parts of the world. This problem may not be appropriately addressed due to insufficient knowledge of its causes, in particular, the locations of the primary pollution sources and the relative magnitude of the problem under different management scenarios. In some situations, this information may be known but not adequately communicated to, or perceived by, the stakeholders who should decide on corrective action. A participatory approach, which includes the negotiation between suppliers and users of information and visualisation of scenarios, could be a powerful tool to overcome these inadequacies. This paper describes the provision of spatial information and the results of spatially explicit pollution modelling exercise to stakeholders in a participatory workshop, and evaluates the extent to which this information influenced decision-making. Workshops were organised with farmers and extensionists in the west region of Santa Catarina State, Brazil. Spatial information (synoptic satellite image, orthophoto mosaic, location of pig producers) and results from a spatially explicit dynamic pollution model (AgNPS) for previously prepared scenarios were presented. Questionnaires were administered at four different times during the workshops to test participants’ reactions to, and opinions of, the information provided. Participants were able to understand and react to the spatial information despite their lack of previous exposure to such materials. Both visualisation and discussion caused major shifts in perception of the problem and suggestions for solutions. Participatory visualisation of scenarios enhanced perception and increased understanding of the water pollution problem caused by intensive pig farming and stimulated the collective search for solutions.

Keywords: Stakeholders’ perception; Water pollution; Visualisation tools; Demand-driven land evaluation; Spatial information

1. Introduction

The decrease in stream water quality, in particular as a source for drinking water, due to intensive agric...
culture is an environmental and social issue of concern in various parts of the world. Spatial identification of polluted drinking water and determination of its quality are often difficult to achieve (Engel et al., 1993). Lack of information, in particular, the locations of pollution sources and the relative magnitude of the problem under different management scenarios, is a reason why this problem may not be properly addressed. In some situations, this information may be known but not be adequately communicated to, or perceived by, the stakeholders who should decide on corrective action. To overcome these difficulties, Bacic et al. (2003) suggested a demand-driven land-evaluation approach, which includes a dialogue between information suppliers (surveyors, land evaluators and modellers) and users (stakeholders and decision-makers) about the information required for land-use planning in each specific physical, social, and economic context. However, this does not guarantee an adequate understanding and use of the information generated as a result of this dialogue. One way to promote such understanding may be visualisation by stakeholders of the provided information, in particular, modelled scenarios in a geographic information system (GIS). If this visualisation is interactive and in collaboration with the information suppliers, this is then a participatory method; such systems are commonly called participatory geographic information systems (PGIS).

Participatory approaches have been used to identify, compare and integrate local knowledge with expert knowledge on soil and land use (Barrera-Bassols and Zinck, 2003; Ryder, 2003) and to identify and analyse the implications of local knowledge for integrated soil management (Al-Kodmany, 1999; Gimblett et al., 2001; Appleton and Lovett, 2003; Tress and Tress, 2003). The main focus has been on linking and visualising local and expert knowledge (Craig et al., 2002). Other applications include studies to recover rich cultural traditions and management practices (Gonzalez, 2000), the visualisation of future scenarios for landscape planning (Tress and Tress, 2003), the benefits of participatory planning as implemented in a planning support system (Geertman, 2002), and the assessment of land suitability with public participation using multi-criteria and multi-objective evaluation (Bojórquez-Tapia et al., 2003).

Most of the effort has been on developing and improving technologies for PGIS. The participants’ perceptions of these tools and the information presented with them have been much less studied. Some authors have used their colleagues and students, rather than actual stakeholders, as experimental subjects to evaluate visualisation tools for PGIS (Ogao, 2002; Appleton and Lovett, 2003). In developing countries, these tools are still restricted because of the supposed inability of the stakeholders to understand them.

The objective of this work was thus to see to what extent stakeholders in a transitional economy could be helped to understand a specific environmental problem (here, water pollution by pig manure in a watersheds in Santa Catarina, Brazil) by visualisation of spatially-explicit pollution modelling results in a PGIS.

2. Material and methods

2.1. The study area

This study was carried out in the upper part of Ari-ranhazinho River microcatchment (2520 ha), located between 52°23′ and 52°19′ W and 27°07′ and 27°12′ S, near Seara town in Santa Catarina State, Brazil. The study area is characteristic for most of the west region of Santa Catarina (25 300 km²). The economy of the area is primarily based on agriculture with a domination of small family farms and intensive pig production. Elevation ranges from 385 to 930 m, a.s.l. and the average slope is about 30%. About 40% of the land is used for annual crops, mainly maize (Tassinari et al., 1997). The underlying geological formation is the “Serra Geral”, composed of dark grayish to black basalt (Silva and Bortoluzzi, 1987). Predominant soils are “Cambissolos” and “Nitossolos” according to the Brazilian system (EMBRAPA, 1999), corresponding to the thermic families of Oxic Dystrudepts and Typic Kanhapludults in the USDA system (USDA, 1999).

2.2. The stakeholders

The main stakeholders in the study area related to water pollution and its control are farmers, extensionists, agro-industries and governmental organisations. The farmers play the most crucial role, as they directly
decide on allocation of land uses to land parcels and land management methods. They operate under the constraints, incentives and guidance of the other stakeholders. A social typology of farms has been developed for Santa Catarina, based on the type of labour and income level (FAO/INCRA, 1997; Tedesco, 1999).

The farm is called a “family” farm when most of the labour is from family members and a “business” farm when most of the labour is hired. It is called “consolidated” when the farm income is higher than three legal minimum wages per person working full-time on the farm, “transitional” when it is between one and three minimum wages and “marginal” when it is less than one minimum wage. According to Instituto Cepa/SC (2001), there are 60 families farming in the area, 27 of them with intensive pig production. Half of the farms in the area are classified as marginal family farms.

2.3. Workshop protocol

Four workshops were organised with the main stakeholders in the area. These took place in the first week of December 2002 and were conducted in Portuguese, which is the first language of all participants. Representatives of all the farms in the study area were invited; these were 30 farmers from marginal family farms and 30 from consolidated and transitional family farms.

Thirty state rural extensionists from municipalities in the west of Santa Catarina, and representatives from both local agro-industries (meat packers) were invited as well. The groups were not mixed in order to avoid inter-group influences.

Each workshop was planned to last about 4 h with the following protocol: (1) explanation of the purpose and structure of the workshop; (2) a first questionnaire (Q1) to collect general information about the participants, and to measure their knowledge and views on environmental problems caused by pig manure in the region; (3) a presentation of spatial information without discussion and interventions; (4) a second questionnaire (Q2) to test the effect of the provided information; (5) open, guided discussion; (6) a third questionnaire (Q3) to test the effect of the discussion; (7) a fourth questionnaire (Q4) to evaluate the information provided and methodology used; and (8) final remarks and conclusions. The first questionnaire (Q1) contained personal and general questions and questions about the spatial and temporal environmental problem perception, the current situation, future possible scenarios, and effectiveness and feasibilities for improvements and solutions. The second (Q2) and third (Q3) questionnaires were similar but without the personal questions. The fourth questionnaire (Q4) contained questions about quality and usefulness of the provided information and working approach. Questionnaires were linked to each other either by the participant’s name or a sequential number in those cases where the participant preferred to remain anonymous. Answers were entered in a database, summarized and presented in this paper.

2.4. Spatial information

The following spatial information was presented: (1) a satellite (LANDSAT 7) false-colour composite image from September 1999 showing the location of the Ariranhazinho watershed (Fig. 1); (2) orthophoto mosaics from three different viewpoints with locations of the main pig producers and their relative manure production superimposed; and (3) satellite false-colour composite images from three different viewpoints with the same superimposed information (see one example in Fig. 2). Satellite images were sharpened with a Brovey transform using band 8 (panchromatic) applied to bands 4, 5 and 3 as red, green and blue in the false-colour composite.

Spatial information was prepared with ILWIS 3.2 Academic Geographic Information System (ITC, 2002) and ERDAS IMAGINE (ERDAS LCC, 2002). The orthophoto mosaic was prepared from aerial photos at a scale of approximately 1:25,000, flown by the private company “Cruzeiro do Sul Levantamentos Aerofotogramétricos” over the period 1977–1979. The Digital Elevation Model (DEM) was developed by interpolation between contour lines digitised from the 1:50,000 topographic map SEARA, SG.22-Y-D-1-1 (MI-2887/1) issued by the Army Ministry in 1979.

The 27 pig farms were identified in the field and the GPS coordinates of the main farm building taken as their location in the GIS. The estimated amount of manure produced was determined by the Instituto Cepa/SC (2001). The highest concentration of animals and related manure production is in the east of the catchment.

Other information presented included the estimated total amount of pig manure produced in the catchment (25,700 m³ manure/year according to
Fig. 1. Location of the Ariranhazinho river microcatchment (outlined) within Santa Catarina State and Brazil; grid coordinates refer to UTM zone 22J. Background is a false-colour composite (bands 4/5/3 as R/G/B) LANDSAT 7 of September 1999.
Instituto Cepa/SC (2001)) and the area of annual crops (1100 ha), where the manure can be used as fertilizer (Tassinari et al., 1997) resulting in an average of 23.4 m³/ha/year. The amount of manure recommended in the region is 60 m³/ha/year (Dartora et al., 1998), which means that, if well managed, the manure should not be seriously affecting the water quality.

2.5. Pollution model scenarios

Results from a dynamic pollution model for previously prepared scenarios were also presented. The scenarios were prepared using AgNPS, the Agricultural Non Point Source pollution model (Young et al., 1987), GRIPS, a “Geo-Referenced Interface Package” for the AgNPS v. 5.0 model (Mannaerts et al., 2002) and ILWIS 3.2 academic (ITC, 2002). As input for AgNPS, the initial parameterisation established by Bacic (2003) for a 150 m x 150 m cell size was used. The simulated spatial patterns of runoff, erosion and sedimentation (the processes by which pollutants are transported) visually matched expert knowledge of these processes in the local environment. Therefore, even though the models were not verified by field experiment, for the purposes of the participatory workshop, it was felt that the produced scenarios were realistic enough at least for relative ranking. Since the aim of this research was to explore the effect of spatial information on the collective understanding, perceptions and analysis of shared environmental problems, detailed accurate predictions were not necessary. Details of the modelling approach are explained by Bacic (2003).

The results of the following scenarios for the spatial distribution of N and P concentrations were presented: (1) current land use without pig manure for small (5 mm rainfall), medium (50 mm) and large (125 mm) storm sizes; the maps showed zero N and P concentration in runoff; (2) current land use with pig manure distributed in annual crops and pasture ac-
Fig. 3. Examples of maps generated by AgNPS scenarios and presented by ILWIS using the GRIPS interface: N concentration in runoff for two scenarios and three different storm sizes.

3. Results

3.1. General information of the participants

Eleven farmers from marginal farms, 10 from consolidated farms and 18 extensionists participated in the workshops, corresponding to 37, 33 and 60% invitation acceptance rates, respectively. Neither local agro-industry sent any representative, although they had been invited to send at least one administrator and several technicians, so, that workshop was cancelled.

Most of the participants from marginal farms have lived in the region for more than 20 years (8 out of 11). The size of their farms varies from 8 to 73 ha, most (9 out of 11) of the farms are smaller than 30 ha. The main activities are maize and milk production; secondary activities include small-scale production of pig, beans and
poultry. Similarly, most of the farmers from consolidated farms have lived in the region for more than 20 years (9 out of 10), but the size of their farms are mostly bigger than 30 ha (6 out of 10). Their main activity is pig farming; secondary activities include production of maize, milk, poultry and wheat. Extensionists have been working in the region from just few months to more than 30 years, most of them (13 out of 18) for at least 5 years.

3.2. Spatial perception of the problem

All the farmers could easily locate rivers, streams and cities on the satellite images, and their own farms, neighbours, roads, villages and streams on the orthophotos, even though this was the first experience with this type of material for most of the participants. The extensionists could also easily understand the presented information and identify the features despite their lack of familiarity with the materials. Most extensionists have seen satellite images only as weather reports on television, and have used aerial photos only in brief exercises at technical school.

When marginal farmers were asked about the location of highest pollution sources, 10 of 11 were able to name the village with the highest pig concentration even before the presentation. Afterwards, they could also identify the position in the catchment (low, medium or high) of the principal pollution sources. During the discussion, they actively pointed out places as shown on the maps and images where pollution should be most severe, and identified from memory the farmers and local place names.

The results from the consolidated farmers were completely different. Most of them did not identify either the community with highest animal concentration or spatial locations with higher pollution severity during the whole workshop. The presentation and discussion did not change their answers.

As the extensionists were not familiar with the study area, they were asked for their opinion about how the presented materials might affect their spatial perception of actual and potential pollution, were these to be provided for catchments with which they were familiar. After the presentation and discussion, 28% of them answered that the presented information could improve their spatial perception of actual pollution; the positive response was a bit higher for potential pollution (33%).

3.3. Temporal perception of the problem

During the whole workshop, most of the participants in all three groups were of the opinion that the pollution problem is higher during the summer, when the river level is lower and the concentration of pollutants is higher. Most of the extensionists and marginal farmers said that during or after a storm the situation is worse, as the farmers usually discharge the manure from the ponds direct to the river. The majority of the consolidated farmers saw the problem from a different point of view, stating that the problem is higher when some farmers discharge the manure even without rain, although this is not a common practice.

In fact, the information presented contradicted the preconception and showed that in medium-sized storms, the concentration of pollutants is predicted to be the highest. With large storms, the amount of pollutants carried to the river is higher but the flow rate also increases, consequently decreasing the concentration in drinking water extracted from streams. This information had an impact in the respondents’ opinions, since the number of participants answering that medium storms were worst for water pollution increased after the presentation from 9 to 82% for marginal farmers, 10 to 60% for consolidated farmers and 6 to 44% for extensionists.

3.4. Main causes of water pollution

The information presented showed that one of the main causes of water pollution might be the high concentration of animals rather than their total population. Before presentation and discussion, most of the farmers considered both important factors. Later in the workshops, they maintained their opinion about animal concentration, but fewer considered the absolute number of animals to be an important cause (Table 1). This illustrates that the presented information and discussions were able to change initial perceptions.

Table 1 summarizes respondents’ opinions about possible causes of water pollution. One important cause of manure concentration, and hence, pollution identi-
Table 1

<table>
<thead>
<tr>
<th>Main causesa</th>
<th>Marginal farmers</th>
<th>Consolidated farmers</th>
<th>Extensionists</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Q1 (%)</td>
<td>Q2 (%)</td>
<td>Q3 (%)</td>
</tr>
<tr>
<td>General high number of animals</td>
<td>100</td>
<td>64</td>
<td>0</td>
</tr>
<tr>
<td>Animal concentration</td>
<td>100</td>
<td>91</td>
<td>0</td>
</tr>
<tr>
<td>Ponds location</td>
<td>100</td>
<td>73</td>
<td>91</td>
</tr>
<tr>
<td>Inappropriate ponds building</td>
<td>91</td>
<td>73</td>
<td>100</td>
</tr>
<tr>
<td>Direct flow to the streams</td>
<td>91</td>
<td>82</td>
<td>100</td>
</tr>
<tr>
<td>Management</td>
<td>36</td>
<td>55</td>
<td>91</td>
</tr>
<tr>
<td>General perception</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Severity levelb</td>
<td>64</td>
<td>45</td>
<td>27</td>
</tr>
<tr>
<td>Urgency for solutionsc</td>
<td>91</td>
<td>45</td>
<td>27</td>
</tr>
<tr>
<td>Feasibility of solutionsd</td>
<td>91</td>
<td>18</td>
<td>55</td>
</tr>
</tbody>
</table>

Q1: Questionnaire 1, pre-visualisation; Q2: Questionnaire 2, post-visualisation; and Q3: Questionnaire 3, post-discussion.

a Proportion of respondents considering the cause to be very important (from three options: very important, important and slightly important).
b Proportion of respondents considering pig manure pollution to be very and extremely severe in the region (from five options: extremely severe, very severe, severe, slightly severe and not severe).
c Proportion of respondents considering the search for solutions to be very and extremely urgent (from five options: extremely urgent, very urgent, urgent, slightly urgent and not urgent).
d Proportion of respondents considering to be very difficult and difficult to find solutions (from four options: very difficult, difficult, easy and very easy).

fied by the participants was the steep slopes, which hinder transport and distribution of manure.

3.5. Severity levels of the problem

Most of the marginal farmers responded that the water pollution problem in the area was at least “very severe” (64%) and “very urgent” to solve (91%) in the first questionnaire (Table 1). After presentation and discussion, these numbers both decreased to 27%. Through the whole workshop, the majority of consolidated farmers did not perceive the problem as either “very severe” or “very urgent”, thus not in urgent need of solution.

The number of participants’ of the three groups answering that the problem is “difficult” or “very difficult” to solve decreased after the presentation and increased again after the discussion.

3.6. Feasibility of improvements

Participants were also asked about the presumed effectiveness of various feasible measures to ameliorate the pollution problem. Table 2 shows that their answers were consistently related to the main causes presented in Table 1. For instance, respondents considering the high number of animals an important pollution cause thought that decreasing the number of animals could be a very effective measure. In addition, the presentation had an important influence on extensionists’ opinions about manure transportation to be spread in other areas nearby, as the number of respondents considering it a “very effective” measure increased from 33 to 67% (Table 2).

Table 2 also presents opinions about the feasibility of implementing various measures. The most striking response was that marginal farmers, who at first thought that decreasing animal numbers and concentration were feasible, changed their minds after the final discussion, but not after information presentation.

3.7. Participants’ evaluation and demands raised

Finally, participants were requested to evaluate the quality and usefulness of the tools and information presented (Tables 3 and 4). In general, they liked both the materials and methods. Farmers and some extensionists stated they would like to have had more time to discuss the issues raised. The 22% of the extensionists who considered the materials irrelevant were likely dis-
Table 2
Effectiveness and feasibility of measures to decrease pollution problems caused by pig manure

<table>
<thead>
<tr>
<th>Measure of improvement</th>
<th>Marginal farmers</th>
<th>Consolidated farmers</th>
<th>Extensionists</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Q1 (%)</td>
<td>Q2 (%)</td>
<td>Q3 (%)</td>
</tr>
<tr>
<td>Decrease number of animals</td>
<td>73</td>
<td>73</td>
<td>9</td>
</tr>
<tr>
<td>Decrease concentration of animals</td>
<td>91</td>
<td>82</td>
<td>100</td>
</tr>
<tr>
<td>Change location of ponds</td>
<td>82</td>
<td>91</td>
<td>100</td>
</tr>
<tr>
<td>Vegetal streams protection</td>
<td>55</td>
<td>82</td>
<td>100</td>
</tr>
<tr>
<td>Manure transportation</td>
<td>91</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Improve management of manure</td>
<td>91</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Avoid direct flow</td>
<td>91</td>
<td>91</td>
<td>82</td>
</tr>
<tr>
<td>Feasibility of measures for improvements</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Decrease number of animals</td>
<td>55</td>
<td>73</td>
<td>9</td>
</tr>
<tr>
<td>Decrease concentration of animals</td>
<td>27</td>
<td>73</td>
<td>0</td>
</tr>
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<td>Change location of ponds</td>
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</tr>
<tr>
<td>Avoid direct flow</td>
<td>73</td>
<td>91</td>
<td>91</td>
</tr>
</tbody>
</table>

Q1: Questionnaire 1, pre-visualisation; Q2: Questionnaire 2, post-visualisation; and Q3: Questionnaire 3, post-discussion.

a Proportion of respondents considering the measure to be very effective (from three options: very effective, slightly effective and ineffective).

b Proportion of respondents considering the measure to be feasible (from three options: feasible, slightly feasible and infeasible).

Table 3
Participants’ evaluation of the quality of information presented

<table>
<thead>
<tr>
<th>Information type</th>
<th>Marginal farmers</th>
<th>Consolidated farmers</th>
<th>Extensionists</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Good (%)</td>
<td>27</td>
<td>50</td>
<td>–</td>
</tr>
<tr>
<td>Good (%)</td>
<td>73</td>
<td>50</td>
<td>72</td>
</tr>
<tr>
<td>Bad (%)</td>
<td>–</td>
<td>–</td>
<td>6</td>
</tr>
<tr>
<td>Irrelevant (%)</td>
<td>–</td>
<td>–</td>
<td>22</td>
</tr>
</tbody>
</table>

Table 4
Participants’ evaluation of the usefulness of information types presented

<table>
<thead>
<tr>
<th>Type of information</th>
<th>Very useful (%)</th>
<th>Useful (%)</th>
<th>Slightly useful (%)</th>
<th>Not answered (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orthophoto</td>
<td>55</td>
<td>20</td>
<td>11</td>
<td>50</td>
</tr>
<tr>
<td>Satellite Image</td>
<td>82</td>
<td>30</td>
<td>13</td>
<td>18</td>
</tr>
<tr>
<td>Farm location</td>
<td>82</td>
<td>40</td>
<td>28</td>
<td>18</td>
</tr>
<tr>
<td>Pollution model</td>
<td>27</td>
<td>50</td>
<td>11</td>
<td>73</td>
</tr>
<tr>
<td>Discussion</td>
<td>45</td>
<td>60</td>
<td>60</td>
<td>55</td>
</tr>
</tbody>
</table>

Marg: marginal farmers; Cons: consolidated farmers; and Exte: extensionists.

appointed that the areas where they work were not the subject of this exercise.

The most valued information varied between groups (Table 4). For instance, the pollution model was the most appreciated by consolidated farmers and the least valued by the other groups. The extensionists considered the discussion generated to be more important than the information presented. Marginal farmers preferred the satellite images and farm location maps.

All the farmers, and 17 of 18 extensionists, felt that the same kind of participatory workshop presenting and discussing spatial information would be useful in the discussion of other issues in the region, such as land evaluation and land-use planning, rural tourism, farmers’ organisation and other environmental problems.

An important result was that the workshops stimulated additional demands. All groups asked for similar workshops to be organised with institutions and governmental organisation. Other important demands
were: (1) to use the same method for other microcatchments; (2) to advance the work after this first step in the search for alternatives and solutions; (3) to organise another workshop to simulate other scenarios interactively with participants rather than statically as in the present study; (4) to organise training to explain how to use the tools in an efficient way; (5) to locate pig producers at municipal and regional, as well as catchment, levels; and (6) to locate the poorest farms with a greater need for support.

The participants also suggested improvements to the workshop protocol: (1) to use short videos to show the problems as they occur in the field; (2) to stimulate more discussion and reduce the number of questionnaires; and (3) to begin the discussions in small groups and only later open the discussion to the whole group, this to facilitate more active participation.

4. Discussion

4.1. General information of the workshops

Although the number of farmers that attended the workshops was small, it was considered satisfactory, given the difficulties in transport, the aversion of some farmers to meetings, and the favourable weather for farm work. The farmers were considered representative by the workshop organiser and extensionists. The absence of the agro-industries' representatives was anticipated. According to the participants from the other groups, the agro-industries have traditionally avoided public debate on water pollution, which may have its source on pig farms with which they have contracts. They take an active role in discussions of the environmental effects of the industrial plant itself, but are apparently reluctant to do so when the direct cause is not from the plant but rather from their associates (contracted farmers). They are, thus, avoiding what is for now only a moral responsibility, but which may at some point be the subject of legislation.

The workshop had a higher impact on the perceptions of the marginal farmers than on those of the consolidated farmers, probably reflecting the different levels of knowledge, perspectives and needs of the different groups. This suggests that different groups should be approached with different interaction styles and with group-specific information (Bacic, 2003). In general, extensionist's opinions changed little. Since they were from other areas, they were not familiar with the presented microcatchment. They frequently tried to shift the debate to the conditions of their own geographic areas. This partially explains why they hardly changed their opinions, as well as some contradictory answers to the questionnaires, e.g. their persistence in answering that the high pig population, rather than concentration was one of the main causes, even after being presented information proving the opposite. Perhaps the underlying problem is a lack of imagination in this group, unlike the farmers who were presented information of direct relevance.

4.2. Stakeholders understanding of the water pollution problem

The ability of farmers to understand maps and images even on first contact is also mentioned by other authors (Gonzalez, 2000). The presentation of relevant spatial information improved communication between information providers and stakeholders (Tress and Tress, 2003), helped to increase participants' understanding and perception of the environmental problems, and thereby stimulated the design of alternative solutions, which is expected to lead to improved decisions (Al-Kodmany, 1999; Gimblett et al., 2001; Appleton and Lovett, 2003; Tress and Tress, 2003).

The inaccurate initial impression of the participants of the main causes of the environmental pollution (before the presentation) could lead to incorrect actions. For instance, the false perception that the total number of animals was the main problem could result in proposals for reducing the number of pigs in the area, perhaps by unpopular and conflict-engendering quotas. However, the information presented showed that the pig production might even be increased if combined with proper management practices including proper dispersion. A high animal concentration is also an option if combined with proper manure treatment; however, this is not now economically feasible.

The results concerning the severity level of the water pollution and the urgency to solve the problems presented in Section 3.5 suggest that marginal farmers, although recognizing the water pollution problem in the field, did not have a clear picture of the causes and feasible solutions. Their understanding improved after presentation. On the other hand, consolidated farmers,
mostly pig producers, did not express concern about the problem throughout the workshop. This may reveal a fear of attracting blame and being forced to pay for solutions without government subsidy. It may be that they have a hidden argument, which they concealed at the meetings, feeling that they have more to lose than to gain by open discussion. Further studies beyond the scenario analysis of the present study with this key group are needed, in particular, on their sociology and objectives.

The number of participants in all three groups answering that the water pollution problem is “difficult” or “very difficult” to solve decreased after the presentation and increased again after the discussion. This may reflect that the information presented showed that the problem is apparently not as serious as they thought, but after discussion it became clear that the solutions depend also on the actions of other stakeholders, such as the municipality and agro-industry. The use of spatial information could help to integrate different views of different individuals and groups into common understanding of feasible solutions (Ball, 2002).

4.3. Contribution of the proposed approach to the decision-making process

Decision-making in an agricultural context is an ongoing process which can be categorized into phases (Simon, 1977; Rogers, 1995; Backus et al., 1997): (1) perception of a problem or opportunity and the corresponding need to make decisions; (2) analysis of the problem; (3) formulation of alternative courses of action; (4) evaluation of the alternatives and past choices; (5) choice of one or more alternatives; and (6) implementation. An interactive collective analysis as presented in this paper could be a powerful tool for stakeholders in the area, supporting both farmers and policy makers in planning and decision-making on management practices aimed at reducing pollution problems. This research dealt with the first three phases mentioned above, and some alternatives were collectively formulated. Among the suggestions were: (1) agro- industries should consider decreasing the concentration of animals instead of concentrating even more in order to decrease their costs for animal transport; (2) new business should start following recommended management practices; (3) established business should modify their current practices with government and agro- industries support (e.g. subsidized credit to build new ponds); (4) support and educational programs should be provided; (5) manure could be transported from high-concentration to low-concentration areas, with public institutions and agro-industries supporting this effort with trucks, pumps and tubes and with machines for spreading. However, the measures considered most feasible are those related to the farmers’ own control, such as stream bank protection and sediment traps with dense vegetation, manure transport within the farm, improved management of manure and the avoidance of manure flowing directly to the streams. Neither the decrease in the number of animals nor in their concentration was considered feasible, probably because there is no substitute for the lost income, although participants realise that decreasing concentration is effective in reducing pollution. This emphasizes that any feasible solution should involve all actors in the process: farmers, extensionists, agro-industries and different levels of government.

As another result of the workshops, a group of farmers spontaneously wrote a letter to the workshop organisers, suggesting a regional conference with the main stakeholders in the pig production chain. They want to use similar procedures and tools as in the workshops. In this conference, the alternatives raised above could be further discussed in a multiparty group. This conference would be the first step towards phases 4, 5 and 6 of the decision-making process outlined above.

5. Conclusions

This paper describes the use of spatial information and pollution modelling in participatory stakeholders workshops on environmental problems, and evaluates their contribution to the decision-making process. The influence of the provided information on the stakeholders understanding and perceptions was systematically evaluated.

Although for most of the farmers it was the first time that they had been exposed to visual spatial information and pollution modelling results, they were able to understand and react to the material. This is an example of the power of visual spatial information as an effective means of communication. The provided information increased participants’ understanding of the
water pollution problem, improved their perception and stimulated the search for solutions.

Spatial information strongly influenced opinions. All the stakeholders showed, in general, a shift in opinions when they were exposed to additional information on the pollution problem. The most striking shifts were found among the marginal farmers; it is speculated that the consolidated farmers may have concealed a similar shift to protect their privileged position.

The presented material was appreciated by the stakeholders, especially the marginal farmer who found most of the material very useful. The consolidated farmers and the extensionists found the discussion more useful than the material itself, while the marginal farmers showed high appreciation for the satellite images and maps with farm locations. The workshops stimulated the formulation of requests for additional information and follow-up actions.

The overall finding of this case study is that presentation of relevant spatial information in a stakeholder’s workshop about environmental problem solving had a positive effect on perception of causes and the identification of solutions. It is expected that this specific conclusion is also valid for similar situations in other parts of the world, an expectation that awaits further investigation.

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