

# **DEMAND-DRIVEN LAND EVALUATION**

**With case studies in Santa Catarina, Brazil**

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**Ivan Luiz Zilli Bacic**

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*To my wife and children  
Iasmine, Thiago and Karoline*

*&*

*To my parents*

*João and Neyse:*

*Wherever you are,*

*thanks for the love you always dedicated to me*



---

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# CONTENTS

## Chapter 1

<b>General introduction</b> .....	<b>1</b>
<b>1.1. Research motivation and problem definition</b> .....	<b>2</b>
<b>1.2. General objectives and research questions</b> .....	<b>4</b>
<b>1.3. Structure of the thesis</b> .....	<b>6</b>

## Chapter 2

<b>The use of land evaluation information by land use planners and decision-makers: a case study in Santa Catarina, Brazil</b> .....	<b>9</b>
<b>2.1. Introduction</b> .....	<b>10</b>
<b>2.2. Background</b> .....	<b>12</b>
<b>2.3. The micro-catchment project</b> .....	<b>14</b>
<b>2.4. Methods</b> .....	<b>16</b>
<b>2.5. Results and discussion</b> .....	<b>17</b>
<b>2.6. Conclusions</b> .....	<b>22</b>

## Chapter 3

<b>The environment for farmers' land use decisions in Santa Catarina, Brazil: implications for land evaluation</b> .....	<b>25</b>
<b>3.1. Introduction</b> .....	<b>27</b>
<b>3.2. Methods</b> .....	<b>29</b>
<b>3.3. Who are the decision makers in rural land use?</b> .....	<b>30</b>
<b>3.4. What are the farmers' decisions that affect rural land use?</b> .....	<b>30</b>
<b>3.5. How do farmers make their decisions?</b> .....	<b>31</b>
<b>3.6. What factors influence farmers' decisions?</b> .....	<b>32</b>
3.6.1. <i>External agricultural policy</i> .....	<b>32</b>
3.6.2. <i>The institutional context</i> .....	<b>35</b>
3.6.3. <i>Legal aspects</i> .....	<b>36</b>
3.6.4. <i>Economic aspects</i> .....	<b>37</b>
3.6.5. <i>Socio-cultural conditions</i> .....	<b>38</b>
3.6.6. <i>Physical and environmental conditions</i> .....	<b>40</b>
3.6.7. <i>Farmers' responses to opportunities and constraints</i> .....	<b>41</b>
<b>3.7. What are the information processes regarding the decisions?</b> .....	<b>43</b>

---

<b>3.8.</b>	<b>A critique of the current planning mechanisms and planning institutions, specifically in Santa Catarina .....</b>	<b>44</b>
3.8.1.	<i>Communication.....</i>	44
3.8.2.	<i>Environmental damage.....</i>	44
3.8.3.	<i>Co-operatives and syndicates.....</i>	45
<b>3.9.</b>	<b>Implications of the planning environment for land evaluation.....</b>	<b>45</b>
3.9.1.	<i>Understanding the actor setting .....</i>	46
3.9.2.	<i>Classification of farmers for land evaluation.....</i>	46
3.9.3.	<i>Demand-driven land evaluation .....</i>	48

## Chapter 4

<b>Applicability of a distributed environmental model at watershed scale in a data-poor environment .....</b>	<b>49</b>
<b>4.1. Introduction.....</b>	<b>51</b>
<b>4.2. Study area .....</b>	<b>53</b>
<b>4.3. Modelling protocol.....</b>	<b>54</b>
4.3.1. <i>Software.....</i>	54
4.3.1.1. <i>AGNPS .....</i>	54
4.3.1.2. <i>GRIPS .....</i>	54
4.3.2. <i>Model input data preparation .....</i>	55
4.3.3. <i>Observed rainfall and water data .....</i>	55
4.3.3.1. <i>Splitting seasons .....</i>	59
4.3.3.2. <i>Eliminating unreliable and incomplete data and selecting storm events..</i>	59
4.3.4. <i>Effect of cell size .....</i>	60
4.3.5. <i>Sensitivity to input data .....</i>	60
4.3.6. <i>Calibration.....</i>	60
4.3.7. <i>Scenario analysis .....</i>	62
<b>4.4. Results and discussion.....</b>	<b>62</b>
4.4.1. <i>Observed rainfall and water data .....</i>	62
4.4.2. <i>Effect of cell size .....</i>	64
4.4.3. <i>Sensitivity to input data .....</i>	65
4.4.4. <i>Calibration.....</i>	66
4.4.5. <i>Scenario analysis .....</i>	70
<b>4.5. Conclusion .....</b>	<b>74</b>

---

<b>Chapter 5</b>	
<b>Collective understanding of shared environmental problems using visualization tools at watershed level.....</b>	<b>77</b>
<b>5.1. Introduction.....</b>	<b>79</b>
<b>5.2. Material and methods .....</b>	<b>80</b>
5.2.1. <i>The study area .....</i>	<i>80</i>
5.2.2. <i>Meetings protocol .....</i>	<i>81</i>
5.2.3. <i>Static spatial information.....</i>	<i>82</i>
5.2.4. <i>Dynamic pollution model.....</i>	<i>84</i>
<b>5.3. Results and discussion.....</b>	<b>87</b>
5.3.1. <i>Meetings .....</i>	<i>87</i>
5.3.2. <i>Reactions from the participants.....</i>	<i>88</i>
5.3.3. <i>Participants' evaluation and demands raised from the meetings .....</i>	<i>95</i>
<b>5.4. Conclusions.....</b>	<b>97</b>

<b>Chapter 6</b>	
<b>A participatory approach for integrating risk assessment into rural decision making: a case study in Santa Catarina, Brazil.....</b>	<b>99</b>
<b>6.1. Introduction.....</b>	<b>101</b>
<b>6.2. Material and methods .....</b>	<b>103</b>
6.2.1. <i>Study area .....</i>	<i>103</i>
6.2.2. <i>Previous interviews and meetings protocol.....</i>	<i>104</i>
6.2.3. <i>Yield predictions/climatic risk for maize .....</i>	<i>105</i>
6.2.4. <i>Economic analysis and risk information.....</i>	<i>107</i>
6.2.5. <i>Risk aversion .....</i>	<i>108</i>
<b>6.3. Results and discussion.....</b>	<b>109</b>
6.3.1. <i>How do decision makers view and calculate uncertainty and risk to make decisions?.....</i>	<i>109</i>
6.3.2. <i>General information about the meetings and participants.....</i>	<i>110</i>
6.3.3. <i>Response to yields predictions/climatic risk information for maize ..</i>	<i>111</i>
6.3.4. <i>Response to economic analysis and risk information .....</i>	<i>113</i>
6.3.5. <i>Risk aversion .....</i>	<i>114</i>
6.3.6. <i>Participant's evaluation and demands raised from the meetings .....</i>	<i>115</i>
<b>6.4. Conclusions.....</b>	<b>117</b>

---

<b>Chapter 7</b>	
<b>General conclusions</b> .....	<b>119</b>
7.1. <b>Main findings: revisiting objectives and research questions</b> .....	<b>120</b>
7.2. <b>Considerations: lessons from Santa Catarina</b> .....	<b>123</b>
7.3. <b>Next steps in Santa Catarina</b> .....	<b>124</b>
7.4. <b>Suggestions for further research</b> .....	<b>126</b>
<b>References</b> .....	<b>127</b>
<b>Summary</b> .....	<b>135</b>
<b>Samenvatting</b> .....	<b>139</b>
<b>Resumo</b> .....	<b>143</b>
<b>Appendix A – ITC PhD dissertations</b> .....	<b>147</b>
<b>Appendix B – Curriculum Vitae</b> .....	<b>157</b>

## **Chapter 1**

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### **General Introduction**

## **1.1. Research motivation and problem definition**

Land evaluation is the process of predicting land performance over time according to specific types of uses (Van Diepen et al., 1991; Rossiter, 1996). These predictions are then used to guide strategic land use decisions. So, one would expect that land use planners and other decision-makers who influence rural land use would be eager to use the results of land evaluation. Unfortunately this is not happening in practice. One of the main motivations for this study was the disappointment resulting from almost 15 years working as a soil surveyor and land evaluator with the feeling that the work was not useful to and used by the potential clients. In our experience in Santa Catarina, Brazil, the work always finished in the moment we sent the maps and reports to the rural extensionists. When we had opportunity to further discuss the reports with them, a common opinion was: “The work is excellent, and we have no comments to improve or change anything”. When visiting them in their offices, it was common to see the maps hanging in the walls, and when asked about the use, they always said: “I am using it a lot, it is very useful”. Although, when we asked them to show us the report because we needed some information, most of them could not even find the reports. When observing their work in the field, it became clear that in their day-to-day work, the land evaluation and soil survey reports were not used.

This apparent irrelevance of land evaluation is also taking place in the international context. Several authors have stated that decision makers do not in general make use of these results, nor are they particularly satisfied with them, if indeed they know of their existence (Rossiter, 1996; Bouma, 1997; Bouma, 1999). To date, more attention has been paid to land evaluation methods themselves than to their relevance and the utilization of the information that they generate.

It has been suggested that to change the existing situation, adapted land use options and planning strategies should be formulated with the participation of the stakeholders and in accordance with their possibilities (Bouma, 1999), i.e. a participatory and demand-driven approach. It is crucial to know what are the problems, the needs and possibilities of the stakeholders before starting the land evaluation process, otherwise there is a



risk that questions may be answered that have no priority or relevance, and/or that questions may not be answered properly according to the community expectation. The shift towards more participatory research is, however, not only inspired by pragmatic reasoning. The modern farmer, especially in developed countries, as well as the land use planner, is a well-trained professional who is less interested in receiving “definite” answers to questions than in having a presentation of a series of realistic options with accurate predictions from which he or she can make a selection. Modern agronomic and soil research has a clear challenge in developing such options in close consultation and interaction with the stakeholders, be it farmers, planners or politicians themselves. That is also the case in Santa Catarina. One of the reasons that the planners do not satisfactorily use the current work in land evaluation, is the lack of a range of alternatives presented. Usually the land evaluation procedures show what is wrong in the land use, what and where are the conflicts, but do not give good and realistic options to the stakeholders choose from. The uncertainties about each land use alternative and the risks to change the current activity should be analysed and presented to the decision makers to help them to make decisions.

Another important aspect is to know and understand the planning environment where decisions are made, analysing as deeply as possible the whole context. According to Bouma (1999), land use and its possible changes are usually more a reflection of socio-economic developments in society than of differences in soil suitabilities for different forms of land use. Then, it is crucial to know what are the important factors and aspects that can really affect the current and the potential land use alternatives, to reach effective results from the land evaluation process. It can also help in the decision about what quantity and quality of data are really necessary.

Information technology continues to improve rapidly, in particular GIS and remote sensing as well as expert systems. In the context of participatory land evaluation, these should be used as much as possible during the whole process, taking into account local conditions, e.g. the readiness of decision makers to interact with information technology. Bouma (1999) points out

that modern information technology has an important role to play in stimulating interaction with decision makers. Visualisation of alternative land use patterns associated with different options is a very powerful tool to involve them in the land use planning process. Interactive computer technology allows, for instance, joint generation of alternative land use scenarios with all associated input data by researchers and decision makers.

The diagram adapted from Rossiter (Figure 1) illustrates the emerging demand-driven paradigm in land evaluation and how this thesis addresses it.

## **1.2. General objectives and research questions**

The general objective of this thesis is to improve use and usefulness of information for rural land use decisions based on an operational demand-driven approach for land evaluation with case studies in Santa Catarina State, Brazil.

To achieve this objective, the following research questions were formulated:

- Are the existing land evaluation reports useful to rural decision makers?
- What interpreted information is necessary for rural decision-making?
- What are the implications of the planning environment for land evaluation?
- What primary information are necessary and feasible to collect or generate?
- What models and research methods can be used and which adaptations are necessary considering local conditions?
- How do decision makers evaluate methods, tools and the new information? Is it worth to invest time and resources to further improve information?

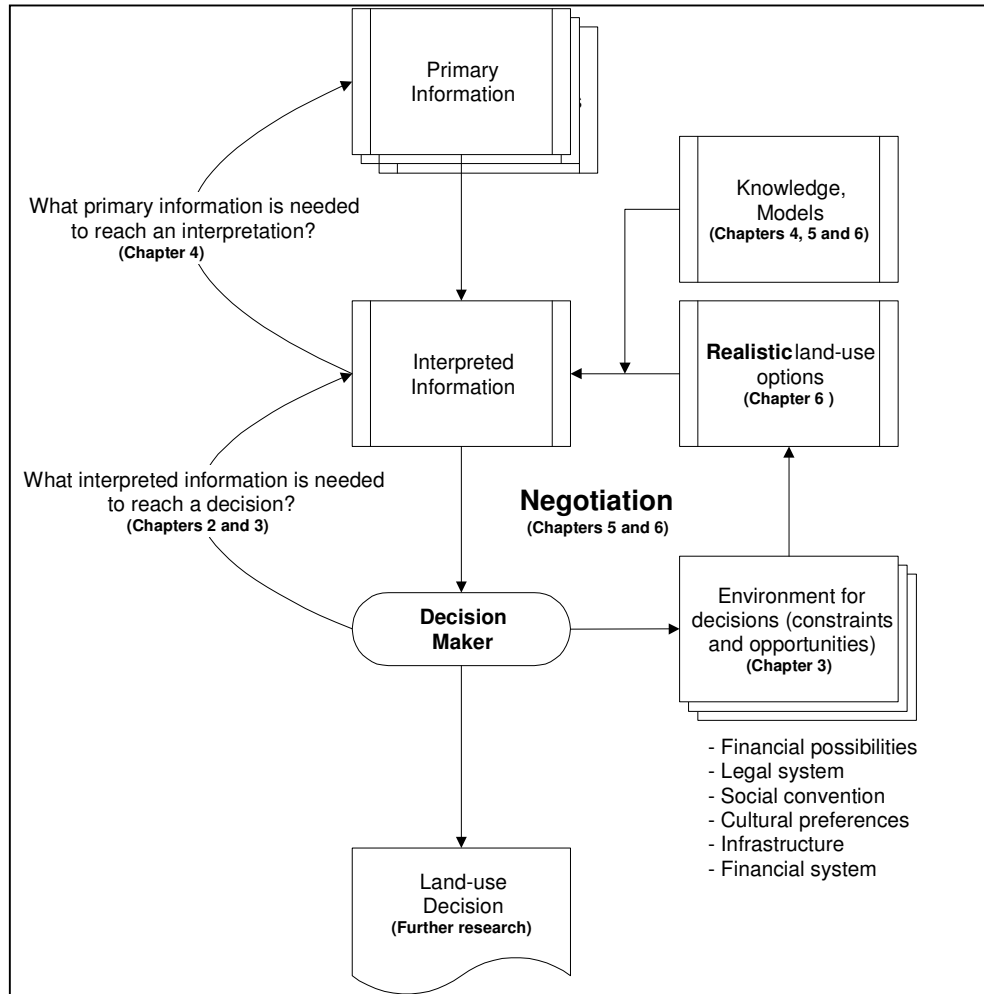


Figure 1 - Demand-driven land evaluation and resource inventory (adapted from Rossiter, unpublished).

### 1.3. Structure of the thesis

This thesis is a collection of papers, all dealing with case studies in Santa Catarina, Brazil and related to demand-driven land evaluation, published or submitted to international peer-reviewed journals. As such, there is some repetition. The case studies presented in chapters 4, 5 and 6 were selected according to the main demands of users as identified in the previous chapters.

**Chapter 2** describes and quantifies the use and usefulness of soil surveys and land evaluation reports to land use planners, observe the relation between latent demand and actual supply and suggest improvements on current methods. It was the basis for the thesis, indicating the main directions to be followed. The main objectives were to give an answer to the following questions: (1) are soil resource inventories and land evaluation reports really useful to the clients?; (2) is the information supplied what they need and want for their land use negotiation activities?; (3) are land evaluations actually used for land use planning and negotiation? If so, how are they used? If not, why not?; and (4) how can the inventories and evaluations be made more useful and relevant?

**Chapter 3** explains the farmers' decision environment in Santa Catarina state, Brazil, which is typical of many market-oriented but low-income economies, with respect to the actors, political, legal and social frameworks, interactions and dynamics and how these affect decision makers. First it concentrates on the following questions: (1) who are the decision makers in rural land use?; (2) what are the farmers' decisions that affect rural land use?; (3) how do farmers make their decisions?; (4) what factors influence farmers' decisions?; and (5) what are the information processes regarding the decisions? Second it addresses a critique of the current planning mechanisms and planning institutions, specifically in Santa Catarina. Finally it discusses the implications of the planning environment for land evaluation.

**Chapter 4** describes the applicability of a data-intensive watershed erosion and water quality model (AGNPS) in a relatively data-poor environment, reporting on the steps necessary to apply the model in a GIS

setting, including input data preparation, cell size and calibration, to predict surface water quality and to evaluate scenarios at small watershed scale in an area of intensive swine production. These scenarios were used as input to the next chapter.

**Chapter 5** shows that visual tools and pollution modelling can increase understanding of environmental problems, change perceptions, generate new demands and improve decisions, even taking into account the lack of habit and low preparation of the rural decision makers common in many areas of the world such as those in Santa Catarina. It also presents decision makers' opinions about the provided information.

**Chapter 6** evaluates the potential of a participatory approach for integrating risk analysis into decision making for rural land use and decision makers' view of the supplied information. It particularly focuses on two of the main risk-oriented information demands in the region: (1) yield predictions for maize on different planting dates and (2) economic information for different land use options. It also estimates the extent to which quantitative information on risk changes decision makers' attitudes towards it.

**Chapter 7** summarizes the main findings of the thesis, provides suggestions for further research and describes next expected steps in Santa Catarina.



## **Chapter 2**

### **The use of land evaluation information by land use planners and decision-makers: a case study in Santa Catarina, Brazil**

I.L.Z.Bacic, D.G.Rossiter and A.K.Bregt

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## **The use of land evaluation information by land use planners and decision-makers: a case study in Santa Catarina, Brazil**

**Abstract.** Land evaluation is the prediction of land performance over time under specific uses, to guide strategic land use decisions. Modern land evaluation has a 30-year history, yet the results have often been disappointing. Land users and planners have been reported to ignore land evaluations, perhaps reflecting poor quality, low relevance, or poor communication. To test the success of a large land evaluation exercise undertaken as part of micro-catchment project in Santa Catarina State, southern Brazil, we queried agricultural extensionists, considered as the primary land evaluation clients. We used a questionnaire with both structured and open questions, to determine their experiences with, and attitudes to, the current land evaluation method. The soil resource inventory and associated land evaluation had some utility, but were not in general used for their intended purpose, namely farm planning. This was mainly because they did not contain crucial information necessary to such planning in the actual context in which the farmer had to take decisions. The primary deficiencies were identified as: (1) no estimate of environmental degradation risk, (2) no financial analysis, (3) no social analysis of decision-makers' attitudes and preferences, (4) no risk assessment for weather, yields, profits and market, and (5) insufficiently-specific land use alternatives. These deficiencies could have been avoided with a demand-driven approach, evaluating and reporting according to the true needs and opportunities of the decision-makers.

### **2.1. Introduction**

Land evaluation is the process of predicting land performance over time according to specific types of uses (Van Diepen et al., 1991; Rossiter, 1996). These predictions are then used to guide strategic land use decisions. So, one would expect that land use planners and other decision-makers who influence rural land use would be eager to use the results of land evaluation. Yet several authors have stated that decision makers do not in general make use of these results, nor are they particularly satisfied with them, if indeed they know of their existence (Rossiter, 1996; Bouma, 1997; Bouma, 1999).



These statements are subjective impressions by information suppliers, i.e. the land evaluators themselves, and have not been substantiated by quantitative studies from the point of view of the demand side, i.e. the clients. More attention has been paid to land evaluation methods themselves than to their relevance and the utilisation of the information that they generate.

Land evaluation has traditionally been based primarily on soil resource inventories, commonly called soil surveys. These have been carried out for more than one hundred years in Russia, the USA and Hungary, and for at least fifty years in most other parts of the world (Boulaine, 1989; Zinck, 1995; Yaalon and Berkowicz, 1997). They were initiated mainly as support for rural land use decision making, in particular the matching of production systems (crops, varieties, rotations, fertilisation and other cultural practices, conservation measures) to soil types. This support became systematised in the land capability approach (Bibby et al., 1991; Klingebiel, 1991), where soil types were categorised by their ability to sustain general classes of land use. Starting in the 1950's, multi-purpose soil survey interpretations for non-agricultural uses became increasingly important (Bartelli, 1966), leading to the development of land evaluation methodologies in the 1970's (FAO, 1976; FAO, 1983; FAO, 1984; FAO, 1985; FAO, 1991). An international workshop for heads of national soil survey organisations to discuss the relevance of soil resource inventories was held at ITC in 1992 (Zinck, 1995). The participants agreed on the importance of soil surveys, but recognised the need for improvements in the information supplied to the clients. However, all these developments were based on opinions and experience from the supply (surveyor) side.

In Brazil, the first soil surveys were carried out in 1936 (Santos, 1995). The first soil interpretation system, a land capability approach, was formulated in 1964 (Bennema et al., 1964), and this was followed by similar systems (Ramalho Filho et al., 1978; Lepsch et al., 1983) which were later adapted for specific regions (Uberti et al., 1991; Bacic, 1998). Many interpretations based on these have been carried out, but no studies have been made concerning their use by, or usefulness to, their ostensible clients.

The optimism that greeted the FAO Framework in 1976 has given way to a realisation that its focus on static land use planning is not appropriate to today's "network society", where multiple stakeholders negotiate land use (FAO, 1996; Bouma, 2001a; Bouma, 2001b). Important questions remain, both in the Brazilian and international contexts:

- Are soil resource inventories and land evaluation reports really useful to the clients? Is the information supplied what they need and want for their land use negotiation activities?
- Are land evaluations actually used for land use planning and negotiation? If so, how are they used? If not, why not?
- How can the inventories and evaluations be made more useful and relevant?

This paper tries to answer these questions in the specific case of the "Micro-catchment Project" carried out in Santa Catarina State in southern Brazil.

The remainder of this paper is structured as follows: the background describes the method for land evaluation used in Santa Catarina, the micro-catchment project in which the method was applied, and the use of land evaluation information from the point of view of information suppliers. This is followed by the description of the methods used to determine utility and relevance, the results, a discussion, and finally conclusions, including suggestions for improvement.

## **2.2. Background**

Most of the soil surveys and land evaluation studies in Santa Catarina are made by the Empresa de Pesquisa Agropecuária e Extensão Rural de Santa Catarina (Agricultural Research and Rural Extension Enterprise of Santa Catarina State), abbreviation EPAGRI, an agency of the State Secretary of Rural Development and Agriculture. Land evaluations based on these surveys are prepared according to the "Metodologia para Classificação da Aptidão de Uso das Terras do Estado de Santa Catarina" (Methodology for Land Suitability Classification in Santa Catarina State) (Uberti et al., 1991).

It classifies land into one of five classes of physical suitability, which are first defined in descriptive terms as follows:

- Class 1 - Good suitability for climatically adapted annual crops;
- Class 2 - Moderate suitability for climatically adapted annual crops;
- Class 3 - Restricted suitability for climatically adapted annual crops, moderate suitability for fruit production and good suitability for pasture and reforestation;
- Class 4 - Restricted suitability for fruit production and moderate suitability for pasture and reforestation;
- Class 5 - Permanent conservation areas.

To make the description operational, specific land characteristics (slope gradient, effective soil depth, stoniness, susceptibility to erosion, fertility and drainage conditions) are measured for each map unit, and these are compared with defined limits for each suitability class, using the maximum-limitation method (Sys et al., 1991).

There is no separate evaluation for different annual crops or for fruit, horticulture, pasture, or forestry, and in addition there is no differentiation between management levels or techniques. This is a land capability approach that traces its roots back to the original system of the USDA from the late 1930's (Klingebiel, 1991; Helms, 1997). It completely ignores the advances in land evaluation methodology proposed as early as 1972 by the FAO, and formalised in the FAO Framework of 1976 (FAO, 1976).

Recently, Bacic (1998), an EPAGRI soil surveyor, proposed a new methodology based on FAO framework for land evaluation and the subsequent guidelines for rainfed agriculture (FAO, 1976; FAO, 1983). This proposal recommended that specific land uses, the so-called Land Utilization Types (LUT), each receive their own evaluation, based on physical aspects, a general financial analysis (Rossiter, 1995), and some social and environmental aspects. He also used the Automated Land Evaluation System (ALES) (Rossiter, 1990; Rossiter and Van Wambeke, 1997) and a GIS for the computation of land suitability according to his system. The new methodology is presently being tested in two pilot micro-catchments, and will then be improved and adapted to other regions in the

state. However, even this improved methodology comes from the experience of the information suppliers, and does not take into account the opinions of the decision-makers.

### **2.3. The Micro-catchment Project**

A project for rehabilitation, conservation and management of natural resources in small rural catchments (the so-called ‘Micro-catchment Project’) was carried out in Santa Catarina from 1991 to 1999. A micro-catchment was defined as an area of about 4,000 ha containing approximately one hundred farms, delineated first by watershed divides, and possibly limited along a main stream course. Several institutions carried out the eight components of the project, namely: (a) administration, monitoring and project evaluation; (b) agricultural research; (c) soil and landform mapping; (d) technical assistance and rural extension; (e) a financial incentive program for soil management, conservation and pollution control; (f) erosion control for rural roads; (g) forestry development and natural resources protection; and (h) training. This paper concentrates on the mapping component of the project, which includes land evaluation for other components.

Land inventory reports and maps (at 1:25 000) were produced for 150 micro-catchments (Santa Catarina, 1999) by groups of evaluators from EPAGRI and the Federal University of Santa Catarina (UFSC). All the evaluators were agronomists, with most working in soil survey and physical land evaluation. The reports included the general socio-economic context, climate, physiography and soils, land suitabilities according to Uberti *et al.* (1991), current land use, land use “conflicts” (derived from the superposition of the land use and land suitability) and recommendations. The inventories were intended to better inform rural extensionists, who assist the direct land users, i.e. the farmers, to make land use plans for their farms. The extensionists were thus the “land use planners” in the context of this project, i.e. the intended clients of the land evaluation exercise. Note that in developed countries, where the farmers have already a good level of knowledge and actively look for information to support their decision-

making, they are the principal clients. However, in developing countries such as Brazil, information from land inventories rarely reach the farmers; instead, it is usually filtered through rural extensionists.

The work of the evaluators finished as soon as they had sent the report to the extensionists. There was no follow-up to see if the extensionists and their clients used the reports and maps. Thus the evaluators had no way to check on the relevance of their work, let alone to know if their recommendations were correct or if the clients needed other information.

A common fault of current land evaluation methods world-wide is that interpretations of technical data are rarely tailored to the special needs of individual decision-makers, and are usually carried out mechanically, according to fixed evaluation systems (Dalal-Clayton and Dent, 1993). In the present case, this observation applies to the map scale, specification of land-use alternatives, and type of evaluation. Maps were presented at 1:25 000, implying a minimum and typical delineation of 2.5ha and 10ha, respectively (Forbes et al., 1982); by contrast, farms in the study area typically cover about 20ha, with fields of about 0.5ha and larger pastures or woodlots. The methodology evaluates general LUTs (annual crops, pastures, reforestation) without specifying management level or specific cultural practices, and evaluates only physical aspects of land suitability; by contrast, farmers use a variety of technologies, including soil conservation options, to grow a range of crops. Furthermore, they make decisions mostly on financial grounds, whereas only a physical land evaluation is provided. This suggests that the scale is too small, the LUT definitions not sufficiently detailed, and the results not expressed in useful terms. If this is true, the study will be of limited utility. This was our preconception, not supported by facts prior to this study.

The feeling among information providers was that the current land evaluation reports and maps had been little used in actual land use planning. During meetings and informal talks with extensionists and their regional managers, the following three possibilities were identified, but with no idea of their relative frequency:

- The information had been used to good effect, by showing the maps to the farmers as a basis for planning activities, such as calculating the time necessary to construct terraces with tractors, and changes in land use and management;
- There had been no use of the information due to the extensionists' lack of knowledge of its value or training about its use. They may not have known why the evaluations were done or their intended uses, or in extreme cases even of their existence. These problems were attributed mainly to frequent personnel changes;
- There had been no use of the information, mainly due to the lack of time to read and properly understand how to apply the information.

This study was designed to quantify use and usefulness of soil surveys and land evaluations by land use planners, observe the relation between latent demand and actual supply, and suggest improvements.

#### **2.4. Methods**

A questionnaire was sent to the 136 rural extensionists responsible for the rural land use planning in the 150 micro-catchments covered by the project. The questionnaire had 25 questions, and was divided into four parts: (a) personal and general information; (b) use of land evaluation reports and maps; (c) training received on the use of the reports and maps; and (d) suggestions for possible improvements in the land evaluation methodology. Self-identification of the respondents was optional. The questionnaire was reviewed by three EPAGRI agronomists, to check clarity, consistency and objectivity.

Distribution was by post, with a cover letter from the extensionists' regional managers. The importance of honest answers to the questionnaires was discussed in a meeting between the surveyors and managers, before the questionnaires were distributed.

Answers to structured questions were entered in a database, and the proportion of respondents for each answer, sometimes categorised by a previous response, was summarised with simple statistics. Answers to open

and semi-open questions were considered subjective opinions and discussed as such.

## **2.5. Results and discussion**

Fifty-nine of the questionnaires were returned, of which four were incomplete and two were clearly inconsistent. In fourteen municipalities extensionists were no longer working. So the effective return rate was 53 out of 122, or 43%. All respondents preferred to identify themselves.

Most of the respondents (85%) were between thirty and fifty years old. Two-thirds were EPAGRI employees and one-third worked for a municipality. Sixty percent had been working in the region for more than ten years and 15% for more than twenty. About four-fifths were already working in the area when the surveys were carried out. Most (72%) of the respondents participated themselves in the inventory fieldwork or supplied socio-economic information. One-third said that the regional managers did not inform them about the importance of the land inventories for land use planning. About 37% did not receive any kind of training on the use of the inventories, 26% received specific training, while 34% received only an informal explanation from the mapping team during the fieldwork.

Table 1 summarises the responses for those sections of the questionnaire concerning the use of inventories in the extensionists' routine work. There was partial support for the preconceptions of the information suppliers and international authors, but also some contradictions.

Only 11% of the respondents did not realise that the material existed. These were workers who entered the project after the surveys had been completed, showing the inadequacy of briefings for new extensionists and lack of continuity.

Table 1 - Responses summarized for parts b, c and d of the questionnaire.

<b>Access to the inventory</b>						
Have seen the inventory (%)			Have not seen the inventory (%)			
91			9			
<b>Types of information used in their work</b>						
Land inventory (%)		Other information (%)		None (%)		
83		17		15		
<b>Land inventory usefulness</b>						
Very useful/Useful (%)		Slightly useful/Useless (%)		No answer (%)		
59		32		9		
<b>How the planners are using the land inventories</b>						
Displaying maps (%)	Meetings with farmers (%)	Planning of land use and management (%)		Other (%)	Not using (%)	
36	30	43		25	17	
<b>Frequency of use of different information supplied</b>						
Type of information	Frequently/sometimes (%)		Rarely/never (%)		No answer (%)	
climate	47		51		2	
land suitability	74		26		0	
land use	70		30		0	
land use conflicts	59		41		0	
physiography and soils	57		43		0	
recommendations	62		38		0	
socio-economic	57		41		2	
topographic map	51		49		0	
<b>Reasons for not properly using the land inventories</b>						
Did not know existence (%)	Inadequate training (%)	Difficult language (%)	Received late (%)	No time to use (%)	Other information required (%)	No answer (%)
11	11	2	9	6	4	61
<b>Training adequacy</b>						
Training adequate (%)		Training not adequate (%)			No training (%)	
28		34			38	
<b>Adequacy of the map scale</b>						
Map scale adequate (%)		Map scale not adequate (%)			No answer (%)	
58		21			21	
<b>Additional information required</b>						
Socio-economic analysis (%)	More land use alternatives (%)	Uncertainties and risks assessment for alternatives (%)	Environmental degradation risks assessment (%)	Other (%)	None (%)	No answer (%)
42	21	34	59	8	11	8



One-third of the respondents considered the information of little value or useless, whereas 59% considered it useful or very useful. However, many of the latter did not use the reports for their main purpose. Although 83% of all respondents stated that they used the material in some way, only 43% used it for its intended purpose, namely planning of land use and management options with farmers. About 36% simply displayed the maps in the office, and 30% used it only as illustrative material in the meetings with farmers, but without consulting it when actual planning decisions were to be made. One-quarter of the respondents used the information for reasons not related to land use planning, mainly as a source for their own reports and as material for students. The most-consulted information was that concerning land suitability and land use (74% and 70%, respectively) and the least-consulted that on climate (47%).

For those that answered the question about the reasons improper use of the land inventory, the results confirm the preconceptions of the information suppliers. Most of these respondents did not know how to use the information (33%), did not know about the existence of the material (29%), had received the material too late (24%), had no time to read and understand the reports (14%), or would like other information not included in the reports. High turnover of personnel may have contributed to the lack of knowledge about the material: one-fifth of all respondents had moved or were replacements who began work after the inventory fieldwork. Again, this suggests a lack of systematic training for new workers.

Over half the respondents (58%) considered the map scale adequate, despite the large delineations relative to typical management units. Three respondents suggested that if extensionists are familiar with the region and the specific farm layout, they are able to infer information at field level from the map unit descriptions. This agrees with the concept of “two-stage surveys” (Beckett, 1968), in which maps at relatively small scales are supplemented by knowledge of the components of a compound map unit. The importance of local knowledge of the soil landscape, in addition to the map unit descriptions, is highlighted by the fact that among the extensionists with at least ten years working in the area, the proportion considering the

scale adequate increased from 58% to 67%. These results do not match the preconceptions of the information suppliers, who expected a general complaint about the scale.

There was a positive correspondence between the orientation received from managers concerning the importance of the information and its proper use by extensionists. Comparing the proportions of positive answers with (31 of 35) and without (13 of 18) orientation using binomial confidence intervals with a pooled standard deviation (Steel and Torrie, 1980), we computed a one-tailed probability of 0.91 that orientation indeed increases any use of the information. The corresponding probability for use of the information for land use planning (19 of 35 with, 4 of 18 without) is even more significant, 0.99.

Most respondents (81%) had suggestions to improve the product. About 60% requested an assessment of the risk of environmental degradation for each LUT. Environmental issues are increasingly important in the region, mainly because of the high concentration of swine and intensive use of agrochemicals. Aware of this, the workers in the field attach high importance to showing farmers the environmental consequences of inappropriate land use as strategic plans are formulated. The intent is to avoid solving one problem (production, income) at the expense creating another (pollution, human and ecosystem health).

Almost half (42%) of the respondents suggested a financial analysis to complement the land inventory. They stated that farmers are severely constrained by their financial situation, and that they can not make land use decisions without information on markets and prices. Clearly, this would require frequent updating, and perhaps is the responsibility of another agency; still, the clear message is that purely physical planning is not useful to many clients.

Related to this, one-third of the respondents requested a risk assessment for each land use alternative, specifically the environmental effects under a range of realistic conditions, as well as predicted profitability under a range of realistic market scenarios. These extensionists stated that their clients are mostly risk-averse, and need to be informed about the risks of each

alternative. Even though many farmers have a limited education, they are more or less integrated into the market, and so need at least a qualitative estimate of risks. This is especially important to decisions to sign forward contracts with processors.

About one-fifth requested detailed information for several alternative land uses specific to each land type, including possibilities of integrating on-farm processing with production. This is because their clients are trying to retain a larger proportion of the total value at farm level. Again, an analysis on on-farm industry is beyond the traditional role of land evaluation, yet in this case was identified as an important determinant of land use.

A small proportion (8%) of the extensionists requested information about the ethnic and cultural characteristics of the communities living in the region, feeling that these at least partially determine farmers' attitudes towards new enterprises. The others probably already knew this information from field experience.

Responses to the semi-open and open questions are by nature not quantifiable, yet they represent the considered opinion of (mostly) experienced field workers concerning their clients' demand for information. Several statements drew our special attention.

First, several respondents considered it vital to understand the social-cultural context, which determine attitudes towards risk, innovation, market integration, and growth, in order better to fulfil their function as advisors to farmers. They felt that land use alternatives should match both real problems (low income, environmental degradation) and social orientation.

A second impression was that an important reason for lack of use, or inappropriate use of the land inventory was the absence of specific training on the use of the reports in planning. The actual training explained the information supplied, the language and the map symbols, but did not cover its practical application for land use planning, that is, how to use the information in the field, together with the farmers and how to make a sound farm plan. But given the limitations of the information, perhaps no training could have turned the reports into truly useful planning tools.

A few respondents stated that the successful use of information by clients depends on the participation of the different actors (soil surveyors, land evaluators, extensionists, and farmers) in the whole process, not just in stages. They were not explicit on what kind of involvement was expected at each stage; this is understandable, since they have no experience of such an integrated exercise.

## **2.6. Conclusions**

Results from a limited survey in a specific area are not conclusive; still, we feel that some general lessons can be drawn. The main improvement we suggest, also recommended by others (Rossiter, 1996; Bouma, 1999), is the adoption of a demand-driven approach, whereby the real needs of, and options open to, decision-makers are identified before any inventory and evaluation project is undertaken. In the project studied in this paper, prior consultation with the extensionists (direct clients) and, through them, the farmers (indirect clients) would have identified key information that should have been supplied by the evaluation in order for it to be truly useful, including (1) the risk of environmental degradation for each system, (2) a financial analysis, (3) a social analysis of decision-makers' attitudes and preferences, and (4) risk assessment for weather, yields, profits and market. All these would have referred to a set of realistic land use alternatives (cropping systems and management techniques, including soil conservation) from which the decision-makers could choose. At least some group leaders or key persons should have participated in the whole process, from survey design through implementation and use, to ensure continuity between objectives and implementation. There should have been systematic training for all extensionists, and especially for new workers who entered the area after the inventory was complete.

A general methodology should begin with the knowledge of the context (physical, environmental, socio-cultural, and economic) in which the project is to be carried out. It then should continue with the identification of the land use problems to be addressed by the evaluation, followed by decisions about what information to collect, how it will be processed and interpreted,

and end with the actual planning process. Some issues can be addressed by re-packaging existing information, while others require new inventories or studies of land performance. This process has been more properly termed “negotiation” (rather than “planning”) by Bouma (2001a; 2001b): the land user is provided a range of alternatives, which affect not only the farm but the larger environmental and economic context. The information to be provided is also the product of a negotiation between information provider and user. Bouma also proposes to improve the acceptance and cost-effectiveness of land evaluations by following a stepwise approach, starting the analysis with expert knowledge, followed if necessary by advanced research. In this way, solutions that can be solved in by simple methods are rapidly found, while at the same time identifying those issues that require more detailed approaches. This leads to a joint decision (in this case by evaluators, extensionists, and farmers) to support further and more costly research, after identifying the inadequacies of the simpler approaches. In the current case, expert judgement based on prior experience could have easily identified unacceptable options (e.g. clean tilled annual crops on steep slopes), whereas more detailed studies would have been needed for others (e.g. optimum land application rates for impounded liquid manure).

A clear message is that, for land evaluations to be useful, they must often be combined with analyses that are beyond the traditional role of the land evaluator, and indeed outside their competence. In the current study these included studies of markets and their risks, commercialisation options, and on-farm processing to retain more added value. The soil survey is essential information, which only reveals its full value when placed in a realistic decision-making context, which in this study area is determined by two over-riding factors: commercialisation, in particular of integrated swine production, and environmental risks.

Finally, contacts between evaluators and planners should not end with the delivery of the reports and maps, but continue during the implementation of plans. This provides a structure for inadequacies in the land evaluation to be communicated to the evaluators, and corrected by new studies whose relevance is already established by client demand.

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## **Chapter 3**

### **The environment for farmers' land use decisions in Santa Catarina, Brazil: implications for land evaluation**

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To be submitted

## **The environment for farmers' land use decisions in Santa Catarina, Brazil: implications for land evaluation**

**Abstract.** Land evaluation is the process of predicting the use potential of land on the basis of its attributes. The results are intended to be used for land resource-related decision making, both strategic land use planning by policy/planning institutions such as extension agencies, and specific local land allocation by the direct land users, that is, the farmers. However, decision makers often do not have appropriate information when making decisions about land allocation and management methods. Among the reasons is the institutional land evaluators' lack of knowledge about the farmers' context where local decisions are made. This study was carried out in the Ariranha River sub-watershed, typical of the west region of Santa Catarina State, Brazil, where agriculture is the basis of the economy. The majority of the rural land is privately owned and more than 90% of the farms are classified as family diversified small farms. To understand the environment for agricultural land use decisions and review its implications for land evaluation we used literature and semi-structured interviews with farmers and extensionists. We found that different groups of farmers have different needs for information and should be approached in different manner. Some farmers would welcome any information on improving their current farming systems, whilst others are also interested in innovative crops or agricultural processes. Yet another group might need motivation more than information. We suggest that if the land evaluation process is begun with a careful analysis of the decision environment of rural land users (farmers) and follows a demand-driven approach, the results will likely be more realistic and therefore more useful to both policy/planning institutions and direct land users. This should lead to more demand and a "virtuous cycle" where planning, land evaluation and clients' needs and possibilities are increasingly inter-linked.



### 3.1. Introduction

Farmers' decision-making about their land and land resources includes allocation decisions based in part on assessing land use potentials. In standard land use planning approaches, such as those of FAO, land evaluation is the process of predicting the use potential of land on the basis of its attributes (FAO, 1976; FAO, 1985; Van Diepen et al., 1991; Rossiter, 1996). The use potential is expressed in terms of the expected benefits from, and constraints to, various land uses, as well as the expected environmental effects of these uses. The predictions of land performance which result from such land evaluations are intended to be used primarily for strategic land use planning by policy/planning institutions such as extension agencies, and specific local land allocation by the direct land users, namely, the farmers. That is to say, which land uses are to be allocated to which land units, and what adaptations of land use systems are necessary. These strategic land decisions may appear to be absolute and invariant when documented, but in practice are usually dynamic, adaptive, and indicative.

Decision making in an agricultural context is an on-going process which can be categorised into phases (Simon, 1977; Rogers, 1995; Backus et al., 1997): 1) perception of a problem or opportunity, i.e. the need for a decision; 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. Standard land evaluation is concerned only with number 4, with some activities grading into 3 and 5.

For both the institutional land use planners and the farmers themselves, difficulties in decision making concern the identification of feasible alternatives, the determination of their relevant attributes, and the collection of relevant information (von Winterfeldt and Edwards, 1986), especially in terms of forecasting economic, institutional and policy context conditions into the future (generally, forecasting long-term physical and climatic conditions is more feasible). Farmers often do not have sufficient appropriate information when making their strategic decisions about land allocation and management methods. They may suspect that their management is causing problems, such as soil erosion, decreasing fertility,

sedimentation, pollution, and toxicities both to the producer and consumer from agrochemicals, but they may not have sufficient information to change to an improved land use or management.

Among the reasons for this lack of information by the land users is the institutional land evaluators' corresponding lack of knowledge about the context where farmers' decisions are made. Early land evaluation approaches mainly called for biophysical resource studies of the areas to assist in the transfer of recommendations from one area to another (FAO, 1976). Later approaches suggested the collection of information on the planning goals, defining criteria for decision making on land use, and identifying opportunities and constraints for farmers (FAO, 1993). In practice, land evaluation reports typically include a description about the area as informative section, but this is rarely taken into consideration with respect to land use and management recommendations. Land evaluations are often conducted by groups of land resource experts using standardized methods and aiming at a diverse user group (Ramalho Filho et al., 1978; Uberti et al., 1991; FAO, 1993), rather than locally adapted participatory methods. Thus, procedures do not take into consideration local resource and socio-economic conditions and local needs, in particular, the environment where the decisions will be taken.

Farmers' decisions are not made in isolation, but rather in the context of an institutional and policy environment. In an economy with private sector agriculture such as the study area discussed in this paper, decisions on how to use private land are ultimately made by the farmer as the direct land user, embedded into the larger social, economic and political framework.

This paper explains the farmers' decision environment in Santa Catarina state, Brazil, which is typical of many market-oriented but low-income economies, with respect to the actors, political, legal and social frameworks, interactions and dynamics and how these affect decision makers. First we concentrate on the following questions: Who are the decision makers in rural land use? What are the farmers' decisions that affect rural land use? How do farmers make their decisions? What factors influence farmers' decisions? What are the information processes regarding the decisions?

Second we address a critique of the current planning mechanisms and planning institutions, specifically in Santa Catarina. Finally we discuss the implications of the planning environment for land evaluation.

### **3.2. Methods**

This study was carried out in Ariranha River sub-watershed (236 km<sup>2</sup>), which is part of the Uruguay River watershed. It is located between Chapecó and Concórdia and is typical of the west of Santa Catarina state, Brazil. The economy of the region, which occupies about 25 300 km<sup>2</sup>, is mainly based on agriculture. The industrial sector is dominated by agro-industries and most of the commercial and services activities are also related to agriculture (Testa et al., 1996). About 49% of population live in rural areas. The majority of the rural land is privately owned and more than 90% of the farms are classified as market oriented family diversified small farms. The main products are maize, pork, and poultry. The most important environmental problem is water pollution caused by rapidly expanding pig production.

We used three information sources: literature, including official documents, personal experience in similar decision environment of the first author, and semi-structured interviews with extensionists and farmers. We interviewed twenty farmers living in the Ariranha River sub-watershed in Seara municipality and all the five extensionists of the municipalities where this sub-watershed is located (Seara, Arvoredo, Xavantina, Ipumirim and Paial) in order to understand the context in which decisions on rural land use are made. The information from the interviews was summarized and described in this paper.

The extensionists were helpful and comfortable in talking from the start of the interviews. However, with the farmers we had to first “break the ice” before they felt comfortable talking. After we explained the reasons for the interview and asked the first questions, they began to express themselves without reserve. Most of the farmers were pleased to have the opportunity to discuss their problems, and even after the end of the interviews they wanted to continue the conversation. In the rest of this paper, when we mention

“farmers” and “extensionists” view, it is to be understood these are the opinions elicited from the interviews.

### **3.3. Who are the decision makers in rural land use?**

Decision makers are often classified in relation to the level where decisions are made (national, regional, farm levels) and the scale and durability of their decisions. However, for the purpose of this paper we first classify decision makers according to the effect of the decision-making on land use, as follows:

- Direct decision-makers: Individuals or collectives who themselves use the land.
- Indirect: Individuals or collectives who do not themselves use land, but who take actions that affect those who do.

Direct decision-makers in the study area consist of the farmers. In Santa Catarina, a social typology of farms according to the type of labour and income has been developed (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 in the farm, “transitional” when it is between one and three minimum wages and “marginal” when it is less than one minimum wage. The predominant types in the study area are family, transitional and marginal.

There are also indirect decision-makers relevant to the farmers’ decisions. These include extensionists, soil surveyors, the government at national, state and municipal levels through its rural policies and agencies, agro-industries, syndicates, cooperatives, farmers’ associations and communities.

### **3.4. What are the farmers’ decisions that affect rural land use?**

Farmers’ decisions can be classified as *strategic* (e.g. land allocation and management, choice of enterprise), *tactical* (e.g. within-season management) and *long-term strategic* (e.g. infrastructure improvements).

The main strategic decisions are: allocation of land use type to land areas including management techniques, measures to avoid degradation, association with agro-industry, participation in government programmes and taking up financial credit. Tactical decisions are very important for the large number of farmers in the region whose decisions are short-term, reactive responses (that is, when the problem appears), but are not of interest to land evaluation.

### **3.5. How do farmers make their decisions?**

Farmers in our survey generally make strategic decisions in three steps, though these are not always seen in a clear sequence: firstly comes awareness about a problem and willingness to make some sort of change; secondly they check available information (e.g. possibilities for credit, conditions to be partner of an agro-industry or to join a government program) to formulate and evaluate alternatives; and finally take the decision itself. This agrees with the phases found in literature (Simon, 1977; Rogers, 1995; Backus et al., 1997). However, extensionists and farmers in the region agree that the steps are mostly followed by instinct and common sense, not employed systematically or in a structured way.

The majority of the farmers simply take decisions when some problem appears. Their plans are mostly for the current season only, based on the farmers' own experiences, and are made in an informal and intuitive manner at each farm, commonly in a family meeting. Sometimes farmers decide to enter a new activity because they have seen someone else's success, similarly to the concept of opinion leaders and followers in the 'diffusion of innovations' literature (Rogers, 1995). In general they start a new activity without long-term planning, and later they tactically adjust and improve according to the situation through learning processes, similar to adaptive or recursive planning (Day, 1963; Found, 1971).

### **3.6. What factors influence farmers' decisions?**

Although the farmers are considered the final decision maker in the region, since they actually select land use systems and implement them, they do not operate in a vacuum. They are influenced by the policy context and by a range of constraints and opportunities, including formal land use plans, social norms, and economic reality. The factors that influence rural decision making can be classified as:

- External constraints: facts of life for the decision maker that restrict choice and can not be changed by own effort;
- Local constraints: factors that restrict choice, but can be changed by the decision maker;
- External opportunities: external factors that encourage certain choices;
- Local opportunities: local factors that encourage certain choices and decision makers may have some influence on them.

Therefore we consider here the factors that influence farmers' decisions and how the environment influences these decisions within a constraints and opportunities context.

#### **3.6.1. External agricultural policy**

The Santa Catarina policy environment for agricultural land use takes place at several levels and scales, as shown in Figure 2.

The national, state and municipal governments with their federal ministries, state secretaries, institutes, enterprises and universities, have their own priorities towards credit facilities, product research, etc., based on political considerations. The national government has two main policy responsibilities towards the rural environment: first, to support this sector by providing producers the infrastructure and legal framework necessary to develop their activities; and second to protect the environment. State and municipal governments are supposed to complement the support given by the national government, where the latter is not competent, for example by improving conditions of local roads, and supporting programs according to the specific characteristics of the state or municipality. To fulfil their

responsibilities, governments create policies, programs, laws and other interventions, which can be categorised as various types of policy instruments (Bressers, 1995; Bressers and Klok, 1995): 1) *Incentive* policy instruments, e.g. product equivalence loans for agricultural activities. The farmers are inclined to decide for a specific land use if and when government policies provide more information and support. For instance, reforestation is expanding because of a government program, well-accepted by the farmers, that provides a monthly payment during a four-year growing period, repayable with forest products, after twelve, sixteen and twenty years; 2) *Control* policy instruments, including laws and support to avoid environment degradation, such as not cultivating slopes over 45°, and minimum distances from manure ponds to streams and roads; 3) *Awareness* policy instruments include, environmental education programs, technical assistance, and adaptive research; and 4) *Permissive conditions*, especially infrastructure like road maintenance and improvement.

Johnson and Cramb (1992) stated that an essential role of the government is intervention in case of market failure, for example unexpected price drops or loss of demand due to international macro-economic or political events. This has been one of the Brazilian national government's responsibilities, although not always successful in the face of opposition from WTO and 'free-trade' rules (notwithstanding the equivalent subsidized production in the USA and Europe).

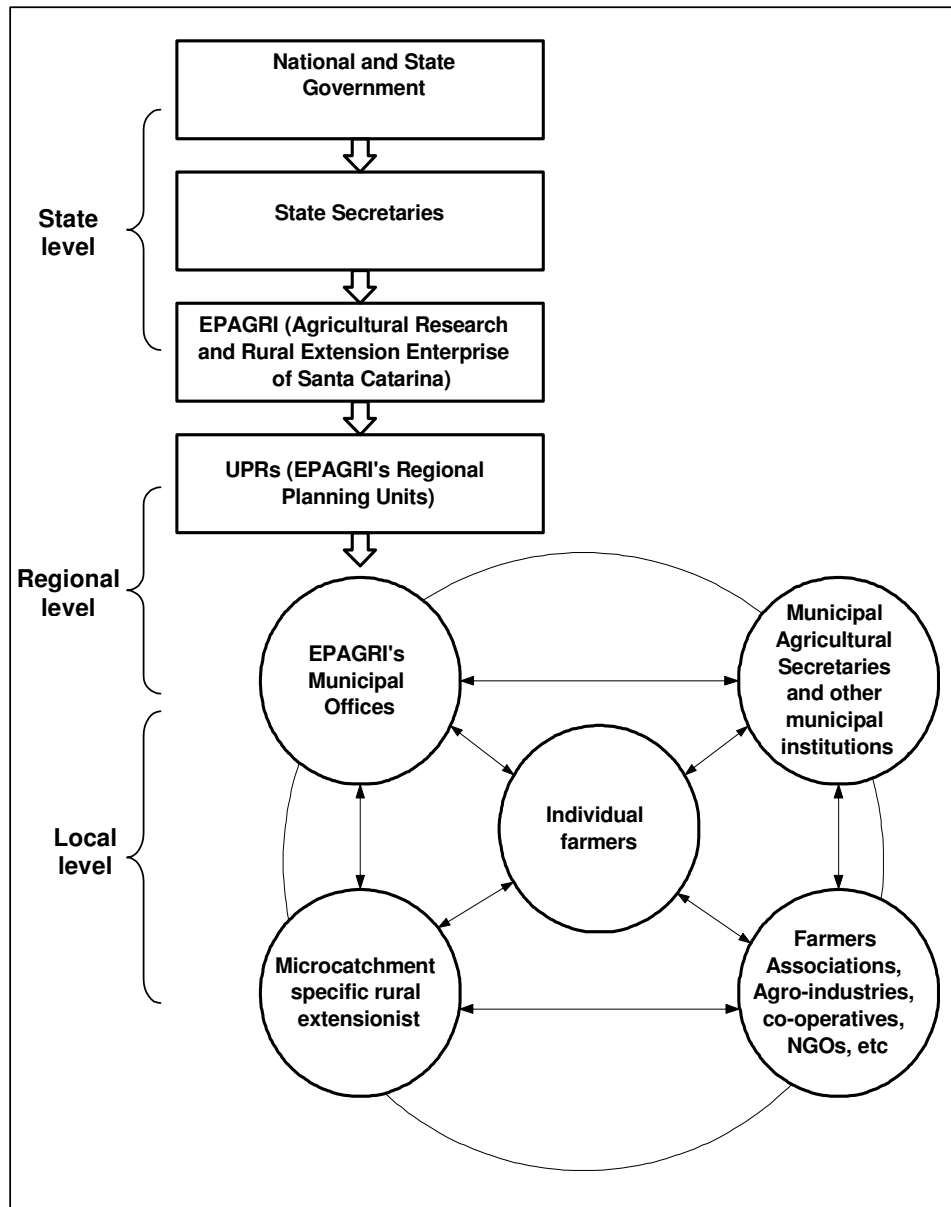


Figure 2. Policy environment for agriculture land use in Santa Catarina, Brazil.



### **3.6.2. The institutional context**

The Rural Development and Agriculture Secretary coordinates the issues directly concerned with agriculture in Santa Catarina State. Agricultural research (including soil surveys and land inventories) and rural extension are carried out by EPAGRI (Agricultural Research and Rural Extension Enterprise of Santa Catarina), under this secretariat, through its state, regional and local offices.

At the local level, EPAGRI's municipal office interacts with other institutions to provide the required support to the farmers. Currently, there is at least one EPAGRI extensionist for each municipality.

The extensionist is usually close to the farmers and is an important component in the rural decision making process as a supporting person, trying to organize farmers (e.g. small associations for machinery, fisheries, small industries, small markets, searching new options, etc) and to better inform them about potentialities and limitations (investment possibilities, local physical suitability, historical trends, prediction of future developments). Extensionists have to be well informed about the common problems in the region and possible solutions. Their main decisions are related to what kind of information they are searching and providing the farmers (land use types, productive systems and management, government programs, recommended agrochemicals and fertilizers, financial possibilities, and economic, climatic and environment uncertainties and risks) and how to communicate the information, whether individually, collectively, by radio, field days, demonstration farmers, or experimental areas.

Soil surveyors, mostly working for EPAGRI, are currently not effectively influencing decisions (Bacic et al., 2003). Their most relevant contributions to the decision making process are what information on soil and land resources to collect and how to acquire and disseminate them.

The rural syndicates and cooperatives currently do not directly influence farmers' decisions. Rural syndicates are organizations formed by the farmers to fight for better conditions for agriculture in general (e.g. influence on rural public policies, financial resources to agriculture),

provide professionals to assist the farmers (technical and legal problems) and give social help such as medical assistance. Their decisions depend on the initiative of the associates and leaders, and are related to the specific objectives that the syndicates want and are able to achieve. Cooperatives were originally intended to give support to the farmers mainly for commercialisation, by aggregating the small-scale production of many individuals, storing them, and seeking a better time to sell at better prices. Another objective was to buy inputs (fertilizers, agrochemicals, seeds) at wholesale.

### **3.6.3. Legal aspects**

There are several laws that the farmers are supposed to follow at national, state and municipal level. For instance, they are not supposed to cultivate protected areas (national forests, parks, margin of the rivers, water sources, mangroves, and areas with more than 45° slopes) and they have to keep a minimum distance between manure ponds and rivers, houses, and roads.

The control, observation of the environmental quality, analysis of projects, application of penalties, etc, are the responsibility of the State Environment and Urban Development Secretary through the Environment Foundation of Santa Catarina (FATMA), supported by other institutions including the state environmental police. Penalties permitted are written warnings, fines, restriction of financial credits, demolition of illegal constructions, and financial commitment for environmental restoration. Although discussion of environmental problems is rapidly increasing, and people are becoming more aware, the state does not have enough capacity to orient, control and apply the penalties. Therefore, the penalties for now remain almost only theoretical.

The legal factors are considered important by extensionists and farmers, but there are complaints. One problem is that when the farmers began some activities the laws were not known. Now they are aware about the laws, but it is difficult to correct existing problems. Currently the farmers needing a loan to start some activity are obliged to have a farm plan and obtain an environmental license. They in general agree with this requirement for new

activities but they also feel that the laws are not realistic for some conditions, as for instance the minimum distance required from manure ponds to the roads, and should be more flexible. Those who make the laws should better understand the context in which they will be applied. For example, farmers who are unable to locate their waste effluent ponds at the legal minimum distance from the streams could be granted a license if they compensated with natural vegetation protection.

#### **3.6.4. Economic aspects**

The economic situation of farmers has an important influence on their land use and management decisions. Sometimes they recognise the need for an alternative approach, and they may know why their management is causing problems, such as soil erosion and water pollution, but they do not have sufficient information or financial resources to resolve it. Mitigating the problems is not economically feasible, considering the low levels of production and profit. This situation is starting to change, since consumers are beginning to look for products with better quality and produced with fewer agrochemicals, even if the prices are higher. A program to certify ecological products has been started by the state government.

The presence or absence of agro-industries has a great economic influence on farmers' decision making. Agro-industries play a very important role in the region, as more than 90% of the pig producers are associated with them (Testa et al., 1996). They make decisions according to their own policies and interests, for instance choosing the best farmers and imposing firm conditions for partnership. They, not the farmers, decide about the partnerships. Partners could be considered more as employees than as equal partners in a contractual relation, because of the large difference in relative power of the two parties. The main advantages for the farmers are that the agro-industries provide technical assistance and some guarantees to their partners. They offer farmers a low economic risk option because of contract guarantees. There is however, a difference of opinion about the agro-industries between farmers who are, and those who are not partners. The partners prefer to work with agro-industry, as they have technical assistance

and a guaranteed market. The non-partners believe that the partners' apparent good financial situation is deceptive, since it is accompanied by high debt. Both groups agree that it is preferable to become a partner if they have sufficient of their own capital to invest, and do not depend on financial credits from agro-industries or banks. The very small farmers with few livestock have no chance to associate to the agro-industries, since there is a compulsory minimum number of animals required. These requirements will probably increase over time, so excluding more farmers. There is also a general opinion that farmers who already have a good infrastructure and no debts can earn money and be in a good financial position. But it will be very difficult for those wanting to enter the partnership from now on.

Availability of credit for specific activities is another important issue, but most farmers avoid asking for bank credit if they can, unless they have no other choice. A common decision is to make only a low investment with their own financial capacity, avoiding paying high interest rates to the bank. In such cases the farmer will have a more secure enterprise, but with few possibilities for expansion.

Farmers are usually looking for activities that can give them the best profit. But if this implies higher risk or harder work, they will also look for other possibilities. This is in accordance with much literature on 'risk avoidance' among poor or peasant farmers. The risk aversion is due to information deficiencies, difficult credit, unreliable markets, lack of technical inputs, as well as attempts to avoid risks of uncertain climate and sickness within the family labour supply (de Janvry, 1972; Ellis, 1993).

One activity that has been adopted experimentally by many farmers is dairy milk production. The main rational reasons are the low need for investment, reasonably good price, and regular income over the year.

#### **3.6.5. Socio-cultural conditions**

Social habits, prejudices and historical factors influence everyone's decision making, and this is no less true for Santa Catarina farmers. Sometimes they do not know how to implement another farming or land use system. It is sometimes the only thing the farmers really know and want to

do. This was confirmed during the interviews, when extensionists and farmers themselves mentioned that the farmers' historical/own experience is one of the factors for decision making, although they can also experiment different land use and management in small areas when they have sufficient information or have seen it working properly.

Age is also becoming a very important issue in the region as young people are leaving, so that in some farms only old people are cultivating the land. In these cases, land use intensity is low, since the older farmers are not able to work the whole area. So, they cultivate only the better areas, thus allowing the recovery of the natural vegetation in the less productive areas or those difficult to work (steep slopes, high stoniness, flood risk areas). This of course is a positive outcome in terms of environmental restoration or conservation.

However, even when age is not an issue, some farmers (mostly the marginal farmers) also prefer a less laborious activity, even if it means lower income. One example is the no-tillage management that was rapidly and widely adopted in the region, primarily because of the low labour requirement and costs rather than environmental consciousness.

Labour availability is a factor. For example, a farmer stopped milk production because of lack of manpower when their children left the farm, and decided to concentrate only on swine.

One of the decisions made by many farmers, especially young ones, is to abandon the rural zones, looking for a more stimulating life in the urban areas. In a series of regional seminars throughout the state in 1999, covering almost 10,000 participants, the majority of young farmers and fishermen stated that they wanted to remain in farming or fishing, but they think that there is a lack of government policies to provide appropriate training and continuing support for rural development, including education, health, entertainment facilities, rural credits and communication (Diário Catarinense, 10/12/1999). These are important social-cultural aspects that cannot be directly influenced by land use planning, but if agricultural production becomes more profitable and secure, the problem will in large part solve itself.

### **3.6.6. Physical and environmental conditions**

Biophysical aspects are important factors for rural decision making as they set the constraints and opportunities under which any land use type must be developed. In the study area, the main factor is the weather (precipitation, temperature, frost), which is almost always a major cause of uncertainty, except in very high technology such as greenhouses. According to Thome et al.(1999), using the land evaluation method of Uberti et al. (1991), other physical constraints in the study area are steep slopes and stoniness, related to the land qualities of: soil workability, erosion hazard and potential for mechanization. However, if the decision makers know the most important uncontrollable factors, they can choose another land use alternative less sensitive to those factors.

A related question is to what extent land decision makers take evaluation information into account. The farmers are not aware of formal methods of land use suitability assessment, but in general they trust their own experience with land suitability. For instance, some of them replaced annual crops by pasture and reforestation on the steep slopes because it was difficult to operate machines and was damaging the environment. Nevertheless, land suitability factors sometimes are overlooked because of the lack of other good land use options, or because of the short-term economic needs of the family.

Environmental problem considerations do not influence decisions, rather, the other way around. According to both the extensionists and farmers, the main environmental problem is the disposal of animal manure, and subsequent water pollution. Manure is sometimes going directly from feedlots to the streams, but runoff from crop fields where the manure has been spread is also important. As a possible solution they suggested limiting the number of animals allowed for farmers who cannot prove they can properly dispose of their manure (as in the Netherlands). Interestingly, in contrast with the excessive manure in some areas, some farmers said they would like to have more to apply in their fields. They would like help from the municipality to transport the manure and a machine to spread it. The

manure should also be rapidly incorporated to the soil, decreasing the manure runoff with the rain.

Another problem identified is the excessive use of herbicides. There is no information about residues in food and drinking water and no inspections for use and sale of forbidden products. Some farmers see the agrochemicals as a health problem to the person applying them, but others also referred to effects on the air, water and other people's health. Agrochemicals are also killing honeybees. The suggested actions were education programs followed by punishment, and research into different alternatives for pest control. Green manure could help to decrease the need for herbicide application.

An additional approach to avoid environmental problems should be a motivation program, e.g. financial support or contests with public recognition. One farmer for instance was proud to be the winner of a soil management competition.

### **3.6.7. Farmers' Responses to Opportunities and Constraints**

Backus et al. (1997) considers that identifying opportunities and constraints in the external environment and changing the farm's operations in response to them is part of the farmer's decision-making process. The distinction between constraints and opportunities is not always clear. If the farmers are well informed, they can transform a big limitation into a good opportunity. For instance, living in a certain climatic zone is a constraint for poorly adapted crops but an opportunity for well-adapted ones. A common example in parts of Santa Catarina protected by law and/or with physical limitations (e.g. steep slopes), where it is forbidden or very difficult to crop, is transformation of crop land into recreation areas or farm hotels.

Next we describe the main constraints and opportunities for land use decision making in the region.

**External constraints:** bean and wheat production decreased because the weather is not good and diseases are very common, leading to low yields (physical). The prices lately have been also very low (economic). The number of pig farmers decreased mainly because some of them were excluded by the agro-industries, as they could not follow the required

pattern or minimum number of animals (economic). There is a lack of infrastructure support (political and economic), for instance for the use of green manure: there is encouragement, technical assistance, the farmers want to do, but it is difficult to find the seeds. It should have in this case not only an encouragement to do, but also the conditions (e.g. to support some farmers to produce the seeds in the region, because this production occurs in the same time as the main crops). Another example is the commercial information for reforestation. There is encouragement, technical assistance and even the structure; the problem is the commercialisation and market information (e.g. what type of wood to produce).

**External opportunities:** Citrus, fish production and reforestation are increasing because of support programs from the government and agro-industries (economic). The discussion about environment degradation and its effect on agricultural production as well as human health has become an important issue for institutions involved or not with agriculture, politicians and people in general. As awareness is constantly increasing, what can be seen almost daily in the mass media, there is a clear opportunity for agro-ecological products (social, economic and environmental) and for more practical environmental protection actions in a near future (environmental).

**Local opportunities:** the use of animal manure increased both because of the large amount available and lower prices compared to chemical fertilizers (economic and environmental). Soil management changed to minimum and no-tillage (social, economic and environmental). The area with cultivated pasture increased (replacing the natural pastures), to improve the pasture quality and consequently increase the number of animals and milk production (economic).

**Local constraints:** Some farmers even if in a bad situation with the current land uses, do not want to change mainly because they are afraid to take risks (risk aversion) and do not want to take loan to avoid debts, in general very difficult to pay (economic). Some of them are not changing because they are thinking about the possibility to leave the rural area (social). Some farms are just for subsistence of the family, as the young people have already left, and only the old people stayed (social). Others are



just lacking ambition; they are satisfied with the minimum conditions to survive, without risks (socio-economic).

### **3.7. What are the information processes regarding the decisions?**

Land inventories, reports and maps, including land evaluation information, are available at the UPR level (EPAGRI's regional planning units) and for 150 micro-catchments in the whole State. The land evaluation method currently in use in Santa Catarina (Uberti et al., 1991) considers only soil conservation aspects. The objective of the land evaluation reports is to give information to administrators and extension workers as a tool for conservation. However, this information has been hardly used by the institutional planners (Bacic et al., 2003), and in general is completely ignored by the farmers. Sometimes, extensionists and farmers are not using the whole potential of information because they do not have easy access to them. Other times, because they consider that available information is not useful. The extensionists use mainly their own personal experience, soil analysis for fertilization recommendation, census, local and regional journals and newspaper, seminars, short and remote courses and external scientific and technical information, although the access to these is difficult. The use of the Internet is recent. Even the extensionists do not have a clear idea about how they could use it to search and get information. Most of them have difficulty using software, often because programs are not in Portuguese. To communicate the information to the farmers, they make use of the radio and organize meetings in the villages, as well as individual visits.

Access to and use of formal information by the farmers is even more limited. They make much use of their personal experience and of others, and get additional information from extensionists, other farmers, short courses (not so frequent), radio, TV, and newspapers. The farmers said it is important to have a telephone; sometimes they spend a whole day to find somebody to give information without success, because the appropriate person is not in the office. Radio has been largely used by the extensionists

to inform farmers (e.g. about new government programs available). As it is accessible to everybody, farmers consider it a good means of communication, but the information needs to be more specific, e.g. providing weather forecast and climatic information to help short-term decisions such as use of pesticides or taking precautionary measures.

It is to be expected that inadequate information is related to risk-averse behaviour by small farmers (Ellis, 1993).

### **3.8. A critique of the current planning mechanisms and planning institutions, specifically in Santa Catarina**

#### **3.8.1. Communication**

Poor communication among the different actors is one of the problems we detected in the decision-making environment. They usually work on common issues but in isolation, instead of discussing the problems and seeking solutions together. Soil surveyors for instance could also have an important role in decision making, if they were collecting, integrating and providing appropriate land resource information, demanded by the extensionists and farmers.

The farmers would like to have more support from the extensionists in the communities, both working with small groups and individually. In general, extensionists wait for the farmers in the office but are rarely visited. Some farmers receive frequent visits from state, municipal and agro-industry extensionists while others are without assistance. To assist those in difficult conditions should be the role of the government extensionists. The main problem is the low number of extension workers. In Seara municipality for instance, there are two extensionists to support 1301 farms (Instituto Ceba/SC, 2001).

#### **3.8.2. Environmental Damage**

EPAGRI's extensionists and non-partner farmers think that agro-industries are not concerned about environmental problems in their partner farms, and that this is the main reason the pollution problem is not solved. As agro-

industries are part of the pig production and industrialization chain, they are supposed to be responsible for reducing pollution, for instance by limiting the number of animals in the farms according to certified evidence of manure disposal, supporting the construction of better located ponds, and recommending manure management and spreading. Agro-industries prevent environmental damage on their own installations to get ISO certification, in order to export their products. However, the partner farmers, who are part of their integrated production system, are not certified. An effective inspection by responsible institutions could help to reduce the problem. Besides, the government at national, state and municipal levels could support collective use of manure to produce energy and transportation of manure to be spread as fertilizer in areas where it is insufficient.

### **3.8.3. Co-operatives and syndicates**

The general opinion from both farmers and extensionists is that syndicates and cooperatives are not filling their originally-intended roles. The syndicates mainly work on their members' pension rights. Most of the large cooperatives are working as agro-product dealers, agro-industries, or even as supermarkets bringing most of their products from other regions. In this last case, they are working against their original function of helping their members to sell their products for maximum benefit. The majority of the farmers have limited access to information and do not have any influence on decision making of the cooperatives. Small associations working on the specific problems of the community could be a solution, since the large cooperatives have changed their original primary purposes.

### **3.9. Implications of the planning environment for land evaluation**

The lessons from this specific decision environment can be extended to the general problem of making land evaluation more successful (Rossiter, 1996; Bouma, 1999). We deal here with three aspects: 1) understanding the actor setting; 2) classification of farmers for land evaluation; and 3) demand-driven land evaluation.

### **3.9.1. Understanding the Actor Setting**

Before starting any land evaluation process, it is important that the working group appreciate the status and relationships of the actors in the planning environment. This includes, among other things, the level of expertise and local technical knowledge of the people and the current status of farming and farming innovations in the area (Bacic et al., 2003). Thus some preliminary but essential tasks are:

- Stakeholder analysis: to see who is important and in which phases. The most active actors in this case study are the farmers, extensionists and agro-industries.
- Analysis of local knowledge: to elicit local technical knowledge of farmers about their farming systems, and suggest training and technical assistance where there are knowledge gaps, e.g. when starting a new activity.
- Needs assessment: the needs of the active stakeholders can be analysed and put forward for support to other decision-making levels with more political influence, e.g. the municipal government.
- Assessment of alternative solutions: to propose and analyse land use options, which are realistic (i.e. fitting local conditions) and attractive to specific groups of land users.
- Organization of initial motivation, skill development, and education programs, which are capacity building for the various categories of farmers.

### **3.9.2. Classification of farmers for land evaluation**

The demand from the land users (i.e. farmers) for land evaluation information is related to their socio-economic and cultural outlook. This is not based on a simple, standard, economic classification (such as used in Santa Catarina), but what is significant is the more subjective behaviour of the farmers with respect to entrepreneurship, responsiveness to opportunities, and propensity to adopt innovations. These in turn are related to their specific economic and social situation, particularly in terms of

family labour stability, access to resources and support, risk levels, etc., but in addition, there are also subjective differences between people, like attitudes towards satisficing.

In the present study area, we found a clear differentiation between actors, their needs and possibilities, which greatly influence their attitudes towards land evaluation. This only partially corresponds to the classification used in Santa Catarina, and may be a better basis for land evaluation initiatives. We identified the following five groups:

- Satisfied: they are content with their current activity and do not plan to make changes, only improve them. This group includes most of the consolidated farms.
- Active: inclined to take risks to improve their current conditions, they search for information and make plans. This group includes some consolidated and some transitional farms.
- Relatively active: do not want to take risks or invest too much; they are waiting for somebody to give them information and would consider gradual land use changes if they were given good options and information. This group includes some transitional and most of the marginal farms.
- Resigned: they are satisfied with the subsistence situation. However, if a neighbour obtains favourable results, they are willing to try it in a small area. They include some of the marginal farms.
- Disappointed/Giving up: they are completely discouraged and do not care if they are given new options or information. This group consist of old farmers and those just waiting an opportunity to leave the farm, including some of the marginal farms.

The 'satisfied' group would welcome all the information related to their current farming systems, which could help them to improve their benefits; the 'active' and 'relatively active' groups might be also interested in information about innovative crops or agricultural processes, even those not common in the region; the 'resigned' and 'disappointed' groups probably need motivation more than information.

### **3.9.3. Demand-driven land evaluation**

At the local level, farmers should appear as the main actors in the whole planning process, as they are responsible for the real final decisions about land use and management in their properties. But, no demand-driven approaches in land evaluation and land use planning methodologies have been made in Santa Catarina. Beginning in the 1980s, consciousness for participation and interactive discussions have been increasing, and some participatory activities have started, where communities discuss their problems and try to find solutions. However to date, the topics discussed do not include rural land use and management.

If the land evaluation process is begun with a careful analysis of the planning environment for rural land use decisions and follows a demand-driven approach, the results will likely be more realistic and therefore more useful to the decision makers. We should also expect that more demands will be generated, leading to a “virtuous cycle” where planning, land evaluation and client’s needs and possibilities are increasingly inter-linked.

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## **Chapter 4**

# **Applicability of a distributed environmental model at watershed scale in a data-poor environment**

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## **Applicability of a distributed environmental model at watershed scale in a data-poor environment**

**Abstract.** Intensification of agricultural production without sound management and regulation can lead to severe environmental problems. An example from western Santa Catarina state, Brazil, is the intensive and concentrated production of swine, causing large accumulations of manure and consequent water pollution. Natural resources scientists are asked by decision makers for advice on management and regulatory decisions. Distributed environmental models are useful tools for this purpose, since they simulate processes over an area and predict the consequences of various management practices. In many areas of the world where model results could be useful, including Santa Catarina, detailed data for calibration and validation are lacking. We applied a data-intensive distributed environmental model (AGNPS) in a data-poor environment: the Ariranhazinho river microcatchment (2 520 ha) near Seara town in western Santa Catarina state. This included data preparation, cell size selection, sensitivity analysis, model calibration and application to different management scenarios. We calibrated the model by making a best guess for model parameters and performed a pragmatic sensitivity analysis using optimistic and pessimistic settings of these. We then adjusted the parameters so that the model outputs (flow rate and sediment concentration) most closely matched the only available observed data: a daily time series of single-reading river levels and sediment concentrations at the watershed outlet. A grid resolution of 150 m was found to give realistic results while being computationally feasible. Winter (synoptic) rainfall events were used for calibration; summer (convective) events were too localized even at the scale of the study area. It was not possible to calibrate over the entire rainfall range, which was thus divided into three (<25 mm, 25-60mm, >60 mm). Predicted sediment concentrations were consistently six to ten times higher than actual, probably because of sediment trapping by vegetated channel banks. Predicted N and P concentrations in stream water, adjust by this empirical sediment concentration factor, ranged from just below to well above regulatory norms. The study shows that expert knowledge of the area, in addition to experience reported in literature, was able to compensate for poor calibration data. It was possible to apply the model for relative ranking of scenarios (actual, recommended, and excessive



manure applications; point source pollution from swine operations) in comparative studies. Finally, we suggest that this methodology could also be useful as a starting point for calibration in a data rich environment.

#### **4.1. Introduction**

Intensification of agricultural production leads to a higher standard of living for producers and more wealth for a country. However, if not coupled with sound management and zoning restrictions, it can easily lead to severe environmental problems, both at the farm level and offsite. This is especially true in transitional economies such as Santa Catarina state, southern Brazil, which on the one hand have a well-developed market system, but on the other have not always matched this with environmental law or practice. One example is the intensive and concentrated production of swine, causing large accumulations of manure and consequent water pollution (EPAGRI, 2002). Indeed, information on environmental degradation risks, in particular water pollution is in high demand by decision makers in the area, both farmers and policy makers. They would like to use this information for designing better management systems and for zoning (Bacic et al., 2003).

Natural resources scientists are called on to give decision makers sound advice on the probable effects of land use and management decisions. Historically, this has involved qualitative assessments of risk at specific locations, but for some time the trend has been towards quantitative predictions over space, i.e., using distributed environmental models. These models are useful tools to cope with the complexity of reality, by simulating various actual and potential management practices and predicting their consequences. One model that has been used worldwide for such purposes is AGNPS (Young et al., 1989). Past applications include the assessment of soil erosion (Prato and Shi, 1990; Engel et al., 1993; Mitchell et al., 1993; Rainis et al., 2002; Walling et al., 2003), the prediction of surface runoff (Engel et al., 1993; Mitchell et al., 1993; Grunwald and Norton, 2000), the assessment of allowable soil nutrient loads (Pekarova et al., 1999; Rode and

Lindenschmidt, 2001), the prediction of effects of different land use management practices (Prato and Shi, 1990; Mostaghimi et al., 1997) and the simulation of the effect of expansion of swine production on the P transport and water quality (Sauer et al., in press).

In Santa Catarina, many studies have been done on the use of swine manure as a fertilizer (Dartora et al., 1998) but none on the resulting environmental problems. Quantification and spatial information about current and potential pollution to help to make plans and decisions is also lacking. Santa Catarina state is an area where the application of a distributed environmental model could have a major effect on decision-making (Bacic et al., Submitted-b). This would be a large advance in land evaluation practice in Brazil, because it would give a quantitative prediction of how the environmental quality of a watershed will evolve under different scenarios. A distributed model could also be a useful tool for group environment visualization and relative ranking of scenarios for interactive decision making.

However, AGNPS and similar models are too often applied to obtain predictions without careful consideration of the preconditions and explanation about how the model input parameters are adjusted for reliable model application. A related issue is the often-arbitrary selection of a grid cell size for the distributed model, which has been shown to affect model predictions (Panuska et al., 1991; Vieux and Needham, 1993).

Finally, in many areas of the world where model results could be useful, resources for detailed model calibration are lacking. Santa Catarina state is representative of such areas. This study therefore examines how a data-intensive model can be applied in a relatively data-poor environment, reporting on the steps necessary to apply the AGNPS model in a GIS setting, including input data preparation, cell size and calibration, to predict surface water quality and to evaluate scenarios at small watershed scale in an area of intensive swine production.

## 4.2. Study area

The study area is the upper part of the Ariranhazinho river microcatchment (2 520ha), with the outlet at 27°10'S; 52°22'W. It is representative of most of the west region of Santa Catarina State, Brazil (25 300 km<sup>2</sup>), where intensive swine production in a hilly landscape is leading to serious environmental problems (Plate 1, page 69). The elevation ranges from 385 to 930masl and the average slope is 30%. The principal land use is annual crops (about 40% of the area), mainly maize; almost 30% is covered by secondary forest and more than 20% is used as pasture (Tassinari et al., 1997). The underlying geologic formation is the "Serra Geral", composed of dark grayish to black basalt (Silva and Bortoluzzi, 1987). The predominant soils are Cambsols and Nitosols according to the Brazilian system (EMBRAPA, 1999), corresponding to thermic families of Oxic Dystrudepts and Typic Kanhapludults in Soil Taxonomy (United States Department of Agriculture, 1999). They are moderately deep to deep, moderately well to well drained and have moderate to high infiltration rates which place them in hydrologic soil group B as defined by United States Department of Agriculture (1986). The average annual precipitation and temperature at the nearby Chapecó meteorological station are 1740mm and 18.7°C respectively. The average temperatures are highest in January and February (23.0 and 22.8°C) and lowest in June and July (13.9 and 14.4°C) (Tassinari et al., 1997).

Almost all the farmers raise pigs and produce as much of their animals' feed (mostly maize) as possible. Most producers are integrated with agro-industry, either for the complete production cycle, for the sow and piglet stage, or for the finishing phase (Bacic et al., to be submitted). The estimated total amount of manure produced is 25 700m<sup>3</sup> per year and the average manure pond is holding 170m<sup>3</sup> (Instituto Cepa/SC, 2001).

The area was chosen because it has been instrumented at its outlet (Plate 2, page 69), and soil and land use information are available.

### **4.3. Modelling protocol**

#### **4.3.1. Software**

##### **4.3.1.1. *AGNPS***

AGNPS, the “AGricultural Non-point source Pollution” model was developed to provide information on water quality to be used to classify pollution problems in agricultural watersheds for single storm events (Young et al. 1987). Despite its name, it also deals with point pollution from feedlots, which are closely approximated in the study area by concentrated swine production. We selected this model due to the following reasons: 1) its outputs closely match the information requested by decision-makers, as well as data available for calibration; 2) it is extensively used worldwide in similar scales; 3) the required input data seemed feasible to obtain; and 4) the availability of GRIPS (see next). We used AGNPS version 5.

##### **4.3.1.2. *GRIPS***

The preparation of input layers was greatly facilitated by GRIPS, the “Geo-Referenced Interface Package” for AGNPS v.5.0 (Mannaerts et al., 2002). This is a stand-alone Windows program that relies on the ILWIS 3 GIS (Nijmeijer et al., 2001) to automatically extract digital terrain and land surface layers from GIS vector data, at a user defined grid cell size, and format them as required by AGNPS. It then runs AGNPS 5.0 and formats the output as ILWIS raster maps for visualization and further analysis. GRIPS uses watershed boundaries, streams and contour lines segment maps to generate the following AGNPS inputs: cell number, receiving cell, flow direction, slope gradient, slope shape, slope length, channel indicator, channel length and channel gradient. GRIPS cannot prepare flawless input layers; in particular, the analyst must verify flow lines from each cell, avoiding sinks and flows outside the catchment. The watershed boundaries, streams and contour lines were digitized from the Seara topographic map (scale 1: 50 000, 20m contours), prepared by the Brazilian Army Ministry.

### **4.3.2. Model input data preparation**

Besides the inputs produced by GRIPS, AGNPS must be parameterized with values that can be entered as a single value for the whole watershed, cell by cell or as a map assigning to each cell the correspondent value in the map. In Tables 2 and 3 we present the criterion and sources used to establish the initial parameterization as input maps and single values respectively. We called this our “best guess” as we tried to get as close as possible to reality according to the available data and our experience, i.e. before any model calibration. This relies crucially on field experience with soil-water-land use relations in the region where the model is to be applied. Table 4 shows the highest and lowest realistic parameter limits for AGNPS map inputs changing according to possible variability in the study area (e.g. soil group, hydrologic conditions, organic matter contents, textural classes and management practices). We called these our optimistic and pessimistic realistic scenarios. The land use and physiography/soil maps as well as the symbols presented in the tables are from Tassinari et al. (1997).

### **4.3.3. Observed rainfall and water data**

The outlet of the watershed was instrumented from 1998 to 2000. A farmer living near the outlet was contracted to measure the rainfall, river level and turbidity daily at 8:00 AM. There were no independent checks on his reliability. Approximately every seven days up to the middle of 1999 and every two weeks until the end of 2000, water samples were collected and analyzed by EPAGRI, the state agricultural research service, for pH, biochemical oxygen demand, dissolved oxygen, coliforms and concentration of sediments, nitrogen (N) and phosphorus (P).

The sediment concentration in the river was measured by EPAGRI according to Clesceri et al. (1998) for about one year to establish a correlation to turbidity; this resulted in a satisfactory regression equation ( $R^2 = 0.93$ ), which was used to convert actual turbidity measurements to inferred sediment concentrations.

CHAPTER 4

Table 2 - Initial parameterization for AGNPS map inputs (Best Guess).

CN values for hydrologic soil group B and average antecedent runoff condition (CN)		
Land use map <sup>(7)</sup>	Description	Value <sup>(1)</sup>
Ca - annual crops	Small grain, straight row, poor hydrologic conditions	76
Cam - pastures	Poor hydrologic conditions - heavily grazed	79
Cp - fruit trees	Wood - poor hydrologic conditions)	66
Cpo - meadow		58
F - forest	Wood - good hydrologic conditions	55
Fr - reforestation	Wood - fair hydrologic conditions	60
Overland Manning coefficient (Mn)		
Land use map <sup>(7)</sup>	Description	Value <sup>(1)</sup>
Ca - annual crops	Chisel plow - residue	0.13
Cam - pastures	Short grass prairie	0.15
Cp - fruit trees		0.6
Cpo - meadow		0.6
F - forest		0.6
Fr - reforestation	Rangeland	0.6
Kfactor (K)		
Physiography/soil map <sup>(7)</sup>	Textural Class	Value <sup>(2)</sup>
C4	clay/silty clay	0.23
E1	silty clay loam/clay loam/silty loam	0.32
E5	clay/silty clay	0.23
FV1	clay/silty clay	0.23
FV5	silty clay loam/clay loam/silty loam	0.25
C factor (C)		
Land use map <sup>(7)</sup>	Description	Value
Ca - annual crops	Maize	0.08 <sup>(3)</sup>
Cam - pastures	Perennial pasture	0.01 <sup>(3)</sup>
Cp - fruit trees	20-40%	0.009 <sup>(4)</sup>
Cpo - meadow	Bush/G/75% - 95% ground cover	0.003 <sup>(4)</sup>
F - forest	Undisturbed	0.001 <sup>(4)</sup>
Fr - reforestation	45-70% cover	0.004 <sup>(4)</sup>
P factor (P)		
Physiography/soil map <sup>(7)</sup>	Land use map <sup>(7)</sup>	Value <sup>(3)</sup>
-	Cam/Cp/Cpo/F/Fr	1
E1 and FV1 (>18%)	Ca	0.8
E5 (12 - 18%)	Ca	0.7
C4 (8-12%)	Ca	0.6
FV5 (<8%)	Ca	0.5

(cont.)

APPLICABILITY OF A DISTRIBUTED ENVIRONMENTAL MODEL

Table 2 (cont.).

Surface conditions constant (SCC)		
Land use map <sup>(7)</sup>	Description	Value <sup>(5)</sup>
Ca - annual crops	Small grain	0.29
Cam - pastures	Poor hydrologic conditions - heavily grazed	0.01
Cp - fruit trees	Woodland	0.29
Cpo - meadow	Permanent	0.59
F - forest	With heavy litter	0.59
Fr - reforestation	Woodland	0.29
Soil Texture (ST)		
Physiography/Soil map <sup>(7)</sup>	Average texture (Clay/Silt/Sand)	Class <sup>(5)</sup>
C4	62/35/3	3
E1	28/60/12	2
E5	55/42/3	3
FV1	63/34/3	3
FV5	27/50/23	2
Nitrogen and Phosphorus as manure fertilizers		
Land use map <sup>(7)</sup>	N (kg /ha) <sup>(6)</sup>	P (kg/ha) <sup>(6)</sup>
Ca and Cam	140	40
Other land use types	0	0

<sup>(1)</sup> (Mitchell et al., 1997)

<sup>(2)</sup> (Maidment, 1993)

<sup>(3)</sup> Calculated for local conditions according to Pundek (1998)

<sup>(4)</sup> (Wischmeier and Smith, 1978)

<sup>(5)</sup> (Young et al., 1987)

<sup>(6)</sup> Manure applied on annual crops and pastures according to recommendations from Dartora et al. (1998)

<sup>(7)</sup> (Tassinari et al., 1997)

Table 3 - Initial parameterization for AGNPS single value inputs for the whole watershed.

Parameter	Value <sup>(1)</sup>
COD factor	70
Channel side slope	10%
Manning channel	0.048
Soil data	
Soil Nitrogen	2 ppm
Soil P	3 ppm
OM	3%
Fertilizer data - pig manure application	
N availability	100%
P availability	100%

<sup>(1)</sup> (Young et al., 1987)

<sup>(2)</sup> (Tassinari et al., 1997)

## CHAPTER 4

Table 4 - Highest and lowest realistic parameter limits for AGNPS map inputs (optimistic and pessimistic realistic scenarios) <sup>(1)</sup>.

CN values		
Land use map	Pessimistic	Optimistic
Ca - annual crops	84	70
Cam - pastures	86	59
Cp – fruit trees	77	55
Cpo - meadow	77	55
F - forest	77	55
Fr - reforestation	77	55
Overland Manning coefficient		
Land use map	Pessimistic	Optimistic
Ca - annual crops	0.04	0.22
Cam - pastures	0.10	0.20
Cp – fruit trees	0.40	0.80
Cpo - meadow	0.40	0.80
F - forest	0.40	0.80
Fr - reforestation	0.40	0.80
K factor		
Physiography/soil map	Pessimistic	Optimistic
C4	0.28	0.17
E1	0.48	0.25
E5	0.28	0.23
FV1	0.28	0.16
FV5	0.48	0.16
C factor		
Land use map	Pessimistic	Optimistic
Ca - annual crops	0.20	0.02
Cam - pastures	0.10	0.01
Cp – fruit trees	0.009	0.002
Cpo - meadow	0.08	0.003
F - forest	0.001	0.0001
Fr - reforestation	0.009	0.002
P factor		
Physiography/soil map	Pessimistic	Optimistic
-	1	1
E1 and FV1 (>18%)	1	0.4
E5 (12 – 18%)	1	0.35
C4 (8-12%)	1	0.30
FV5 (<8%)	1	0.25
Surface conditions constant		
Land use map	Pessimistic	Optimistic
Ca - annual crops	0.05	0.29
Cam - pastures	0.01	0.22
Cp – fruit trees	0.29	0.59
Cpo - meadow	0.29	0.59
F - forest	0.29	0.59
Fr - reforestation	0.29	0.59

<sup>(1)</sup> Values changed according to possible variability of soil groups (B and C), hydrologic conditions, organic matter contents, textural classes and management practices in the study area



We converted observed stream levels to flow rate (discharge in  $\text{m}^3/\text{s}$ ) using a rating curve derived from a set of current meter gauging experiments carried out by EPAGRI. We assumed that the cross section profile at the gauging station was stable. In order to obtain direct storm runoff volumes and peak discharges to compare to AGNPS volumes and peak flows, a simple base flow separation was applied to the flow data. This was based on an analysis of recession characteristics of the streamflow hydrographs of the catchment (Wilson, 1990; sec. 7.3).

#### ***4.3.3.1. Splitting seasons***

We split the dataset into two different seasons: November to April and May to October, broadly representing summer and winter respectively. We distinguished between the summer with localized events at the rain gauge from convective thundershowers smaller than microcatchment scale and vice versa, and the winter with large regional weather patterns. The localized storms typical in the region during the summer are not appropriate for calibration, as the rainfall measurement relates to just one point located in the microcatchment outlet. Therefore, for the model calibration we just used the data from the winter season.

#### ***4.3.3.2. Eliminating unreliable and incomplete data and selecting storm events***

To evaluate the consistency of the data at the Ariranhazinho outlet, we compared the monthly precipitation data to the reliable data collected at the nearby Chapecó meteorological station, which values were expected to be similar during the winter. This station ( $27^{\circ}07\text{S}$ ;  $52^{\circ}37\text{W}$ ; 679masl) is located about 40km west of the study site, in the same climatic zone. We then removed inconsistent data, as well as those without records for river level.

The storm events to be used on further analysis were selected by expert judgment, eliminating those that seemed to be hydrologically unsuitable for the modelling purposes (e.g. small storms not affecting the river level).

#### **4.3.4. Effect of cell size**

Selection of an appropriate model cell size was based on different points of view: (1) model manageability, considering its intended use for interactive scenario analysis together with clients; (2) limitations of the model algorithms (i.e. unrealistic results at certain cell sizes); and (3) scale of available input data and information quality.

#### **4.3.5. Sensitivity to input data**

We carried out a sensitivity analysis within realistic limits based on literature and expert knowledge of the study area. Starting from the “best guess”, we varied the parameter input values (CN, Manning coefficient, K factor, C factor, P factor and surface conditions constant) according to the optimistic and pessimistic scenarios. We did not take into consideration possible interactions between factors, as we varied only one factor at the time, keeping all the others constant. We pre-selected nine different storm sizes (12.5, 20, 25, 32.5, 40, 60, 80, 100, and 120mm), ranging from small size at which we did not expect sediment transport and runoff, to large storms with an expected return period of 5 years in the region as fitted by a Gumbel distribution (Maidment, 1993; sec. 18.2.2) (Figure 3).

#### **4.3.6. Calibration**

It was not possible to calibrate the model for nutrient content of outflow water, our main target in this paper, because the model requires some inputs for predictions that are highly time and space variable and thus difficult to measure, such as time and amount of pig manure application to fields, management practices and direct flow from ponds to the streams. Therefore, we adjusted the model to peak flow rate and sediment concentration. These are directly related to the pollutant transport.

The most difficult issue we faced was that the calibration dataset was small and based on measurements whose reliability was difficult to assess. Therefore, we adopted a strategy of calibrating the model by: 1) making best guess, optimistic and pessimistic scenarios (section 4.3.2); 2) performing a

pragmatic sensitivity analysis to see which parameters most affected the result for the area conditions (section 4.3.5); and 3) comparing observed results to the prepared scenarios and adjusting the most sensitive parameters so that model output would most closely match selected storms. The three scenarios were simulated for all selected storms (54) ranging from 8.2 to 108.4mm. The coefficient of Nash and Sutcliffe (1970) was used to evaluate the model efficiency.

As explained above, we used just the data from the winter season for the model calibration. However, we believe that winter calibration is also valid for summer in this subtropical climate, considering that the soil in the region is under actively growing vegetation during the whole year, and consequently assuming that soil moisture conditions, infiltration and runoff rates are similar for both seasons.

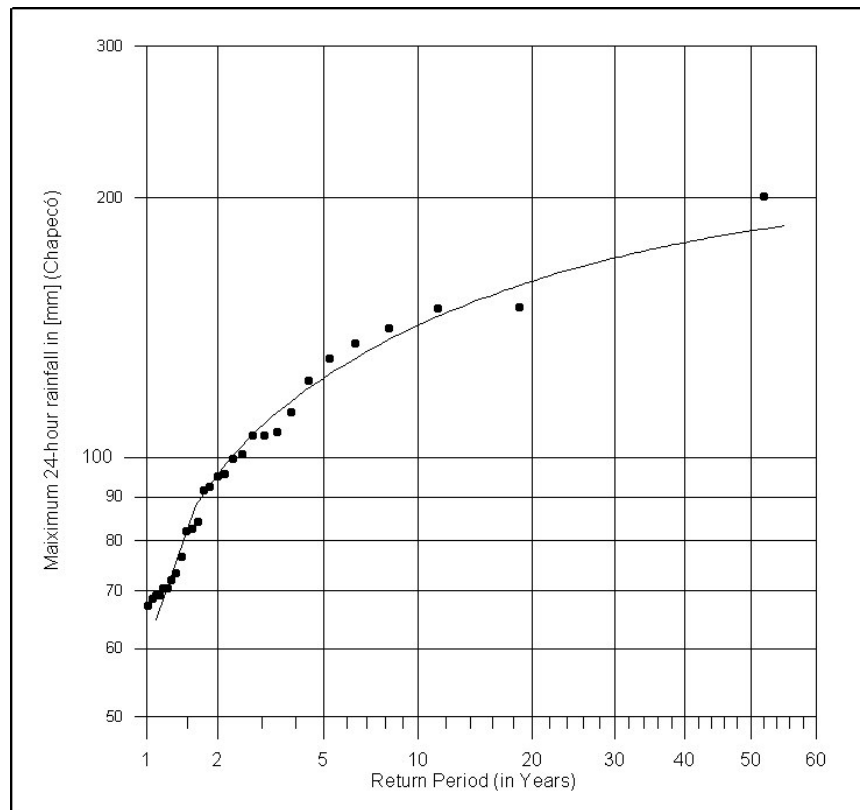


Figure 3 - Gumbel extreme values distribution fitted to maximum 24 hours rainfall at Chapecó meteorological station.

### **4.3.7. Scenario analysis**

Once we had adjusted the model for peak flow rate and sediments concentration, we built the following realistic scenarios to apply the model to evaluate water pollution: 1) Realistic manure application: current swine density, with existing pig manure produced in the catchment distributed in annual crops and pasture ( $15\text{m}^3/\text{ha}$ ); 2) Recommended manure application: pig manure distributed in annual crops and pasture according to recommended amounts ( $60\text{ m}^3/\text{ha}$ ) (Dartora et al., 1998); 3) Exaggerated manure application: distribution of pig manure in annual crops and pasture exceeding in four times the recommended amounts; 4) Point sources and realistic manure application: direct discharge from two manure detention ponds to the streams combined with realistic manure application. All the scenarios were simulated under three different storm sizes: small (20mm), medium (40mm) and large (80mm).

## **4.4. Results and discussion**

### **4.4.1. Observed rainfall and water data**

The comparison of precipitation data at the Ariranhazinho outlet and at the Chapecó meteorological station shows the same pattern of monthly rainfall except for May 1998 (Figure 4). This increases our confidence in the local observations. In May 1998, there is a missing rainfall measurement, which consistently affected the river level. Therefore, we decided to remove this month from the dataset for further analysis.

In Figure 5 we show the observed precipitation and direct flow rate for the winter season. After removing incomplete and unreliable data, we selected 54 events, which we used for the calibration, from the total rainfall records of 144.

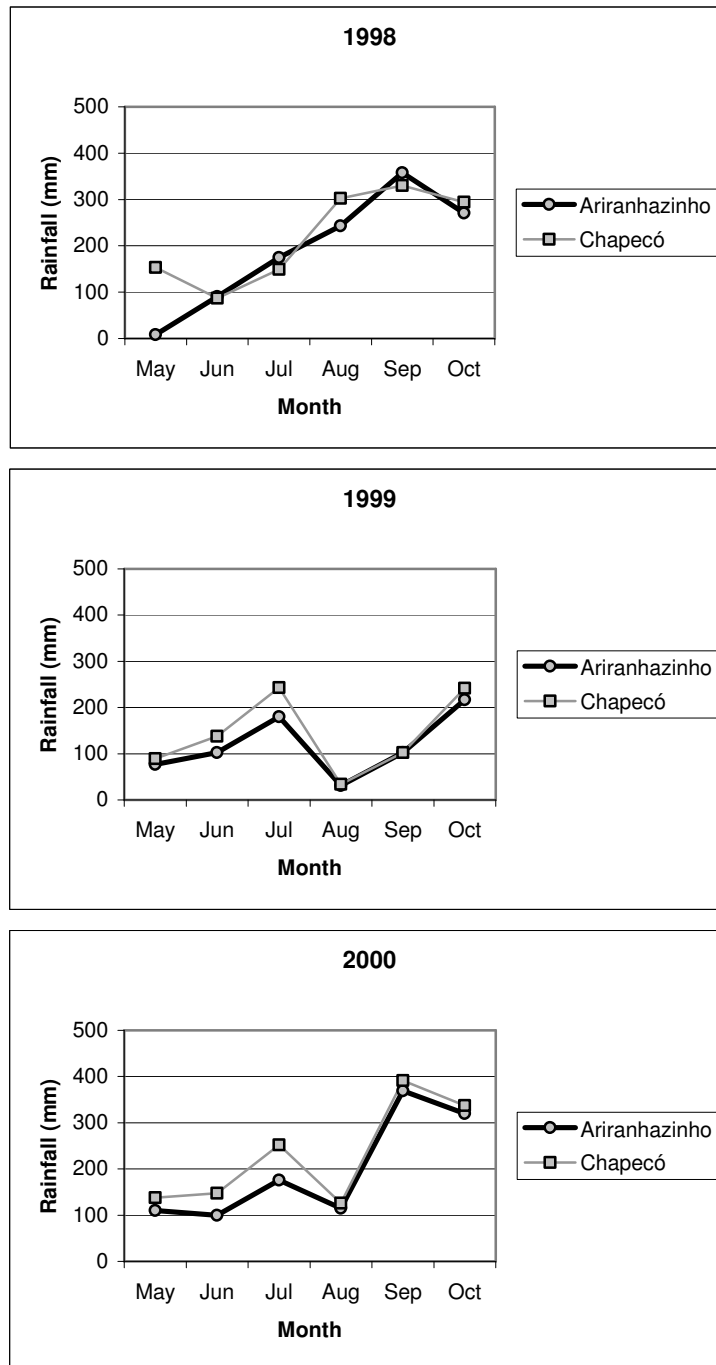


Figure 4 - Rainfall comparison between Ariranhazinho outlet and Chapecó meteorological station measurements.

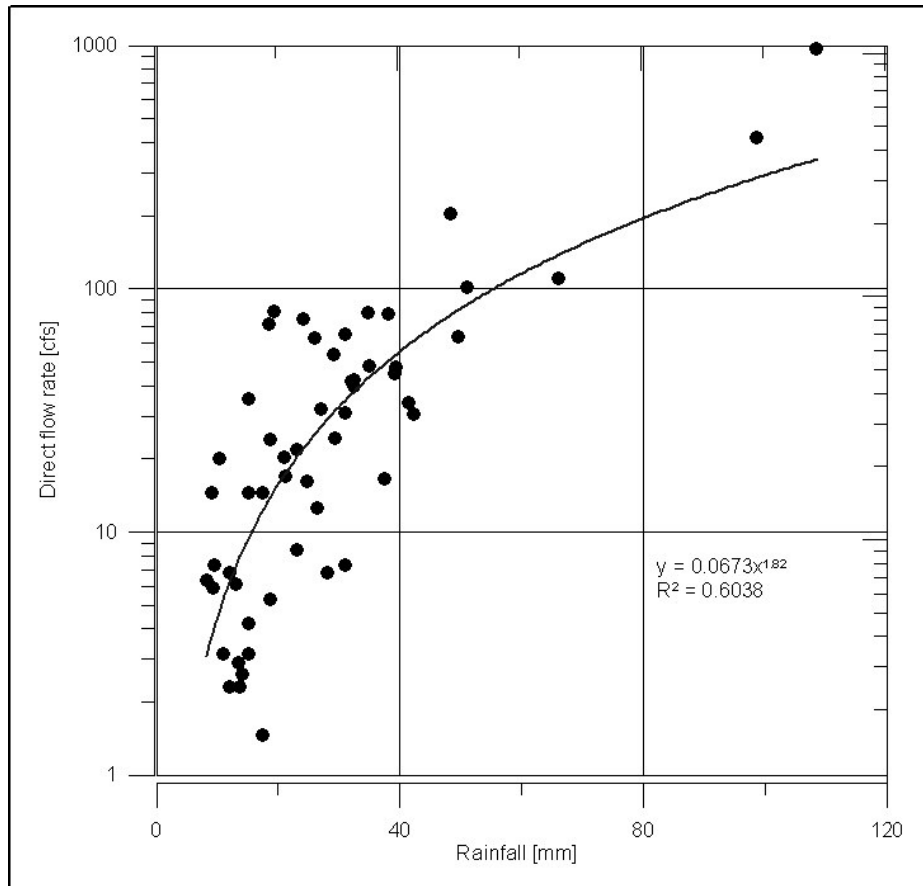


Figure 5 - Observed rainfall and direct flow rate from May to October (winter).

#### 4.4.2. Effect of cell size

We first observed the model manageability: depending on the size of the watershed and the cell size, the number of cells can lead to difficulties to run the model (time consuming and computer lack of memory). In particular when the intention is to carry out an interactive procedure with the clients, the time to run the model and make changes on the inputs can be a constraint. For instance, a 150m by 150m cell size gives a manageable number of cells of approximately 1100 in the studied microcatchment. It takes about 40 seconds to convert data, run the model and create the output maps in ILWIS. By contrast, for a 50m by 50m cell size, the number of cells

exceeds 10 000, and the same procedures takes approximately five minutes, a seven-fold increase for a nine-fold improvement in resolution.

The cell size in combination with the drainage network density and the digital terrain model also affects overland flow channel lengths and slopes generated by the GIS flow direction algorithms. In turn, these variables affect the time of concentration and peak runoff rate of the catchment with TR55 hydrology option we selected in AGNPS (Young et al., 1994). Time of concentration obtained with this option for different cell sizes were confirmed with those estimated using standard engineering hydrology watershed lag time equations. A cell size of 150 by 150m gave appropriate hydrologic results.

Finally, we analyzed the cell size according to the scale of the input data: the scale of soil and land use maps is 1:25 000, corresponding to a minimum legible delineation of 2.5ha (Forbes et al., 1982). A comparable cell size is 2,25ha (150m by 150m). Less than 3.7% of the area corresponds to map units smaller than 9ha (four cells of 150 by 150m), which could be maximum possible units to be eliminated by using this cell size.

Therefore, we decided to use a 150 by 150m cell size for the remaining of this study.

#### **4.4.3. Sensitivity to input data**

The results from the sensitivity analysis for peak flow rate and sediment concentration are summarized in Table 5. The parameter that most significantly affected the peak flow rate predictions is CN. The relative sensitivity decreases with storm size, although, even for large size storms the sensitivity is still high. The Manning coefficient has a smaller effect on the peak flow rate predictions. For sediment concentration, predictions are primarily affected by changes in CN, followed by the variation in K and C and factors.

Table 5 - Sensitivity analysis for peak flow rate and sediment concentration (abbreviations from Table 2).

Peak Flow Rate (%)													
Rainfall	CN		Mn		K		C		P		SCC		
(mm)	OPT	PESS	OPT	PESS	OPT	PESS	OPT	PESS	OPT	PESS	OPT	PESS	
12.5	0.0	-	0.0	0.0	-	-	-	-	-	-	-	-	
20	-100.0	4014.0	0.0	2.0	-	-	-	-	-	-	-	-	
25	159.5	3955.7	0.0	1.5	-	-	-	-	-	-	-	-	
32.5	-96.9	909.5	-0.5	0.9	-	-	-	-	-	-	-	-	
40	-78.2	632.7	-0.6	0.9	-	-	-	-	-	-	-	-	
60	-68.5	260.3	-6.4	8.8	-	-	-	-	-	-	-	-	
80	-55.2	147.8	-8.8	12.2	-	-	-	-	-	-	-	-	
100	-45.5	100.5	-9.7	13.4	-	-	-	-	-	-	-	-	
120	-38.7	74.3	-10.2	14.0	-	-	-	-	-	-	-	-	

Sediment Concentration (%)													
Rainfall	CN		Mn		K		C		P		SCC		
(mm)	OPT	PESS	OPT	PESS	OPT	PESS	OPT	PESS	OPT	PESS	OPT	PESS	
12.5	0.0	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	-	
20	-100.0	-52.6	-12.9	26.9	-17.2	58.8	-49.4	-21.4	-0.9	0.6	-	-	
25	90.3	40.8	-12.5	29.1	-11.4	41.7	-44.9	-13.8	-1.3	0.7	-	-	
32.5	97.8	239.9	-4.4	14.7	-25.1	82.4	-65.6	-35.8	-8.4	5.1	-	-	
40	-49.0	90.8	-3.0	7.2	-30.9	104.3	-87.1	-49.5	-18.6	11.5	-	-	
60	3.6	-2.1	-3.3	5.2	-30.6	106.8	-94.8	-55.6	-21.9	14.3	-	-	
80	-55.2	147.8	-8.8	12.2	-31.4	109.2	-95.7	-58.9	-20.3	13.1	-	-	
100	13.9	-0.2	-5.7	8.6	-32.4	111.4	-96.0	-60.9	-19.1	12.1	-	-	
120	7.7	0.1	-6.8	9.7	-33.1	112.7	-96.2	-62.0	-18.5	11.6	-	-	

#### 4.4.4. Calibration

AGNPS peak flow rates predictions under the best guess scenario are underestimated for small storms, well estimated for medium storms and overestimated for large storms. This model behavior can be attributed to the curve number method used here for the estimation of runoff volumes and consequently peak rates. To calibrate the model in this condition, we should vary a parameter that at the same time increases the values for small storms and decreases for large storms, what is not possible within realistic parameter values variations (see Table 5). This is consistent with other calibration attempts. Many authors disregard small events when calibrating AGNPS model (Mitchell et al., 1993; Grunwald and Norton, 2000) because they contribute little to runoff and sediments and nutrients transport. For



large storms, it is well known that AGNPS overestimates the peak flow rate even after calibration (e.g. Mitchell et al., 1993). A possible solution is to calibrate the model for different storm ranges and use the appropriate input parameter values for each simulated event, depending on its size. We therefore separated the dataset into three different ranges which appears to be matching the observed and predicted values: (1) pessimistic scenario for small storms (<25mm); (2) best guess scenarios for storms ranging from 25 to 60 mm; and (3) optimistic scenario for large storms (>60mm). The model efficiency values (Nash and Sutcliffe, 1970) were respectively 0.02, 0.10 and 0.85, which are better than the coefficients obtained considering all storm events (-13.09, -0.04 and 0.85).

Figure 6 shows the predicted and observed peak flow rates divided into the three mentioned ranges.

Some known AGNPS model inconsistencies were observed when simulating small storm events around the rainfall threshold for runoff generation (<12mm). Although no overland flow is generated by the model, a minimal channel flow is simulated. This is reflected in the unrealistically high predictions of sediments concentration. For this reason, these small storms were eliminated from the dataset for further analysis of sediments concentration.

Using the same ranges and simulations from flow rate, we found that the AGNPS predictions are always significantly higher than observed values. Keeping all other parameters, we changed K, P and C factors to the optimistic values, which decreased the predicted estimates for sediments concentration without affecting the flow rates. Yet the predicted values were overestimated with ratios of 10.2, 6.0 and 7.6 respectively for the three selected storm ranges. This overestimation by the model is likely explained by sediment trapping by vegetated channel banks and riparian areas in this semitropical area; these are usually heavily vegetated banks and thus act as sediment traps for the upland field erosion. Thus the AGNPS-predicted sediment deliveries to the drainage network and resulting sediment concentrations are much higher than actual values.

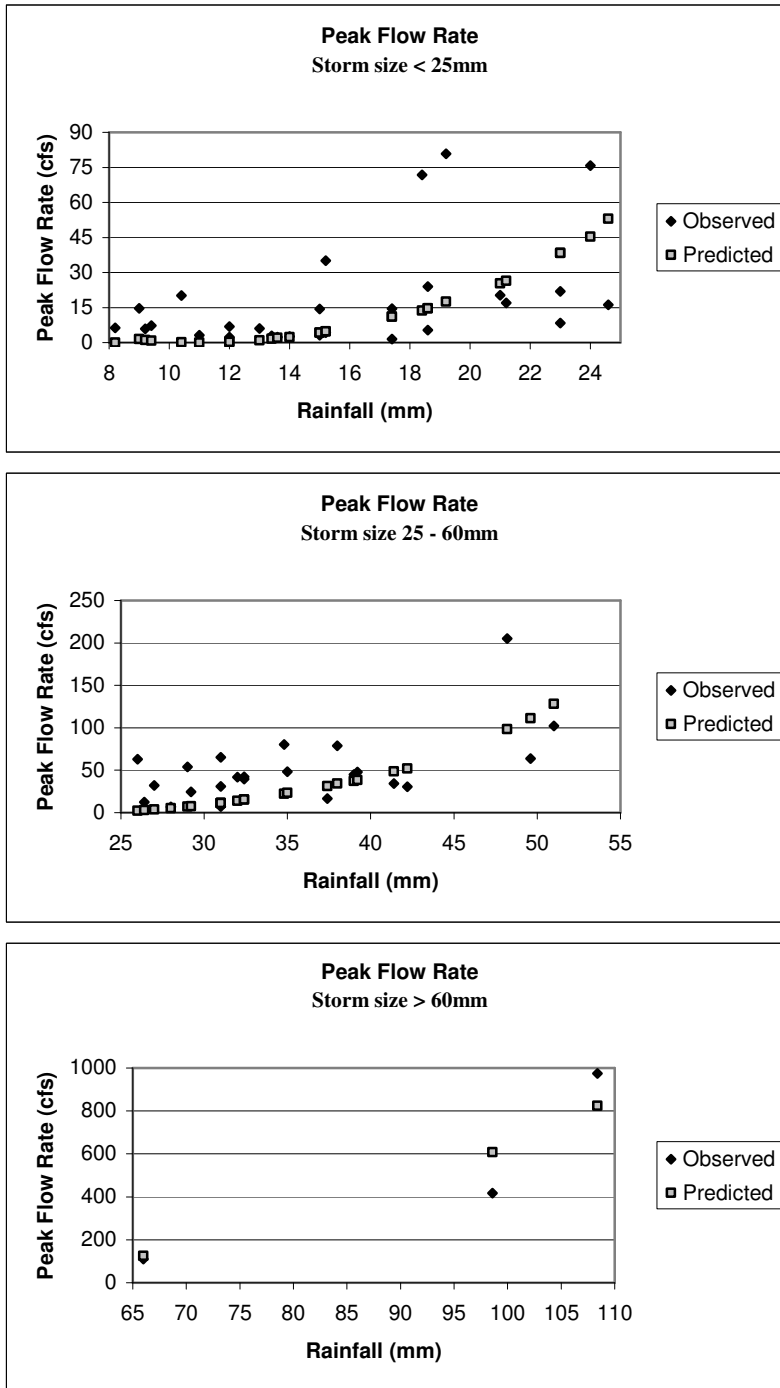


Figure 6 - Observed and predicted peak flow rates for three storm sizes ranges.



Plate 1 – Overview of a pig farm, with the manure pond next to the river.



Plate 2 – EPAGRI's technician measuring river cross-section and flow rate in the Ariranhazinho river outlet.

To calibrate the model for these low actual sediment concentrations, we would have had to radically alter some input parameters, well beyond realistic values. Instead, we divided the predicted concentrations by the ratios calculated above for each storm size categories. Figure 7 shows that this procedure results in a good agreement between observed and predicted values. Although this is an ad-hoc method, we note that AGNPS makes no provision for sediment traps in channels, so our procedure or something like it will always be required in such situations.

#### **4.4.5. Scenario analysis**

Figures 8 and 9 show N and P concentrations in runoff, respectively, for the study area under different scenarios. The predicted values were divided by the ratios according to storm size as explained above, except for the manure flowing direct to the streams, which is not related upland erosion and only partially to sediment transport. The spatial pattern of N and P concentrations in runoff is mainly related to land cover and land use. The point sources and their location within the catchment directly affect the N and P concentrations in the drainage network and streamflow as can be observed from Figures 8 and 9.

According to the regulations of Santa Catarina state, the total acceptable N and P concentrations in water are 11.5 and 0.025ppm respectively. The figures show that predicted N and P concentrations are considerably higher than adequate under exaggerated manure application (except for large size storms), and this scenario can accordingly be rated “high pollution risk”. With the recommended manure application, predicted N and P concentration are lower, so that this scenario can be rated “medium pollution risk”, assuming adequate management practices such as incorporating (disking in) manure immediately after its application. Finally, the realistic manure application scenario show low predicted values of N concentration and values close to the limits for P; therefore, it could be considered to have a low water pollution risk if satisfactorily managed.

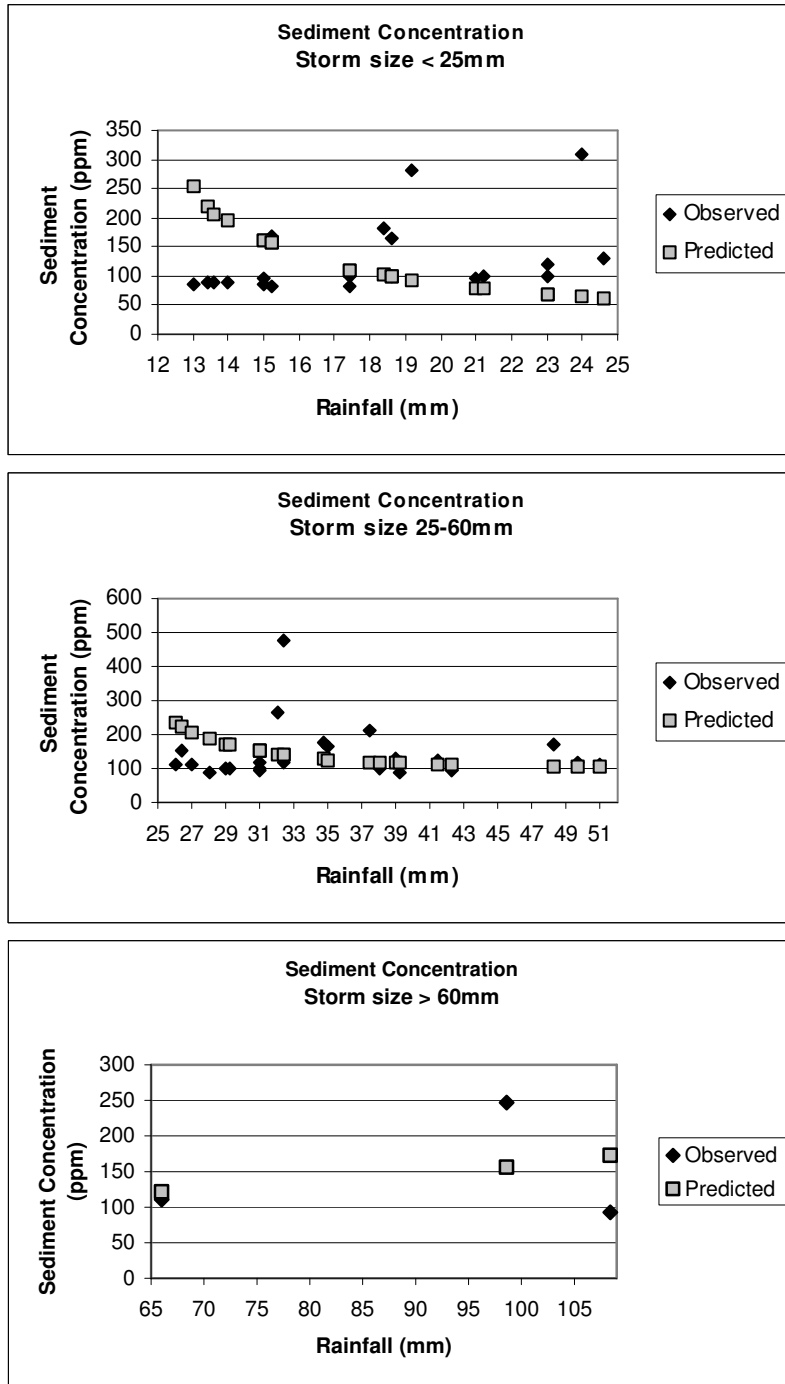


Figure 7 - Observed and predicted (divided by the calculated ratios) sediment concentration for three storm sizes ranges.

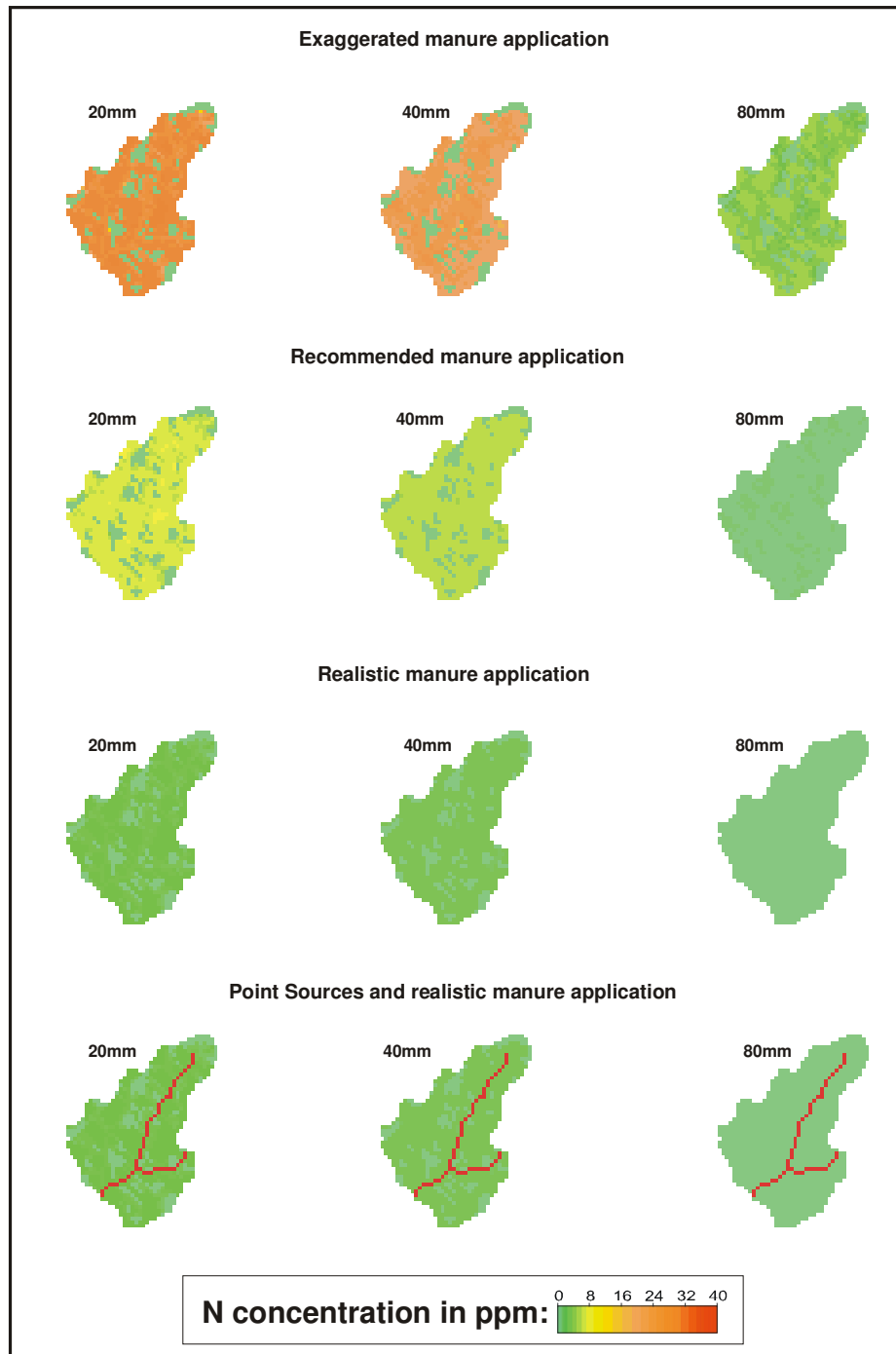


Figure 8 - N concentration (ppm) in runoff for four scenarios and three different storm sizes.

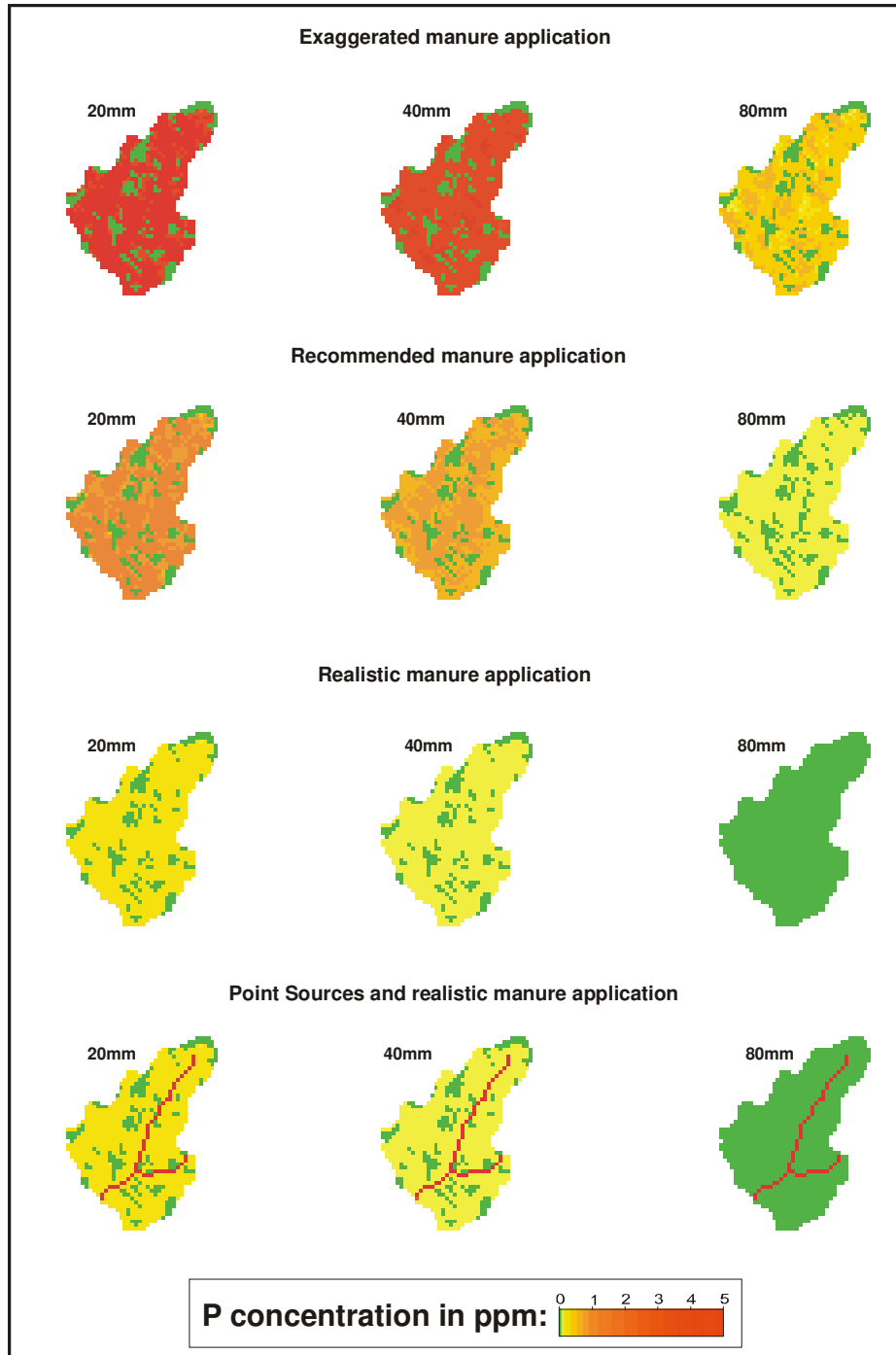


Figure 9 - P concentration (ppm) in runoff for four scenarios and three different storm sizes.

In our data-poor environment, we were not able to determine validated absolute values for pollution. Still, the relative (comparative) results show that the existing pollution problem in the catchment is mainly related to the management practices and direct discharge of manure to the streams instead of to the high number of animals as most of the people in the region suppose (Bacic et al., Submitted-b). For instance, we observed that the predicted water pollution for just two point sources could be greater than that expected for exaggerated manure application, which corresponds to about sixteen times the current manure production in the whole catchment. These results as well as other scenarios will be eventually used in interactive decision-making in Santa Catarina.

#### **4.5. Conclusion**

This paper deals with the applicability of a data-intensive watershed erosion and water quality model in a relatively data-poor environment. It demonstrates that, even without expensive procedures for data measurement and collection, it is possible to consistently apply a distributed environmental model such as AGNPS, for relative ranking of scenarios in comparative studies.

The evaluation of the data collected at the Ariranhazinho outlet by comparison with nearby meteorological station and data selection by expert judgment, gave us the necessary confidence to use the data for further analysis.

The pragmatic sensitivity analysis proved to be helpful, as it showed the realistic model sensitivity parameters within local conditions limits.

The strategy adopted for calibration showed that the expert knowledge of the area in addition to literature information compensates in part for poor data. This strategy can be useful in many areas of the world where resources for detailed model calibration are lacking and direct application without a careful attention on model input parameters adjustment could lead to higher uncertainties in model simulations and in the predictions and recommendations derived from those simulations. We believe that even considering that the predictions are not so accurate, it is reasonable to



assume that the best simulations can be used to evaluate water pollution caused by pig manure under different scenarios, giving estimates at an order of magnitude. However, for studies demanding accurate absolute predictions (e.g. regulatory projects), a complete model evaluation, including accurate and detailed dataset for calibration and validation, is required.

The uncertainties related to the time and amount of release of the pollutant sources (i.e. manure detention ponds) by the farmers in combination with the daily gauging and occasional sampling of the water quality, did not permit accurate verification of AGNPS simulations of point source impacts. However, modelling scenarios based on realistic pollutant flow suggest that the practice of detention pond release to the river system significantly affects the downstream water quality and nutrient export. A similar interactive analysis could be a powerful tool to decision makers in the area, helping both farmers and policy makers to make plans and decisions on management practices that could help to minimize the pollution problems. For instance, the number of animals in the catchment could be even higher if correct management practices and some actions were taken (e.g. a collective plan to transport and spread manure nearby).

Even in a data poor environment such as the study area some simple improvements are easily achievable. First, to overcome the difficulties of using summer data because of local storms, recording rainfall gauges could be installed at several points in the catchment. A second improvement would be a simple instrument to measure the highest river level in 24 hours, rather than a single daily measurement; this is especially relevant in small catchments with short concentration times. This would allow the peak flow rate to be estimated with considerably more accuracy.

Finally, we suggest that the methodology presented in this paper could be useful not only to adjust parameters for application in a data poor environment, but also as a starting point for calibration in a data rich environment.

***Acknowledgements***

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## **Chapter 5**

### **Collective understanding of shared environmental problems using visualization tools at watershed level**

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Submitted to Landscape and Urban Planning

## **Collective understanding of shared environmental problems using visualization tools at watershed level**

**Abstract.** Decreasing quality of drinking water is one of the main issues related to environmental degradation in diverse parts of the world. It seems reasonable to assume that the question is often not appropriately attacked because of the lack of proper information, leading to an incorrect perception of the actual location and causes of the problem. Otherwise the information may be known but not adequately communicated, leading decision makers to ignore it. A demand-driven land evaluation approach, which includes the negotiation between information suppliers and users about the information to be provided and the visualization of scenarios with community participation by use of Geographic Information Systems (GIS) and modelling, could be a powerful tool to overcome these difficulties. This paper describes one of the steps towards a demand driven land evaluation approach, as an effort to increase the use of information by farmers, land use planners and other decision makers. It demonstrated with experimental support the importance of this approach to the negotiation between information providers and users about the information to be provided and tools to be used. We organized meetings with the main different groups of direct and indirect decision makers in the west region of Santa Catarina State, Brazil, from which we were expecting different reactions. We presented static visual information (satellite image, orthophoto mosaic, location of the main pig producers) and visual outcomes from a dynamic pollution model for previously prepared scenarios. We used questionnaires to test participants' reactions through the meetings and to evaluate their opinions about the provided information. Different groups responded differently for the presented information. In general, extensionists opinions changed little. The greatest differences in answers through the meetings were from the marginal farmers, followed by the consolidated farmers. We found that visualization of scenarios with community participation was useful to increase participants' understanding of the water pollution problem, improve their perceptions, stimulate the search for solutions and generate new demands, even taking into account the lack of habit and low preparation of the rural decision makers common in many areas of the world such as those in Santa Catarina.

## 5.1. Introduction

Decreasing quality of drinking water is one of the main issues related to environmental degradation in diverse parts of the world. Spatial identification of the problem and its severity level is often difficult (Engel et al., 1993). It seems reasonable to assume that the question is often not appropriately attacked because of the lack of proper information, leading to an incorrect perception of the actual location and causes of the problem. Otherwise the information may be known but not adequately communicated, leading decision makers to ignore it. To overcome these difficulties, Bacic et al. (2003) suggested a demand-driven land evaluation approach, which includes the negotiation between information suppliers and users about the information to be provided and a further actual land use negotiation. This still does not guarantee adequate understanding of the supplied information. Visualization of scenarios with community participation by use of Geographic Information Systems (GIS) and modelling, commonly called participatory geographic information systems (PGIS), could be a powerful tool in this process.

PGIS has been increasingly used for collective understanding and decision making. The main focus has been on digital cartography that links local and expert knowledge (Craig et al., 2002). Participatory approaches have been used for instance to identify, compare and integrate soil and land local knowledge with expert knowledge (Barrera-Bassols and Zinck, 2003; Ryder, 2003) or local soil knowledge implications for integrated soil management (Barrios and Trejo, 2003). Other applications, also coupled with GIS, include studies to recover rich cultural traditions and management practices (Gonzalez, 2000), visualization of future scenario for landscape planning (Tress and Tress, in press), and assessment of land suitability with public participation using multi-criteria and multi-objective evaluation, resulting in land suitability groups that minimize conflicts and maximize consensus among the stakeholders, without further evaluation of the acceptance of the results by the sectoral representatives (Bojórquez-Tapia et al., 2001).

Most of the effort to date has been on improving technologies, so that communication to and reactions from the clients have not been a focus of research. Some visualization tools have been tested, for instance, with authors' colleagues and students (Ogao, 2002; Appleton and Lovett, in press), rather than with actual decision makers. Furthermore, these tools are still restricted in developing countries due to the supposed inadequate preparation of the decision makers to understand them.

We believe that visual tools and pollution modelling can increase understanding of environmental problems, change perceptions, generate new demands and improve decisions, even taking into account the lack of habit and low preparation of the rural decision makers common in many areas of the world such as those in Santa Catarina. Therefore, this study is an attempt to introduce these tools in such environment and investigate their effects on rural decision makers. We also evaluated decision makers' opinions about the provided information.

## **5.2. Material and methods**

### **5.2.1. The study area**

This study was carried out in the upper part of Ariranhazinho River microcatchment (2 520ha), located between 52°23' and 52°19'W and 27°07' and 27°12'S (Figure 10). It is part of Uruguay River watershed and is characteristic of most of the west region of Santa Catarina State, Brazil (25 300 km<sup>2</sup>), where the economy is primarily based on agriculture, the small family farms are predominant and swine production is intensive. According to Instituto Cepa/SC (2001), there are 60 families farming in the area, 27 of them with intensive pig production. For further details about the area see also (Tassinari et al., 1997; Bacic et al., Submitted-a; Bacic et al., to be submitted).

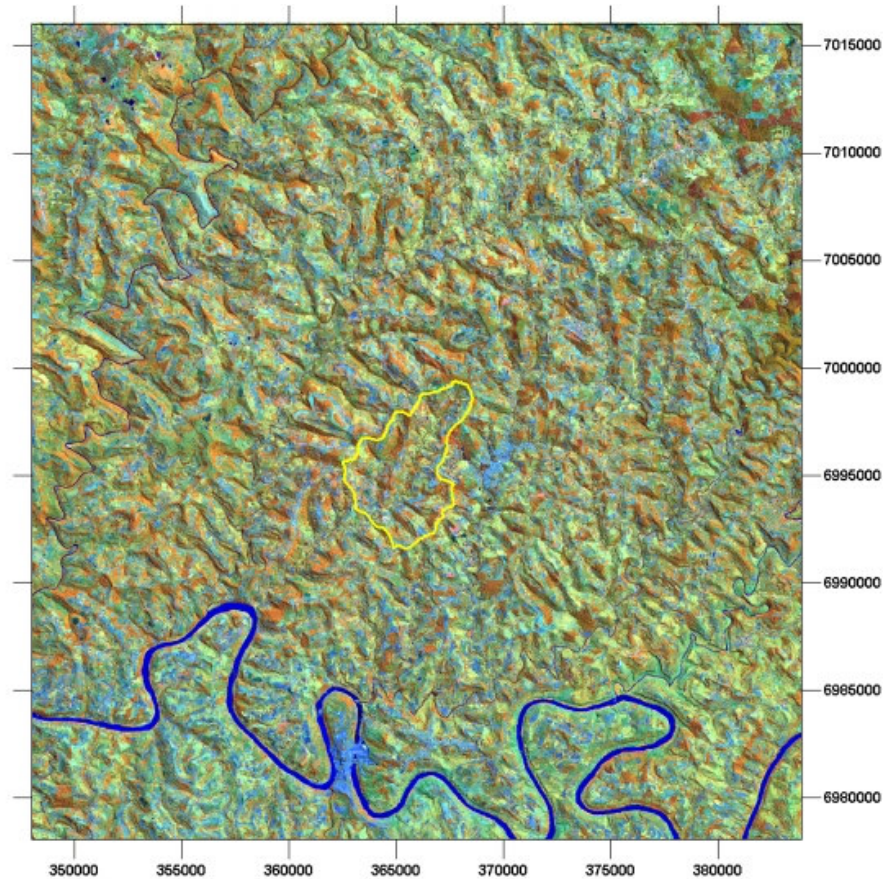


Figure 10 - Overview of the Ariranhazinho river microcatchment location, showing Uruguay River in the southern part and Seara town directly to the east of the microcatchment (UTM projection system zone 22J).

### 5.2.2. Meetings protocol

We organized four meetings with the main different groups of direct and indirect decision makers in the area identified by Bacic et al. (to be submitted), from which we were expecting different reactions. The meetings occurred in the first week of December 2002 and were conducted in Portuguese, the main language for all the participants. We invited 30 farmers from family marginal farms and 30 from family consolidated farms, classified according to Instituto Cepa/SC (2001), 30 state rural extensionists from different municipalities in the west of Santa Catarina, and an open number of representatives from agro industries. The term “consolidated” is

used when the income is higher than three legal minimum wages per person working full time in the farm, and “marginal” when it is less than one minimum wage (FAO/INCRA, 1997; Tedesco, 1999).

Each meeting was planned to last about 4 hours, with the following protocol: 1) introduction about the structure of and reason for the meeting; 2) first questionnaire to collect general information about the participants, and to test their existing knowledge and view about environmental problems caused by pig manure in the region; 3) presentation of additional visual information, without discussion and interventions; 4) second questionnaire to test the effect of the visualization; 5) open guided discussion; 6) third questionnaire to test the effect of the discussion; 7) fourth questionnaire to let them evaluate the information provided and methodology used; and 8) final remarks and conclusions. Answers to structured questions were entered in a database, summarized and described in this paper. Answers from open questions and comments collected during the meetings were considered personal opinions and discussed as such.

The first questionnaire included personal and general information, spatial and temporal environmental perception, current situation, future possible scenarios, effectiveness and possibilities for improvements and solutions. The second and third questionnaires were similar excluding the personal information. The fourth questionnaire included questions about quality and usefulness of information and work methods, what could be improved, and if similar procedure could be useful to solve other problems in the region

Self-identification of the participants was optional. However, as we wanted to relate the same respondent for different questionnaires, we distributed numbers for those did not want to identify themselves.

### **5.2.3. Static spatial information**

During the meetings we presented the following static visual information prepared with ILWIS 3.11 Academic (ITC, 2002) and ERDAS IMAGINE (ERDAS LCC, 2002): 1) satellite false color composite image locating the Ariranhazinho watershed in a larger context (Figure 10); 2) 3D orthophoto mosaic from three different points of view locating the main pig producers



(see example in Figure 11); and 3) 3D satellite false color composite images from three different points of view locating the main pig producers (see example in Figure 12).

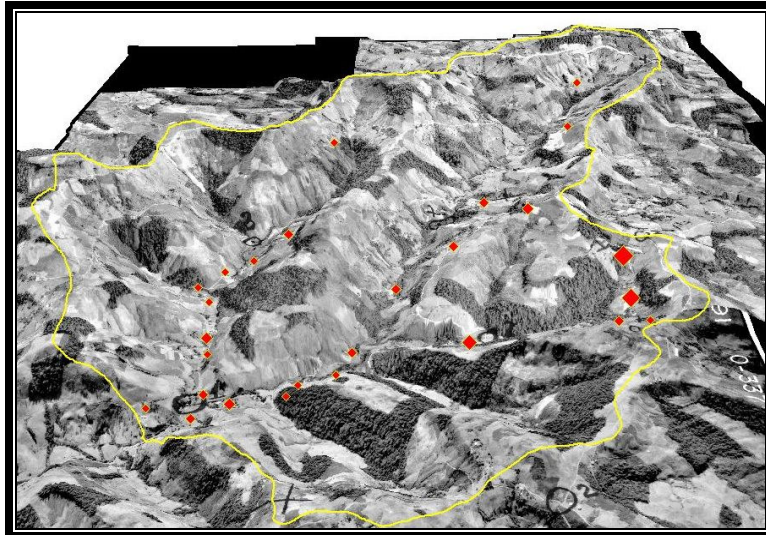


Figure 11 - 3D Orthophoto mosaic locating pig farms. Size of diamonds is proportional to the estimated amount of manure produced (Instituto Cepa/SC, 2001).

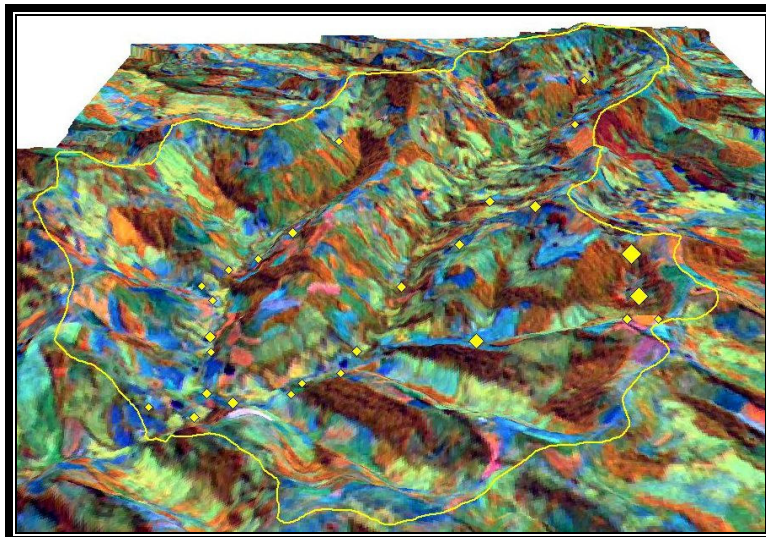


Figure 12 - 3D satellite color composite images locating pig farms. Size of diamonds is proportional to the estimated amount of manure produced (Instituto Cepa/SC, 2001).

Using LANDSAT 7 satellite images from September 1999, we produced a resolution merge by applying the Brovey Transform method (ERDAS, 1999) to the bands 4, 5 and 3, using band 8 as the high-resolution image. We prepared the orthophoto mosaic from aerial photos made by Cruzeiro do Sul Levantamentos Aerofotogramétricos in scale approximate of 1:25 000 from 1977 to 1979. The DEM was prepared using the contour lines from the topographic map SEARA, SG.22-Y-D-I-1 (MI-2887/1), in scale 1:50 000, issued by the Army Ministry in 1979.

The 27 pig farms were located with GPS. The symbol sizes showing the pig producers in the area in Figures 11 and 12 are proportional to the estimation of manure amount produced according to Instituto Cepa/SC (2001). There is a high concentration of animals in the east, contrasting with other parts of the catchment.

Non-spatial information presented included the estimated total amount of pig manure produced in the catchment (25 700 m<sup>3</sup> manure/year according to Instituto Cepa/SC (2001)) and the area with annual crops (1 100 ha), where the manure could be used as fertilizer (Tassinari et al., 1997), resulting in 23.4 m<sup>3</sup>/ha/year. The amount of manure recommended in the region is 60 m<sup>3</sup>/ha/year (Dartora et al., 1998), which means that, if well managed, the manure should not be seriously affecting the water quality.

#### **5.2.4. Dynamic pollution model**

We also presented visual outcomes from a dynamic pollution model for previously prepared scenarios. We used AGNPS, the AGricultural Non-point source Pollution model (Young et al., 1987), GRIPS, Geo-Referenced Interface Package (Mannaerts et al., 2002) and ILWIS 3.11 Academic (ITC, 2002). As input for AGNPS, we used the initial parameterisation established by Bacic et al. (Submitted-a), which was called the “best guess”, for a 150m by 150m cell size. This resulted in visually satisfactory spatial patterns for the regional conditions, even before model calibration. Therefore, for this paper we assumed that AGNPS model could make a good pollution prediction at least for relative amounts. Since our aim was to see how visualization would affect decision making, exact predictions were not

needed at this stage of decision making process. For more details of the modelling approach see Bacic et al. (Submitted-a).

The following prepared scenarios and resulting output maps showing the spatial distribution of N and P concentrations in water were presented:

- Current land use without pig manure for three different storm sizes selected subjectively as small, medium and large for the regional conditions (5, 50 and 125mm); the maps showed zero N and P concentration;
- Current land use with pig manure distributed in annual crops and pasture according to the recommended amounts (Dartora et al., 1998) for three different storm sizes (5, 50 and 125mm); the resulting maps showed the highest concentration for the medium-sized storm;
- Current land use with four times the recommended values of pig manure distributed in annual crops and pasture (excessive fertilizer), for three different storm sizes (5, 50 and 125mm); the concentration of N and P were higher then in the previous scenario; and
- Current land use with excessive fertilizer, simulating vegetal protection around the manure ponds (by changing the CN values in every cell with a pond/pig producer) for a 50mm storm event; the simulated protection resulted in lower N and P concentration.

The flow direction map generated by AGNPS and examples of output maps presented in the meetings are shown on Figures 13 and 14 respectively. To make the participants understanding of the flow direction map easier, we also presented an animation of a stylised microcatchment, explaining the pollution sources and how the pollutants flow.

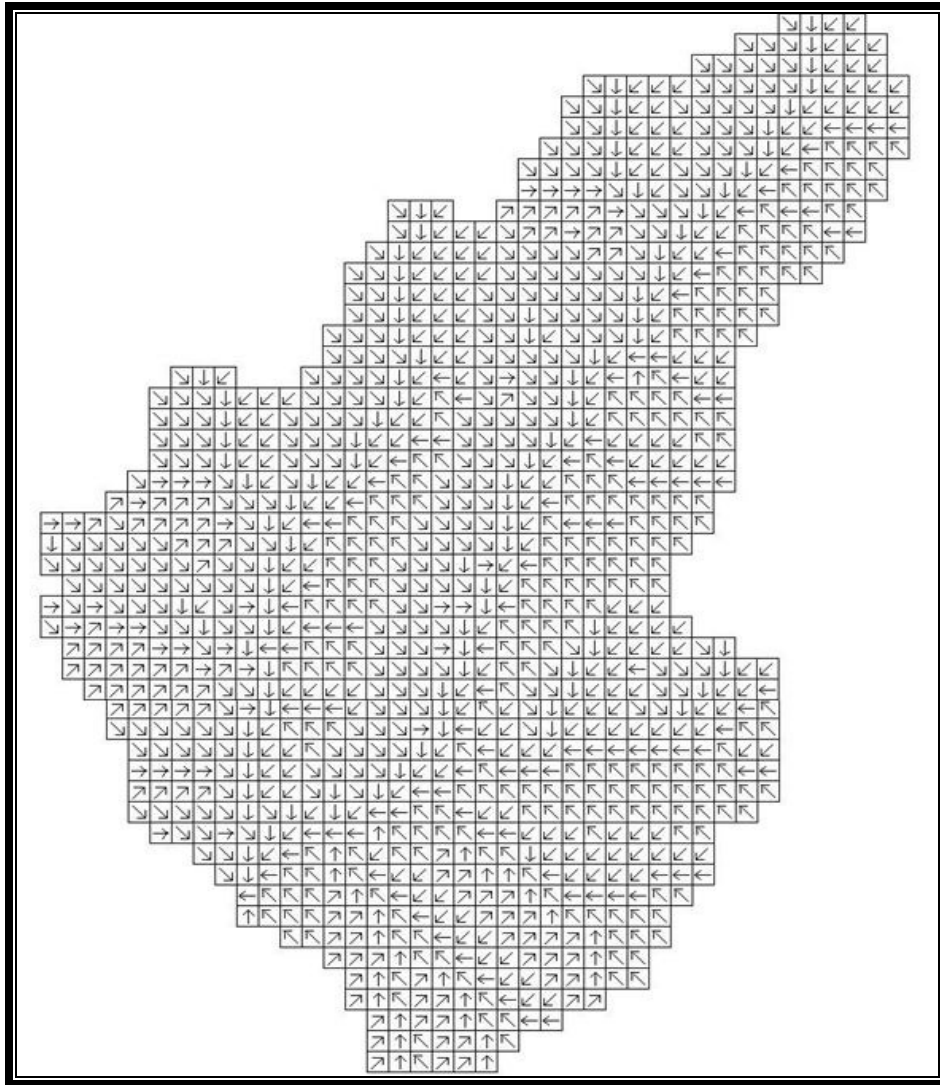


Figure 13 - Map of flow direction for the Ariranhazinho river microcatchment.

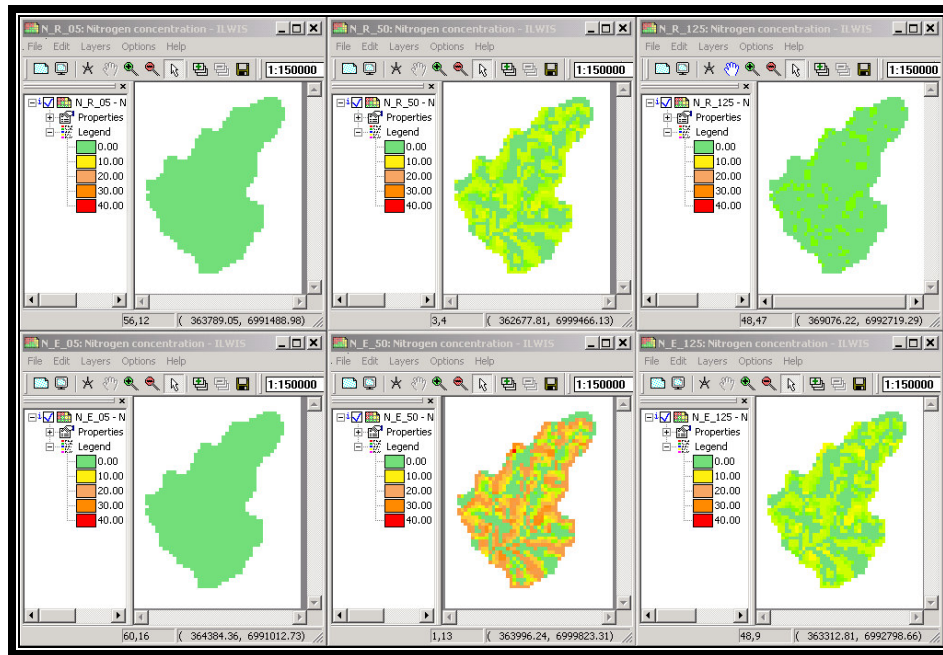


Figure 14 - Examples of AGNPS output maps (N concentration). Upper and lower maps show respectively recommended and exaggerated application of pig manure in three different storm sizes (5, 50 and 125mm).

### 5.3. Results and Discussion

#### 5.3.1. Meetings

Eleven farmers from marginal farms and ten from consolidated farms participated in the meetings, corresponding to 37% and 33% acceptance for invitations respectively. We considered the number of participants reasonable, considering the transport difficulties, the aversion of some farmers to meetings, and the favourable weather for farm work. Eighteen rural extensionists (60% of the invited) attended the meeting. As predicted by extensionists, nobody from agro industries attended and that meeting had to be cancelled. The non-attendance was likely because the theme was related to environment problems, and their central focus is economic.

Most of the participants from marginal farms had been living in the region for more than twenty years (8 out of 11). The size of their farms varies from 8 to 73 ha, with most (9 out of 11) of the farms smaller than 30 ha. The

main activities are maize and milk, followed by small-scale production of pig, beans and poultry. Similarly, most of the farmers from consolidated farms had lived in the region for more than twenty years (9 out of 10), but the size of their farms are mostly bigger than 30 ha (for 6 out of 10), varying from 19 to 85 ha. The main activity for the majority is pig farming (8 out of 10). As secondary activities, they also produce maize, milk, poultry and wheat. Extensionists had 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.

The receptivity from all the farmers, both marginal and consolidated, and most of the extensionists was friendly. But the farmers seemed to be more enthusiastic, pleased and grateful for the opportunity.

### **5.3.2. Reactions from the participants**

It was not possible to objectively test whether this work had any effect on decision making, since that will only be apparent after some time. However, we were able to draw some conclusions on: 1) how do different decision makers react to the information; 2) participants understanding and how the demanded information affects their spatial and environmental perceptions; 3) what other problems in the region and new demands generated can be addressed with similar procedures; and 4) what can be improved in the methods, tools and information for the next negotiation rounds.

All the farmers could easily locate rivers, streams and cities in the satellite images, and their own farms, neighbours, roads, villages and streams in the orthophotos. The extensionists could also easily understand the presented information and identify the features. This was the first experience with this kind of material, except for the extensionists that had seen vertical aerial photos before. This facility to understand maps and images even in their first contact with such material is also mentioned by other authors (Gonzalez, 2000).

Tables 6 and 7 summarize the responses for the structured questions, categorized by respondent type. Figure 15 shows graphically the trend of answers presented in Table 6, across the three questionnaires with one graph for each participant group.

Table 6 - General perceptions and main causes of pig manure pollution.

		Participant type	Questionnaire 1 Pre-visualization (%)	Questionnaire 2 Post-visualization (%)	Questionnaire 3 Post-discussion (%)
General perception	Severity level <sup>(a)</sup>	Marginal	64	45	27
		Consolidated	20	20	20
		Extensionist	44	56	44
	Urgency for solutions <sup>(b)</sup>	Marginal	91	45	27
		Consolidated	10	0	10
		Extensionist	56	56	44
	Possibility for solutions <sup>(c)</sup>	Marginal	91	18	55
		Consolidated	60	40	80
		Extensionist	89	72	83
Main causes <sup>(d)</sup>	General high number of animals	Marginal	100	64	0
		Consolidated	80	40	20
		Extensionist	28	44	39
	Animal concentration	Marginal	100	91	100
		Consolidated	90	90	100
		Extensionist	89	83	89
	Ponds location	Marginal	100	73	91
		Consolidated	50	80	60
		Extensionist	39	22	28
	Inappropriate ponds building	Marginal	91	73	100
		Consolidated	60	80	80
		Extensionist	17	28	28
	Direct flow to the streams	Marginal	91	82	100
		Consolidated	50	80	70
		Extensionist	78	67	83
	Management	Marginal	36	55	91
		Consolidated	30	80	80
		Extensionist	33	72	72

<sup>(a)</sup> 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).

<sup>(b)</sup> 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).

<sup>(c)</sup> Proportion of respondents considering to be very difficult and difficult to find solutions (from four options: very difficult, difficult, easy and very easy).

<sup>(d)</sup> Proportion of respondents considering the cause to be very important (from three options: very important, important and slightly important).

Table 7 - Efficiency (E) <sup>(a)</sup> and possibility (P) <sup>(b)</sup> of measures to decrease pollution problems caused by pig manure.

Measure	Participant type	Questionnaire 1		Questionnaire 2		Questionnaire 3	
		Pre-visualization		Post-visualization		Post-discussion	
		E	P	E	P	E	P
		(%)		(%)		(%)	
Decrease number of animals	Marginal	73	55	73	73	9	9
	Consolidated	30	40	10	40	0	20
	Extensionist	17	11	17	11	33	17
Decrease concentration of animals	Marginal	91	27	82	73	100	0
	Consolidated	60	70	90	60	90	60
	Extensionist	89	17	67	44	89	33
Change ponds location	Marginal	82	64	91	82	100	9
	Consolidated	90	90	80	80	70	80
	Extensionist	33	39	33	50	28	39
Vegetal streams protection	Marginal	55	82	82	100	100	91
	Consolidated	70	80	70	90	80	90
	Extensionist	39	72	44	89	33	83
Manure transportation	Marginal	91	91	100	100	100	91
	Consolidated	70	80	90	80	90	80
	Extensionist	33	39	72	61	67	67
Improve manure management	Marginal	91	91	100	91	100	82
	Consolidated	90	80	90	90	90	90
	Extensionist	89	83	89	89	94	83
Avoid direct flow	Marginal	91	73	91	91	82	91
	Consolidated	90	100	80	80	80	80
	Extensionist	78	89	94	94	83	100

<sup>(a)</sup> Proportion of respondents considering the measure to be very efficient (from three options: very efficient, slightly efficient and inefficient).

<sup>(b)</sup> Proportion of respondents considering the measure to be possible (from three options: possible, slightly possible and impossible).



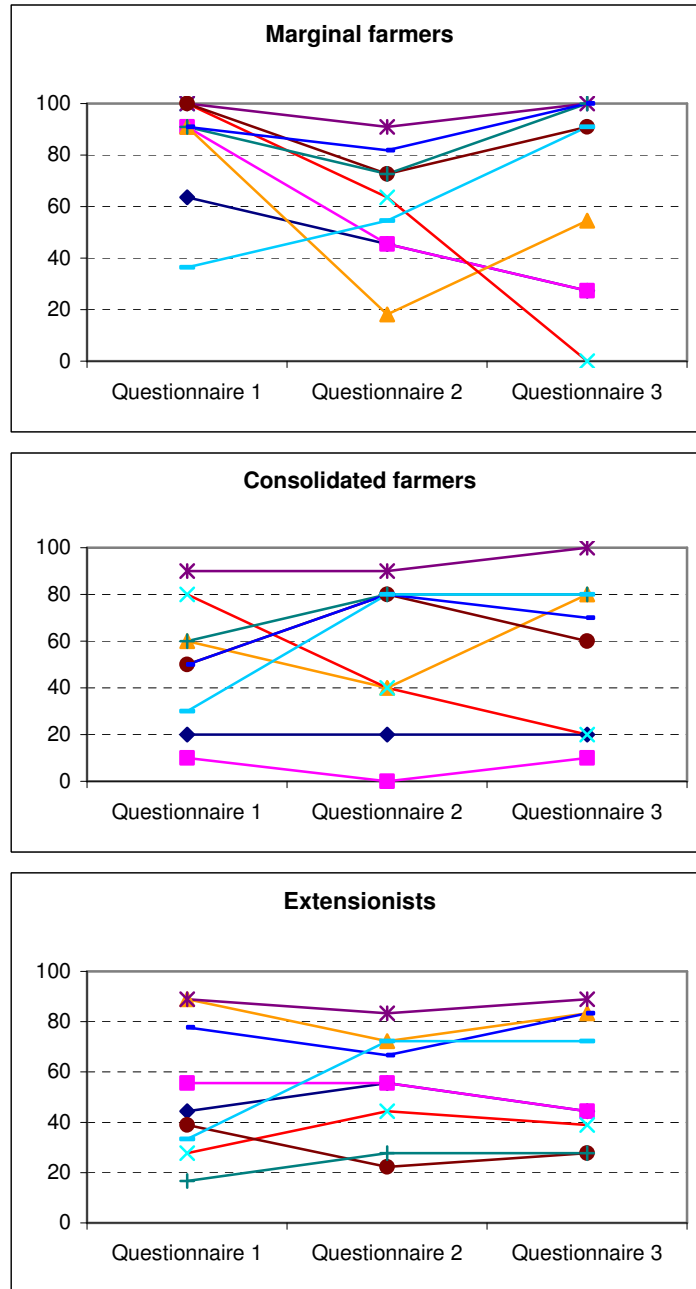


Figure 15 - Trend of answers presented in Table 6 (general perception and main causes of pig manure pollution) across the three questionnaires for the different participant groups.

The greatest differences in answers through the meetings were from the marginal farmers, followed by the consolidated farmers. In general, extensionists opinions changed little (Figure 15 and Tables 6 and 7). In the case of the extensionists, we observed that although we tried to situate them in the presented watershed, the discussion revealed that most of the time they were still thinking about conditions in their own municipality.

Regarding the general perception of the water pollution problem in the region (Table 6), most of the marginal farmers answered the problem was at least very severe (64%) and very urgent to solve (91%) in the first questionnaire. After presentation and discussion these numbers decreased to 27%. The majority of consolidated farmers did not see the problem as very severe and very urgent to solve during the whole meeting. These show that marginal farmers although perceiving the water pollution problem in the field, did not have a clear picture of the causes and possible solutions, which improved after presentation. On the other hand consolidated farmers, mostly pig producers, did not express concern about the problem. This may reflect their fear to be blamed and forced to pay alone for solutions.

Considering the general possibility to find solutions, all three groups showed the same pattern. The number answering that the 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 the problem is apparently not so serious as they thought, but after discussion it became clear that the solutions depend mainly on the awareness of other decision makers, as the municipality and agro industries.

Concerning the spatial perceptions, when marginal farmers were asked about the location of highest pollution sources, 10 out of 11 were able to name the village with the highest pig concentration even before the presentation. After the presentation they could also identify spatially the position in the catchment (low, medium or high portion) where the pollution could be more problematic. The presentation was useful to place them in a spatial context, in addition to their local view. During the discussion they were pleased to be able to point in the maps and images places where pollution should be accumulating, and relate this to the farm owners 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 the spatial location for higher pollution accumulation during the whole meeting. The presentation and discussion did not change their answers. Again, it seems that they did not want to blame themselves or their colleagues for the pollution. As the extensionists were not familiar with the area, they were asked for their own opinion about their spatial perception of current and potential pollution. After the presentation and discussion, 28% and 33% of the extensionists answered that the presented information could improve their spatial perception for current and potential pollution, respectively.

During the whole meeting, the majority in all three groups felt 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 worst, 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. The visualization showed that in medium size storms the concentration of pollutants should be higher, as in large storms the amount of pollutants carried to the river is higher but the flow rate also increases, consequently decreasing the concentration. 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.

The information presented showed that one of the possible main causes of water pollution is the high concentration of animals, and the total number of pigs is not so important. Before presentation and discussion, most of the farmers considered both important reasons. Later in the meetings, they maintained their opinion about concentration, but fewer considered the absolute number. This illustrates that the presented information and

discussions were helpful to show the main causes of pollution, changing their initial perceptions. Table 6 also shows respondents opinions about other possible causes of water pollution. One additional important cause mentioned was the steep slopes making transport and even distribution of manure difficult.

Participants were also asked about efficiency of measures for improvements. Table 7 shows that their answers were consistently related to the main causes presented in Table 6. For instance, respondents considering the high number of animals an important pollution cause thought that decreasing number of animals could be a very efficient 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 efficient measure increased from 33% to 67%.

Table 7 also presents opinions about possibilities to implement measures to improve water quality in the area. The measures considered most feasible are those related to the farmers' own control (e.g. vegetal protection, manure management and avoid manure flowing directly to the streams).

Although not quantifiable, several responses to open questions and comments during the discussions that followed the presentation drew our attention. One of them relates to the common statement that the farmers are responsible for all the pollution problems, but it is clear that alone they cannot afford to find solutions. Any solution should be though involving all actors in the process (farmers, extensionists, agro industries, municipality), including the urban consumers. For instance, agro industries should be considering decreasing concentration of animals instead of concentrating even more in order to decrease their costs for animal transport. New business should start following all the recommendations and established business should start changing the problems gradually with government and agro industries support (e.g. subsidized credit to build new ponds). Support and educational programs should be then followed by punishment by the environmental institutions and pressure from the whole society. The farmers are not always completely aware about the problem: their view is mostly

economic. Farms with a large number of animals should have a large enough area to use all manure as fertilizer, or be located close to other farms that could use the manure. Transport of manure to be applied in other areas seemed to be one of the best solutions to everybody. Public institutions and agro industries should help with trucks (transport), pumps and tubes to send manure to upper parts, and with machines for application.

### 5.3.3. Participants' evaluation and demands raised from the meetings

Finally, they were requested to evaluate the quality and usefulness of presented tools and information (Tables 8 and 9).

Table 8 - Quality of presented information by participant type.

	Very Good (%)	Good (%)	Unimportant (%)	Bad (%)
Marginal	27	73	-	-
Consolidated	50	50	-	-
Extensionists	-	72	22	6

Table 9 - Usefulness of different types of information presented (% of respondents).

Type of participant	Usefulness	Type of information				
		Orthophoto	Satel. Image	Farm location	Pollut. model	Discussion
Marg	Very useful	55	82	82	27	45
	Useful	45	18	18	73	55
	Slightly useful	-	-	-	-	-
	Not answered	-	-	-	-	-
Cons	Very useful	20	30	40	50	60
	Useful	50	60	40	30	20
	Slightly useful	20	-	-	-	-
	Not answered	10	10	20	20	20
Ext	Very useful	11	33	28	11	61
	Useful	72	44	56	44	28
	Slightly useful	17	22	17	44	11
	Not answered	-	-	-	-	-

Results show that in general they liked the material presented and the methods of the meetings. Farmers and some extensionists stated they would like to have more time to discuss the raised issues.

The most appreciated information varied according to the groups (Table 9). 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 more important than the information presented. Marginal farmers preferred the 3D satellite images and farm location. It seems that they were more attracted by the nice colors in the satellite images than by the clearest features in the orthophotos.

All the farmers and 17 of 18 extensionists felt that the same kind of participatory meeting presenting visual tools and additional information would be useful to discuss other problems in the region, as for instance traditional physical land evaluation, rural tourism, farmers' organization, other environmental problems, new land use options for family farming and socio-economic studies.

An important result was that the meetings stimulated demands. One of them was a letter written by a group of farmers to suggest a regional conference with similar procedures and tools inviting all the main actors in the pig production chain. They also asked to present the work to diverse people and institutions in different government levels mainly to those that have the power to implement solutions. 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 organize another meeting to simulate other scenarios interactively with participants; 4) to organize training to explain how to use the tools in an efficient way; 5) to locate pig producers in municipal and regional levels; and 6) to locate the poorest farms with more needs for support.

The participants also mentioned some points they think could be improved to make the meetings more productive: 1) to use short videos to represent the problems; 2) to stimulate more discussion and avoid as much as possible the use of questionnaires; and 3) to make the discussion in small groups and later opening the discussion to the whole group more objectively.

## 5.4. Conclusions

This paper describes one of the steps suggested by Bacic et al. (2003) towards a demand driven land evaluation approach, as an effort to increase the use of land evaluation results by farmers, land use planners and other decision makers. It demonstrated with experimental support the importance of this approach to the negotiation between information providers and users about the information to be provided and tools to be used.

Although it was a first attempt to present visual tools and pollution modelling to farmers and extensionists in the region, they were able to easily understand and reacted to them, as also showed in other participatory works (Gonzalez, 2000).

Different groups had initially a different level of knowledge and perceptions about water pollution caused by pig manure, what reflected in different responses for the presented information. In general, extensionists opinions changed little. The greatest differences in answers through the meetings were from the marginal farmers, followed by the consolidated farmers. Though, even if in different levels, the information was useful to increase participants' understanding of the water pollution problem, improve their perceptions and stimulate the search for solutions. They still believe something can be done to improve water quality if all the responsible actors sit together to discuss the problem with well-defined information (e.g. location and description of the causes and quantification of the problem).

The majority of the participants liked the material presented and the methods of the meetings, but the most appreciated information varied according to different groups. The pollution model was the most appreciated by consolidated farmers and the least valued by the other groups. The extensionists considered the discussion generated more important than the information presented and marginal farmers preferred the 3D satellite images and farm location.

The new demands generated are important achievements of the present work. We consider that the participants' reactions, comments and suggestions made during the discussion and described in open questions

were even more important than the numbers about quality and usefulness of the information. The participants responded to the supplied information, by criticizing, suggesting and asking for additional information, opposite to the usual unreceptive reactions for previous works (Bacic et al., 2003).

We recommend for the next negotiation rounds, to collect and generate information to supply the new demands raised and to involve agro industries in the process, by approaching them in a different way as for instance with personal visits instead of invitation for meeting, to show that the interest is not to charge them but try to find a solution together. In addition, more accurate data and further research to overcome the limitations detected in this study are needed, as for instance to improve pollution model accuracy decreasing uncertainties about the modelling predictions.

Finally, as the receptiveness and reactions to the supplied information from diverse extensionists was different and they are in close and frequent contact with the farmers, we suggest carrying out the next steps in selected areas according to the extensionists' demand.

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## **Chapter 6**

### **A participatory approach for integrating risk assessment into rural decision making: a case study in Santa Catarina, Brazil**

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## **A participatory approach for integrating risk assessment into rural decision making: a case study in Santa Catarina, Brazil**

**Abstract.** Incomplete information is one of the main constraints for decision-making, which are then by definition risky. We investigated attitudes towards risk, and the degree to which these could be changed by objective information, in Santa Catarina State, Brazil, typical of transitional economies, where neither direct (farmers) nor indirect (extensionists) decision makers had been exposed to concepts of risk. We conducted semi-structured interviews and meetings with different groups of farmers, according to their economic classification, and extensionists, from which we expected different reactions. We presented the time-series and frequency distribution of maize yield predictions, simulated by the GAPS computer program, for 16 actual seasons and 16 feasible planting dates over a five-month period. These represent climatic risks, both within and between years. The same simulations allowed us to present probabilities of achieving specific yield targets for each planting date, using the @RISK computer program. Production risk was assessed by the range, the coefficient of variability (CV), and the probability of meeting a target. We also presented a simple economic analysis (gross margin) and income probabilities for seven land use options over a recent five-year period, followed by an interactive exercise where probabilities of achieving user-supplied target gross margins were calculated according to participants' actual information. Finally, we re-assessed participant's attitudes toward risk after following these visualisations and interactive exercises. Although the effect of this exercise on actual decision-making will only become evident with time, we can already conclude that the different groups had markedly different levels of knowledge, analytic capacity, economic conditions, perspectives and needs, and therefore should be approached differently and with group-specific information. Farmers were mostly moderately or extremely risk averse. However, at the end they declared themselves willing to take risks if they have adequate information. Despite their lack of previous exposure to these concepts, participants were able to understand the presented information. Therefore, we believe that a participatory approach, by gathering, presenting and periodically discussing demanded information with decision makers is certainly a practice to be further explored to effectively integrate risk assessment into rural decision making.

## 6.1. Introduction

Incomplete information can be considered as one of the main constraints for any kind of decision-making. Among the deficiencies in information are: imperfect information on the past and present state of affairs, imperfect models, and the inherent inability to know the future. These all ensure that the decision maker sees “through the glass darkly” while struggling to make a reasonable decision based on current information, leading to decisions under risk.

The concepts of “Uncertainty” and “risk” are constant in our lives, but we do not always use them consciously. A standard dictionary (Crowther, 1995) definition of “Uncertainty” is “the state of being uncertain or a thing that is uncertain or causes one to be uncertain”. “Uncertain” is defined in turn, as “feeling doubt about something; not knowing something definitely; that cannot be confidently predicted or described”. Thus uncertainty expresses our lack of knowledge, for example about the true state of nature (data uncertainty), the true parameters of a model (model uncertainty), or the true location of a sample point (spatial uncertainty). By contrast, “risk” is defined as the “possibility of meeting danger or of suffering harm or loss” (Crowther, 1995) or as “hazard, chance of bad consequences...” (Sykes, 1983), or as ‘...the likelihood that the decision made will be wrong’ (Eastman, 1993). The common element in these definitions is that risk is a probabilistic assessment of an unfavourable (to the decision-maker) outcome. To this chance or likelihood of a wrong decision, we can add the cost of such a decision, and thus speak of a risky outcome. For example, it is not so serious to choose a slightly less-than-optimal land-use system than it is to permit the use of a land-use system that will cause serious water contamination, even if both (incorrect) decisions have the same likelihood of being made. The decision-maker should be interested in this strong definition of risk, i.e. likelihood of a bad decision, and the consequences of such an outcome. Risk can also be based on the subjective expectations of individual decision-makers, or on objective measures computed from historical or experimental data (Barry, 1984). In decision analysis (Raiffa, 1968; Winkler and Murphy, 1985; Winston, 1991; Pratt et al., 1995), risk is

a technical concept, which refers to the decision-maker's preference (or avoidance) of a higher but uncertain expected value, compared to a lower but certain value. A risk-averse decision maker prefers the lower, certain payoff; the extremely risk-averse selects the 'maximin', i.e. the decision that has the maximum chance of the minimum payoff from any choice. By contrast, the risk-taking decision-maker prefers to gamble on a higher payoff. A risk-neutral decision-maker simply attempts to maximise expected value over all decisions.

Morgan and Henrion (1990) argue that uncertainty analysis must be considered as an integral part of any decision-making process. Lately, these concepts are becoming more important for policy analysis and decision making in different branches of knowledge, such as engineering (Ayyub et al., 1992) and data quality (Bouma et al., 1996; Glemser and Klein, 2000).

Uncertainty and risk have been also considered in rural decision-making studies (Backus et al., 1997), crop production risk and yield simulation (Dumanski et al., 1996), price risk analysis and land evaluation (Johnson and Egan, 1993; Johnson and Cramb, 1996). An example where risk is explicitly taken into account in a land evaluation context is the 'Sustainable Land Management' concept (Smyth and Dumanski, 1993; Smyth and Dumanski, 1995). One of the five 'pillars' in this framework is the reduction of production risk, by which is meant the reduction of production variability, conventionally measured by the coefficient of variability of a time-series at one location, or of a group of yields in a homogeneous area (Dumanski et al., 1996). This concept distinguishes between farming (enterprise) risk and production (yield) risk. The first comes from the socio-economic context in which the producer operates, and includes uncertain prices and policies. The second comes from nature, and includes uncertain weather, pest & disease incidence, and soil response to management; these often interact.

However, information on risk for rural land use decisions is still limited and the existing information is not always available to every decision makers or it may not be compatible with their needs and analytic capabilities (Just et al., 2003). This is also true in Santa Catarina State, Brazil, where

there is a gap between the technical recommendations, which are always aimed at increasing income, and the needs of small farmers, who are mainly interested in decreasing risks in order to at least keep their current (even if low) status (Dalmazo and Albertoni, 1990). Risk assessment has not been a research focus even though it is one of the highest demands by decision makers in the region (Bacic et al., 2003). Studies about the influence of the information on rural decision makers are also lacking.

We hypothesized that a risk analysis for different land use options with community participation could reduce the distance between information providers and the decision makers, and thereby produce new information demands. Therefore, we decided to evaluate the potential of a participatory approach for integrating risk analysis into decision making for rural land use and decision makers' view of the supplied information. We particularly focused on two of the main risk-oriented information demands in the region (Bacic et al., 2003): (1) yield predictions for maize on different planting dates and (2) economic information for different land use options. We also evaluated the extent to which quantitative information on risk changes decision makers' attitudes towards it.

## **6.2. Material and methods**

### **6.2.1. Study area**

This study was carried out in Ariranha River sub-watershed (236 km<sup>2</sup>), typical of the west of Santa Catarina state, Brazil (25 300 km<sup>2</sup>). The economy of the region is mainly based on agriculture. Most rural land is privately owned, and more than 90% of the farms are classified as market-oriented family diversified small farms (Testa et al., 1996). The main products are maize, pork, and poultry (Bacic et al., to be submitted). Because of the humid sub-tropical climate, maize may be planted at any time during the last five months of the year (August-December), i.e. from mid-winter to late spring.

Farmers and extensionists in the area had never been exposed to formal risk concepts nor been shown time series and probabilities computation.

This was a first attempt with this client group, typical of transitional economies.

### **6.2.2. Previous interviews and meetings protocol**

We first conducted semi-structured interviews with extensionists and farmers to discover their attitudes towards uncertainty and risk when making decisions. We interviewed twenty farmers living in the Ariranha River sub-watershed in Seara municipality and the five extensionists of the municipalities where this sub-watershed is located (Seara, Arvoredo, Xavantina, Ipumirim and Paial). The information from the interviews was summarized and described in section 3.1.

We then prepared three meetings, with different groups of direct (farmers) and indirect (extensionists) decision makers from which we were expecting different reactions. We invited 30 farmers from family marginal farms and 30 from family consolidated farms, classified according to Instituto Cepa/SC (2001), and 30 state rural extensionists from different municipalities in the west of Santa Catarina. The term “consolidated” is used when the income is higher than three legal minimum wages per person working full time in the farm, and “marginal” when it is less than one minimum wage (FAO/INCRA, 1997; Tedesco, 1999).

Each meeting was planned to last about 4 hours, with the following procedure: 1) explanation of the structure of and reason for the meeting; 2) first questionnaire to collect general information about the participants, and to test their existing knowledge and view about weather uncertainties, maize planting date, risk aversion, economic risks and land use options preferences; 3) presentation of additional information, without discussion; 4) second questionnaire to test the effect of the information; 5) open guided discussion; 6) third questionnaire to test the effect of the discussion; 7) fourth questionnaire to let participants evaluate the information provided and methodology used; and 8) final remarks and conclusions. Answers to structured questions were entered in a database, summarized and described in this paper. Answers from open questions and comments collected during the meetings were considered personal opinions and discussed as such. We

observed that the discussion hardly affected participant's opinions. Therefore we mostly present "after presentation/after discussion" results together.

### **6.2.3. Yield predictions/climatic risk for maize**

During the meetings we presented yield predictions, climatic risks and probabilities of achieving specific yield targets for different maize planting dates. Yield predictions were calculated with the GAPS (General-Purpose Atmosphere Plant Soil Simulator) computer program (Buttler et al., 1997; Rossiter and Riha, 1999), using climatic information collected from 1984 to 2001 (except for the season 1986-1987, which had incomplete data) at the Chapecó meteorological station, located about 40km west of the study area, in the same climatic zone. We assumed constant values for soils and management, which are fairly uniform in this catchment. GAPS modelling options were: Stockle-Riha maize growth model, tipping bucket soil-water flow, and Linacre evapotranspiration. Predictions were made for 16 planting dates (every 10 days) and for 16 seasons, for a total of 256 simulations. These were used for relative comparison without model calibration, as no experimental yields were available; however this model has been shown to give realistic predictions for well-drained soils in sub-tropical climates.

We used @RISK (Palisade Corporation, 1998) to calculate and present the probabilities of achieving specific yields, e.g. the mean for the considered period and interactively with participants according to their own targets. Probabilities were calculated from uniform distribution estimated from the max. and min. of the 16 simulations for each date.

Table 10 displays an example of predicted maize yields and risks presented and discussed at the meetings in tabular and graphical forms. The production risk is assessed by the range, the coefficient of variability (CV), and the probability of meeting a target.

Table 10 - Predicted yields (kg/ha), statistics and probabilities for different maize planting date.

Cropping Time	Statistics					Target – mean yield	
	Min	Max	Mean	Range	CV(%) <sup>(a)</sup>	(Kg/ha)	Probability (%)
1-Aug	4800	8200	5981	3400	16.2	6584	25
10-Aug	4500	8600	6169	4100	17	6584	32
20-Aug	4900	8800	6338	3900	17.3	6584	38
1-Sep	5600	8800	6575	3200	14	6584	44
10-Sep	5600	9000	6738	3400	14.7	6584	50
20-Sep	5600	9300	6888	3700	15.7	6584	56
1-Oct	5300	9500	6931	4200	15.8	6584	69
10-Oct	5500	9800	6931	4300	17.4	6584	57
20-Oct	5600	10000	7019	4400	16.4	6584	68
1-Nov	5600	10100	6981	4500	16.2	6584	63
10-Nov	5400	9900	6644	4500	15.1	6584	44
20-Nov	5500	9400	6619	3900	13.2	6584	37
1-Dec	5600	9100	6619	3500	12.9	6584	38
10-Dec	5000	8900	6431	3900	15.9	6584	38
20-Dec	5300	8600	6350	3300	13.5	6584	31
30-Dec	4600	8000	6125	3400	14.2	6584	25
Mean	5388	8963	6584	3575			
Absolute Range	1100	2100	1038	1300			
Relative Range	20.4%	23.4%	15.8%	36.4%			
Min	4500	8000	5981	3200			
Max	5600	10100	7019	4500			

<sup>(a)</sup> Coefficient of variation

Simulated maize yields (Table 10) were fairly high, with an overall mean of 6584 kg/ha and no prediction below 4500 kg/ha. These high yields correspond to production situations with no limitations other than solar radiation, temperature, and moisture, the “PS2” of Driessen and Konijn, (1992). These yields can in fact be achieved in the region under good management and with recommended manure applications, so we felt confident in using them to illustrate the climate risks associated with each planting date. Average yields at each planting date ranged from 5981 to 7019 kg/ha, a fairly narrow range of 1038 kg/ha or  $\pm 15.8\%$  of the overall mean. This represents the average variation due to planting date. The variation of the minimum due to planting date, especially important to risk-averse farmers, is  $\pm 20.4\%$  of the mean minimum; the comparable figure for



the maximum yield is  $\pm 23.4\%$ . Year-to-year variation (climatic uncertainty) is evaluated by the CV and range at each planting date; these ranged from 12.9% to 17% and 3200 to 4500 kg/ha respectively, which are low compared to many areas of the world but still important. In this humid subtropical climate, any planting date in any year is predicted to give a reasonable yield. Still, a difference on the order of 4000 kg/ha can easily make the difference between a profit and loss.

#### 6.2.4. Economic analysis and risk information

We used @RISK to prepare and present a simple economic analysis (gross margin) and income probabilities for five land use options economically produced in the area (bean, soybean, pig, milk and maize) and two promising alternative land uses (onion and garlic). As input information for @RISK we used production costs, yields and output product price collected from Instituto Cepa/SC (the Santa Catarina state government institute for rural planning and economy) databank for the available 5 years period (1995 to 1999). The gross margin for all the land use options is shown in Table 11.

Table 11 - Gross margin results for the selected land use options.

	Gross margin (R\$) <sup>(a)</sup>						
	Bean	Soybean	Onion	Garlic	Swine	Milk	Maize
1995	53.69	28.57	2031.65	-1144.76	16000.00	3497.29	74.70
1996	77.19	233.33	573.80	-783.78	9510.00	2513.39	139.54
1997	88.87	325.80	1267.60	2222.11	19045.90	2421.59	101.08
1998	14.77	168.83	1781.75	-2327.86	10916.10	2302.38	122.13
1999	-28.79	-53.18	637.81	-3962.84	-6258.40	-711.96	-6.90
Mean	41.15	140.67	1258.52	-1199.42	9842.72	2004.54	86.11
CV <sup>(b)</sup>	85.24	91.86	191.61	-52.61	100.57	125.97	150.14

<sup>(a)</sup> Brazilian Reais

<sup>(b)</sup> Coefficient of variation

We also carried out an interactive exercise with @RISK, calculating gross margin according to participants' actual information and income targets. Figure 16 shows a screen with an example of @RISK partial output for swine.

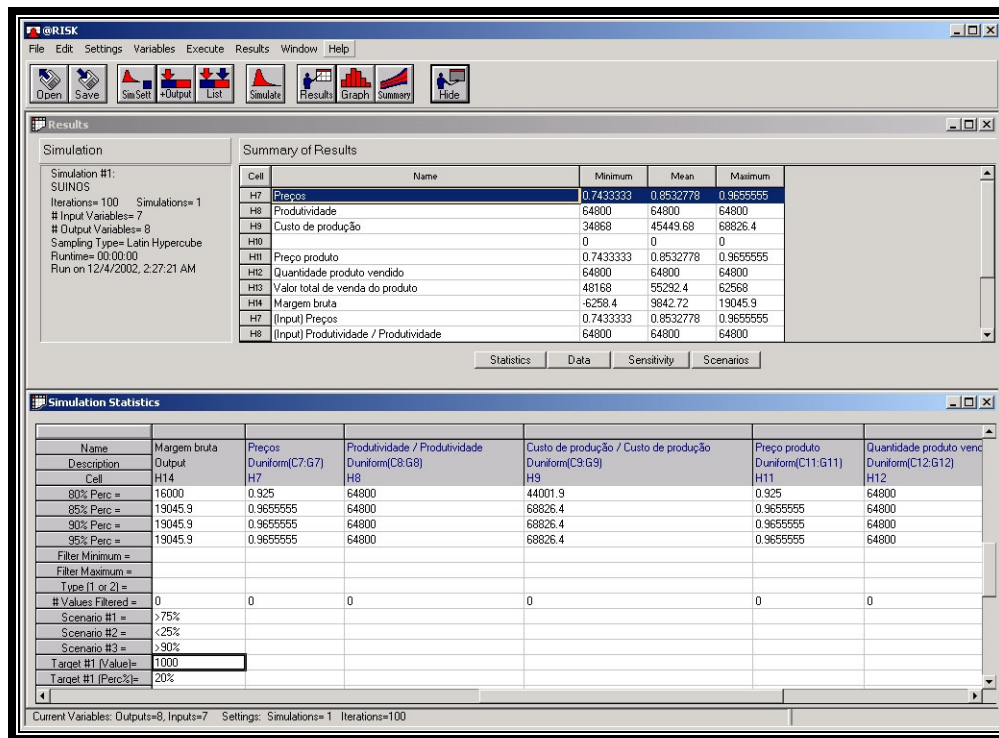


Figure 16 - Example of @RISK output presented in the meeting.

### 6.2.5. Risk aversion

To test participants' risk aversion, we first asked them how did they classify themselves according to risk aversion. Then, we presented three land use options with their respective gross margin for a five-year period (Figure 17): (1) pig production, which had the highest mean income during the analysed period, but with a high variation and possibility for large losses; (2) milk production, with a lower mean income, lower variation, but with possibility for small losses; and (3) onion, which presented the lowest mean income, small variation over time and no losses within the analysed period. Finally we asked which of the three situations they preferred and classified them according to their choice. Extensionists were asked their opinions of the attitudes towards risk of their client farmers.

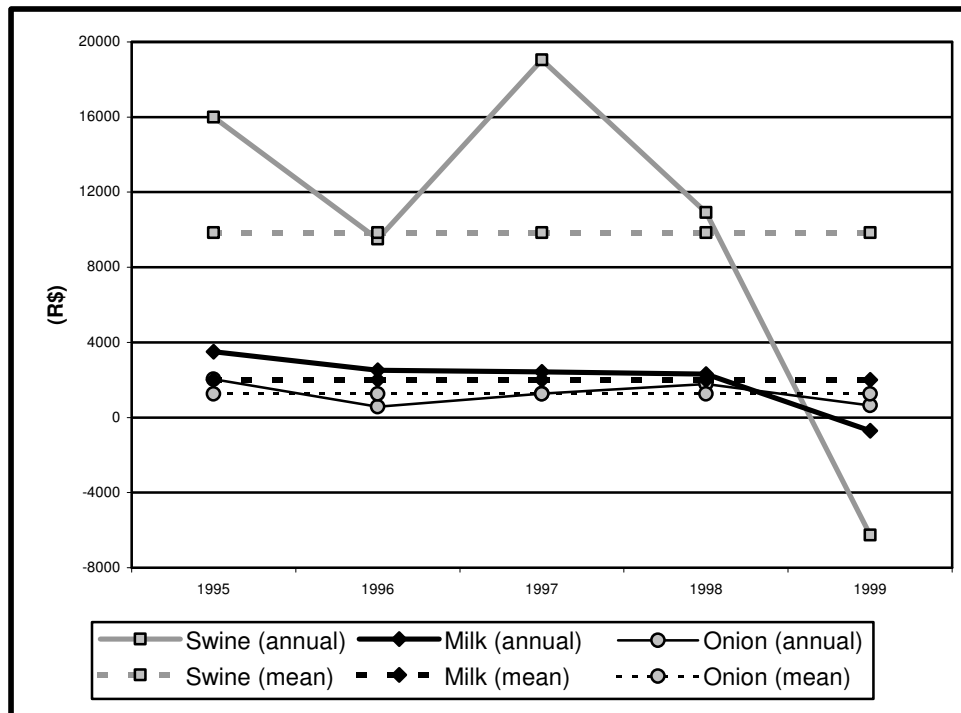


Figure 17 - Annual and mean gross margin to test participants' risk aversion.

### 6.3. Results and Discussion

#### 6.3.1. How do decision makers view and calculate uncertainty and risk to make decisions?

From the interviews, we found that one of the reasons the farmers hardly change the land use and management is their aversion to risk taking. This refers to an unquantified (intuitive) risk, as no previous studies have tested it.

The following procedures were mentioned to avoid or mitigate risks: (1) when considering a different land use option, search for information with which to make a more informed decision (e.g. market forecasts and management practices, possibilities for support, infrastructure and training); (2) change land use slowly, first trying in an experimental small field, and if

the results are satisfactory, change gradually over larger areas; (3) decrease climate risks by planting over the entire feasible period, taking into account climate forecasts and previous experience; (4) avoid large investments and high-interest loans to decrease economic risks; (5) diversify production; (6) increase or improve the current activity, even if it is not giving good income, instead of trying a new one until certain that the new activity is better; and (7) avoid crops with high production risks; for example, beans and wheat have serious problems with diseases in the region.

Extensionists are mostly giving the farmers information about production systems. But they also help the farmer avoid risks by recommending cheap technologies with low investment (e.g. green and animal manure instead of chemical fertilizers). They often recommend reducing production costs even if this decision results in a lower yield. This is another example of risk aversion, in this case of the extensionist.

### **6.3.2. General information about the meetings and participants**

Eight farmers from marginal farms and seven from consolidated farms attended the meetings. We considered the number of participants reasonable, considering the transport difficulties, the aversion of some farmers to meetings, and the favourable weather for farm work. Eighteen rural extensionists (60% of the invited) participated in the meeting. One of them left just before the fourth questionnaire.

All the participants from marginal farms had been living in the region for more than fourteen years. The size of their farms is smaller than 20 ha. The main activity for most of them is maize. As secondary activities they have small-scale production of milk, fruits and trees. Most of the farmers from consolidated farms had lived in the region for more than eighteen years (6 out of 7), and the size of their farms are mostly bigger than 20 ha (for 4 out of 7), varying from 6 to 66 ha. The main activity for the majority is pig farming (5 out of 7). As secondary activities, they also produce maize and milk. Extensionists had 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.

The receptiveness from all the farmers, both marginal and consolidated, and most of the extensionists was friendly. The farmers seemed to be more enthusiastic than the extensionists.

### 6.3.3. Response to yields predictions/climatic risk information for maize

The general perception about possibilities to find solutions to decrease climatic risks after presentation and discussion was “difficult” (Table 12). Few changes occurred after presentation and discussion. Some participants reduced their perception of difficulty, stating that an accurate local past climatic information related to actual data on past yields, in addition to a precise weather and climate forecast, would help them to better decide the time cropping with a lower degree of uncertainty.

Table 12 - General perceptions about (1) possibilities to decrease climatic risk and (2) yield differences for different planting dates.

Possibility for solutions	Marginal			Consolidated			Extensionist		
	Q1 <sup>(a)</sup>	Q2 <sup>(b)</sup>	Q3 <sup>(c)</sup>	Q1 <sup>(a)</sup>	Q2 <sup>(b)</sup>	Q3 <sup>(c)</sup>	Q1 <sup>(a)</sup>	Q2 <sup>(b)</sup>	Q3 <sup>(c)</sup>
	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
Very difficult	25	-	-	57	14	-	6	-	-
Difficult	63	76	100	43	57	100	61	67	67
Do not know	12	12	-	-	29	-	6	-	-
Easy	-	12	-	-	-	-	27	33	33
Very easy	-	-	-	-	-	-	-	-	-

Perception of differences	Marginal			Consolidated			Extensionist		
	Q1 <sup>(a)</sup>	Q2 <sup>(b)</sup>	Q3 <sup>(c)</sup>	Q1 <sup>(a)</sup>	Q2 <sup>(b)</sup>	Q3 <sup>(c)</sup>	Q1 <sup>(a)</sup>	Q2 <sup>(b)</sup>	Q3 <sup>(c)</sup>
	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
High	26	12	-	29	-	-	44	44	33
Medium	37	88	100	71	100	100	50	50	56
Low	37	-	-	-	-	-	6	6	11

<sup>(a)</sup> Questionnaire 1: before presentation

<sup>(b)</sup> Questionnaire 2: after presentation

<sup>(c)</sup> Questionnaire 3: after discussion

In the opinion of the participants, the main source of climatic risk for maize in the region is related to the lack of rain, especially during critical crop periods. They also mentioned the possibility of low temperatures and frost for early planting (August), a common practice to attempt double cropping. However, in our 15 simulated years, this was not encountered. To avoid crop failure, they plant maize in small areas approximately every two weeks from August to January. Participants within the three groups stated that August and October are the most risky months; which was confirmed for October by the highest CVs and widest ranges at these planting dates (Table 10).

The general view about possible differences in yields and risks related to the planting dates was “medium” after presentation and discussion (Table 12). The information presented had higher influence on the marginal farmers views, as more than half of them changed opinions. It seems that most of them did not have a clear perception about possible yields differences and risks, what makes this information important to help them to make a better decision. Few changes in opinions occurred within the other two groups.

Although most of the participants seemed to have a clear view regarding possible differences, their answers about best and worst time to crop related to yields and risks revealed some hesitation. Three of the marginal farmers did not state an opinion for both yields and risks before presentation but were able to answer later in the meeting. The consolidated farmers showed a clear opinion about yields from the beginning, but just three of them were able to answer the question related to risks before information presentation, raising to six after presentation. Interestingly the extensionists changed opinion more than the farmers about best time to crop: nine changed opinion about best yields; ten about worst yields; nine about lower risks and eleven about higher risks. It seems that they were not entirely confident about the best time to plant, therefore accurate local information could be useful to improve their recommendations to the farmers in their own regions.

#### **6.3.4. Response to economic analysis and risk information**

The answers to the question about best land use options according to highest income and lowest risks within the three groups before the information presentation reflected that they were mainly thinking about the present situation and not long-term. For instance, Table 11 shows that, by far, the highest mean income in the survey period was for pig farming, but the participants considered that milk, maize and beans provide a better income, which was true in the last year of the survey. In this case, the information was useful to give them a wider view considering a long-term scenario.

An interesting result was about land use options preferences before/after the presentation (Table 13). After the presentation and discussions the majority of the marginal farmers (five out of seven) changed the original view and answered that if they were going to start an activity now, it could be one of the newly explained options: onion. This change was most likely caused by their frustration with their current activities, and the promising results presented for onion. On the other hand, the consolidated farmers seemed to be satisfied with their current activities and demonstrated less changes in their opinions. During the discussion they stated their interest in more information on their current or already known activities instead of information concerning new options. Most of the extensionists did not change their original preferences about land use options to be recommended to the farmers and just two of them stated they would recommend a new option at least as a test after they are presented more accurate information. It seems that some extensionists are more conservative and resistant to new options than farmers. During the discussions some of the extensionists stated that since (in their opinion) farmers are not willing to try other options, it is not worth their while to present information about them. However, when such information was presented to the marginal farmers, they were enthusiastic about testing alternative land uses. Apparently some extensionists do not want changes and are even filtering information delivered to the farmers. This could be explained by the lack of enough information to give them confidence to recommend a different alternative,

or lack of time to properly study them, before providing the farmers an adequate assistance.

Table 13 - Participants' answers about land use options preferences if they were just starting farming <sup>(a)</sup>.

New activity	Marginal			Consolidated			Extensionist <sup>(e)</sup>		
	Q1 <sup>(b)</sup>	Q2 <sup>(c)</sup>	Q3 <sup>(d)</sup>	Q1 <sup>(b)</sup>	Q2 <sup>(c)</sup>	Q3 <sup>(d)</sup>	Q1 <sup>(b)</sup>	Q2 <sup>(c)</sup>	Q3 <sup>(d)</sup>
	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
Pig	50	38	-	43	71	71	17	33	39
Maize	50	13	50	86	57	86	67	72	67
Milk	38	38	13	43	43	71	83	89	83
Bean	13	13	-	-	-	14	17	6	6
Soybean	-	-	-	-	-	14	33	28	22
Onion	-	63	63	-	-	-	11	22	22
Garlic	-	-	-	-	-	-	11	-	-

<sup>(a)</sup> Participants could choose one or more options

<sup>(b)</sup> Questionnaire 1: before presentation

<sup>(c)</sup> Questionnaire 2: after presentation

<sup>(d)</sup> Questionnaire 3: after discussion

<sup>(e)</sup> Extensionists' recommendations to the farmers in their region

### 6.3.5. Risk aversion

All the marginal farmers classified themselves as risk-averse before the presentation and after discussion (Table 14). But when they were asked about preference on possible circumstances presented graphically (Figure 17), 63% of them preferred the land use option that should be selected by someone who is extremely risk-averse. For the consolidated farmers the results before and after presentation/discussion were similar: only one farmer answered he was risk-taker to the direct question and selected the graph related to risk-averse behaviour. Similarly, five extensionists answered the farmers in their regions were risk averse and chose the extremely risk averse related graph. We believe that the answers based on



the graphs better reflect participants’ opinions, as they demonstrated their preference from three realistic conditions.

Table 14 - Risk aversion test by means of a direct question and asking preferences after presenting graph (Figure 17).

Risk aversion (question)	Marginal			Consolidated			Extensionist <sup>(d)</sup>		
	Q1 <sup>(a)</sup>	Q2 <sup>(b)</sup>	Q3 <sup>(c)</sup>	Q1 <sup>(a)</sup>	Q2 <sup>(b)</sup>	Q3 <sup>(c)</sup>	Q1 <sup>(a)</sup>	Q2 <sup>(b)</sup>	Q3 <sup>(c)</sup>
	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
Extremely risk averse	-	25	-	-	14	14	6	6	6
Risk averse	100	63	100	57	72	72	83	77	83
Risk taker	-	12	-	43	14	14	11	17	11

Risk aversion (graph)	Marginal			Consolidated			Extensionist <sup>(d)</sup>		
	Q1 <sup>(a)</sup>	Q2 <sup>(b)</sup>	Q3 <sup>(c)</sup>	Q1 <sup>(a)</sup>	Q2 <sup>(b)</sup>	Q3 <sup>(c)</sup>	Q1 <sup>(a)</sup>	Q2 <sup>(b)</sup>	Q3 <sup>(c)</sup>
	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
Extremely risk averse	-	-	63	-	-	14	-	-	33
Risk averse	-	-	25	-	-	86	-	-	56
Risk taker	-	-	12	-	-	-	-	-	11

<sup>(a)</sup> Questionnaire 1: before presentation

<sup>(b)</sup> Questionnaire 2: after presentation

<sup>(c)</sup> Questionnaire 3: after discussion

<sup>(d)</sup> Extensionists’ opinions about the farmers in their region

### 6.3.6. Participant’s evaluation and demands raised from the meetings

The methods of the meetings and the quality of the presented information were considered good by most of the participants, with the exception of a significant minority of extensionsits (Table 15). A general complaint was that the meeting became tiring due to the large number of questionnaires.

The most appreciated information varied according to different groups (Table 16). The marginal farmers preferred the information on planting date (climatic risks) for maize, since most of them are planting maize at different times. They also appreciated the income probabilities information, in particular for potential land use options. The most appreciated information by consolidated farmers was about economic analysis and income probabilities, specially the interactive analysis about their own business. The

extensionists considered the economic analysis the most useful. All groups stated that the discussions generated during the meetings were important.

Table 15 - Assessment of the methods and presented information quality by participant type.

	Very Good (%)	Good (%)	Unimportant (%)	Bad (%)
Marginal	12	76	12	-
Consolidated	-	100	-	-
Extensionists	-	67	28	5

Table 16 - Usefulness of different types of information presented (% of respondents).

Type of participant	Usefulness	Type of information				
		Planting date	Probabilities	Econ. analysis	Econ. risk	Discussion
Marg	Very useful	12	-	-	-	-
	Useful	63	75	50	50	62
	Slightly useful	-	-	12	-	-
	Not answered	25	25	38	50	38
Cons	Very useful	28	43	72	28	57
	Useful	44	43	28	44	28
	Slightly useful	28	14	-	28	-
	Not answered	-	-	-	-	15
Ext	Very useful	6	17	28	17	44
	Useful	66	50	55	55	33
	Slightly useful	22	27	11	22	17
	Not answered	6	6	6	6	6

Almost all the participants would like the same information for other potential land use options, as for instance citrus, grape, popcorn and cucumber. They also asked us to suggest and gather information about what we think are promising alternatives to the region.

Marginal farmers specifically asked for additional information about onion (e.g. land suitability, production system, management, required labour and market), as they are willing to start some tests in their farms. Consolidated farmers suggested improving the provided information with local and updated data. Extensionists suggested creating permanent discussion groups for regular debates.

A specific request was to analyse special weather conditions (e.g. for an “El Niño” affected year) relating this to the actual and model predicted yields. It could help decision-making when these atypical events are predicted by meteorological service. A general suggestion raised in the three groups was to improve the information with a larger and consequently more reliable time series, in particular for the economic related information.

#### **6.4. Conclusions**

Results from a study such as this are not definitive, as effects of the information on actual decision-making require some time to become evident. However, they allowed us to draw some conclusions.

As also stated by Just et al. (2003) it is clear that different groups have different levels of knowledge, analytic capacity, economic conditions, perspectives and needs. Therefore, different groups should be approached differently and with group-specific information. After the presentation and discussion, most of the participants gave the impression of having understood the presented information, and therefore changed opinions.

Marginal farmers expressed their disappointment with their current farming system and are willing to test new land use options if they are given a set of realistic alternatives from which they could choose, along with accurate and detailed information. A correct judgment of promising opportunities enables timely adoption of those technologies that are indeed profitable (Backus et al., 1997).

Consolidated farmers in general seemed satisfied with existing business, and demonstrated interest in additional information to improve it rather than start new alternative. In this case, more research effort should be made to support farmers in what they are doing before telling what they should be doing (Backus et al., 1997).

We provisionally distinguish two groups of extensionists: (1) the majority, open to at least test innovative alternatives and eager for information to better assist the farmers; (2) the minority, self-confident, conservative and skeptical about new methods and tools, apparently limiting and even filtering the information they deliver to the farmers. We suggest that further

steps in this research (e.g. meetings to present more accurate and additional required information) should be carried out initially together with those in the first group. The second group could be supplied with additional information about traditional land uses.

The farmers mostly revealed a risk averse or extremely risk-averse behavior (Table 14), which is expected to be the case with inadequate information (Ellis, 1993). They are willing to take some risks if they have adequate information to help them to make better decisions. Therefore, they particularly need to be informed about the risks, enabling them to make a more detailed assessment of impacts of selecting different land use alternatives (Johnson and Cramb, 1996).

Most of the participants liked the information presented and the methods of the meetings. A number of new demands were raised, which by itself is an important achievement of this work. Interestingly, one of the requested information was a physical land evaluation of land qualities constraining the various land uses, which information has been systematically ignored by decision makers, including the same farmers (Bacic et al., 2003).

Therefore, we believe that a participatory approach, by gathering, presenting and periodically discussing demanded information with decision makers is certainly a practice to be further explored to effectively integrate risk assessment into rural decision making.

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## **Chapter 7**

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## **General Conclusions**

### **7.1. Main findings: revisiting objectives and research questions**

The main conclusions related to the general objective and specific research questions described in section 1.2., are as follows:

- a) The general objective of this thesis was to improve use and usefulness of information for rural land use decisions based on an operational demand-driven approach for land evaluation with case studies in Santa Catarina State, Brazil.*

It was not possible to objectively test whether the demand-driven land evaluation approach presented in this thesis was effective on actual decision-making, as that will only be apparent after some time. However, it was possible to draw important conclusions, demonstrating that this is certainly an advance in land evaluation practice and should be further explored.

Regarding the specific conditions for Santa Catarina State, the first important achievement was to open the minds of the land evaluators, showing them that the information they are delivering is not satisfying the expectations and needs of their clients.

By contrast, the interactive approach presented here was clearly valued by the decision makers. It was the first time in the author's 17 years as a land evaluator that decision makers reacted to information presented by land evaluators. They praised, criticised, changed their perceptions, made suggestions and requested more information, even the previously-ignored physical land evaluation. Even the negative reactions were a positive achievement of this work, as it is better to correct the path earlier than to invest time and resources to realise later that the work was not useful.

- b) Are the existing land evaluation reports useful to rural decision makers?*

The soil resource inventory and associated land evaluation had some utility but were not in general used for their intended purpose, namely farm planning (chapter 2). For example, this research showed that different groups of decision makers should be approached differently and with group-

specific information (chapter 5). In addition, a demand-driven approach can help to identify real needs of, and options open to, decision-makers before any inventory and evaluation project is undertaken (chapter 2).

*c) What interpreted information is necessary for rural decision-making?*

The crucial interpreted information necessary in the actual context for rural decision making in Santa Catarina was identified as: (1) estimation of environmental degradation risk; (2) financial analysis; (3) social analysis of decision-makers' attitudes and preferences; and (4) risk assessment for weather, yields, profits and market. All these would be referred to a set of realistic land use alternatives from which the decision-makers could choose (chapter 2).

*d) What are the implications of the planning environment for land evaluation?*

This research showed the importance of: (1) understanding the actor setting, concerning the level of expertise and local technical knowledge of the people and the current status of farming and farming innovations in the area; (2) classifying the decision makers for land evaluation, regarding their socio-economic and cultural outlook, as well as their subjective behaviour with respect to responsiveness to opportunities, propensity to adopt innovations and attitudes towards satisfaction. It is expected that if the land evaluation process starts with a careful analysis of the planning environment for rural land use decisions and follows a demand-driven approach, the results will likely be more realistic and therefore more useful to the decision makers. It is also expected that more demands will be generated, leading to a "virtuous cycle" where planning, land evaluation and client's needs and possibilities are increasingly inter-linked (chapter 3).

*e) What primary information are necessary and feasible to collect or generate?*

Much of the detailed information collected in expensive general-purpose surveys may not be needed; conversely, these surveys may miss crucial information for evaluating relevant options. In addition, it is recommended

to collect only what is needed and to the required precision (Figure 1). For instance, the most sensitive parameters in a model should be more accurate (chapter 4). Chapters 5 and 6 presented the results for demanded interpreted information according to available primary information. They also showed the importance of preliminary evaluation with decision makers even when presenting limited information, in order to set new primary data collection priorities and discuss possibilities to improve it, as for instance making arrangements with farmers and rural technical secondary schools for data collection under appropriated supervision.

*f) What models and research methods can be used and which adaptations are necessary considering local conditions?*

A critical decision land evaluators frequently face is concerned with: (1) selection of appropriate research methods; (2) which models to use to deal with defined problems; and (3) how to fit them to actual local conditions. Common questions when facing typical adverse conditions in developing countries (e.g. data-poor environment and low preparation of the decision makers) are: (1) is it possible to provide adequate information to decision makers in view of local actual conditions?; and (2) it is not worth to make effort to prepare information they supposedly are not prepared to understand? The options are: (1) to wait for ideal conditions; or (2) start with possible actions according to local conditions and advance gradually when conditions get better. This thesis showed one example of the applicability of a data-intensive water quality model (AGNPS) in a relatively data-poor environment, demonstrating that it is possible to consistently apply such model even without expensive procedures for data measurement and collection (chapter 4). In this case, it was shown that the expert knowledge of the area in addition to literature information compensates in part for poor data. The thesis also demonstrated that apparently unprepared decision makers were able to properly understand and react to new tools, even though it was the first attempt to introduce these in the region (chapters 5 and 6).



*g) How do decision makers evaluate methods, tools and the new information? Is it worth to invest time and resources to further improve information?*

Most of the contacted decision makers liked the new tools and information, and exposed their opinions about what could be improved and what they thought would not be further investigated. Their reactions are important to outline next steps towards problems solutions and to identify other demands (chapters 5 and 6).

## **7.2. Considerations: lessons from Santa Catarina**

The environment where decisions are made is very complex and involve different fields of knowledge (e.g. socio-economic, physical, environmental and political) and the local priorities are sometimes beyond the traditional role of the land evaluators, and indeed outside their competence (e.g. commercialisation options, on farm processing, education and health). Ideally, demand-driven land evaluation should be carried out by a multidisciplinary and inter-institutional group, what is not always an easy task. Alternatively, the group can be initially formed with the traditional soil surveyors and land evaluators, involving and consulting expert in other fields when required for specific situations.

The following steps are suggested for an operational demand-driven land evaluation approach, especially in transitional economies such as Santa Catarina (adapted from Bouma, 1999):

- 1) Learning from the past by evaluating the use and applicability of existing information on land evaluation in the region to be studied (chapter 2);
- 2) Problem definition with interaction of decision makers, checking their needs and priorities for interpreted information (chapter 2);
- 3) Assessment of the planning environment and its implications for land evaluation (chapter 3);

- 4) Selection of research methods and models to deal with required interpreted information, given the existing data and possibility to collect more (chapters 4, 5 and 6);
- 5) Adaptation of methods and models considering local conditions, especially difficulty or expense of collecting detailed data (chapters 4, 5 and 6);
- 6) Establishment of primary data requirements (chapters 4, 5 and 6);
- 7) Collection and generation of primary information according to local possibilities (chapters 4, 5 and 6);
- 8) Application of adapted methods and models (chapters 4, 5 and 6); and
- 9) Presentation, discussion and assessment of quality of methods, models and new information in close interaction with decision makers and according to their expectations and needs (chapters 5 and 6).

It is expected that these steps will be repeated (i.e. feedback from results to problem definition), as the evaluator and decision makers converge on realistic solutions to defined problems and new demands emerge.

### **7.3. Next steps in Santa Catarina**

Although the professionals in Santa Catarina are becoming aware of the importance for participatory approaches related to extension service and rural research, there is still little effective participation by the supposed beneficiaries. Consultation is common, but participation and consultation are not the same thing. Top-down consultation by which people are asked to provide facts or opinions, usually about proposals drawn up by others, tends to disillusion the supposed beneficiaries and rarely reveals the full range of information available. Participation means people being actively involved in identifying needs, making plans and implementing them. However, the opportunity to advance in the demand-driven and participatory approaches in Santa Catarina is clear. Diverse actions by the State Agriculture Secretary, and in particular by its institute of rural extension and research (EPAGRI), are converging to this, as for instance: (1) the extension service

is currently working on communities' organization for participatory planning; (2) discussions had started about implementing participatory research; and (3) the support from EPAGRI to the present research on demand-driven land evaluation.

Regarding specifically demand-driven and participatory land evaluation, it is expected that the ideas raised in this thesis, will be continued and improved. Maybe it will not be possible to immediately organize a multidisciplinary and inter-institutional group, but we can move towards this direction by starting with the soil surveyors and land evaluators, involving and consulting expert in other fields (e.g. animals, plants, socio-economy, hydrology and climate), most of them working for EPAGRI and other institutes under the same Secretary. Besides, the relationship with and access to experts in the Universities, other state and national organizations and NGOs are excellent in Santa Catarina.

The next expected step in the area studied in this thesis, would be to respond the unanswered questions, as for instance: (1) to gather more detailed and accurate information about promising land use alternatives; (2) to improve the precision of the risk and economic analysis using a longer accurate time-series for the actual and promising presented land use alternatives; (3) to approach agro-industries and try to better involve them in the environmental discussions; (4) to present the improved water pollution modelling results (AGNPS) and other visual tools in a regional seminar trying to involve all the actors related to the pig manure pollution process in the search for solutions; (5) to evaluate minimum necessary dataset and to validate the water pollution model for accurate absolute predictions as suggested in chapter 4; and (6) to apply the water pollution model in other microcatchments as already requested by extensionists.

Another intended action is to link the agro-ecological zoning (Thome et al., 1999) with the land evaluation method proposed by (Bacic, 1998) and other demanded information as described in this thesis (e.g. production system, socio-economic, risk analysis and environment) to search for realistic alternative land uses.

Finally, it would be interesting to search for a close interaction with other groups around the world, which are working or planning to work in the same directions.

#### **7.4. Suggestions for further research**

Demand driven land evaluation has been suggested by several authors as an attempt to make the information more relevant and useful to rural decision makers for land use planning. This research showed that this approach is possible in practice, but its effectiveness needs time to be definitely confirmed. Thus, further actions should be carried out as for instance to proceed with the negotiation process with decision makers, repeating the steps suggested in section 7.2 until realistic solutions to defined problems had been presented. Besides, the effect of the approach on actual decisions should be tested.

It would be interesting to test the approach in other areas, to confirm the potential identified for Santa Catarina. It is expected that the structure presented in this thesis provides a reference point for other studies, but the problems and demands are specific for the studied area and should be identified and adapted for other conditions. These may lead to different choice of methods and models.

Although some indications were identified in the present research about needs for primary information to support appropriate decisions, further research is certainly needed.

In many areas of the world where model results could be useful, resources for detailed model calibration and validation are lacking. In chapter 4, the applicability of a specific data intensive model in a data-poor environment was evaluated. It would be interesting to have other models tested in such environment.

Finally, results presented in this thesis showed that a number of new demands were raised by decision makers. One of the requested information was about the previously-ignored physical land evaluation. The link between the demand-driven and classical land evaluation approaches should be further investigated.

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## SUMMARY

The main objective of this thesis is to improve use and usefulness of information for rural land use decisions based on an operational demand-driven approach for land evaluation with case studies in Santa Catarina State, Brazil. To achieve this objective, the following research questions were formulated: (1) Are the existing land evaluation reports useful to rural decision makers?; (2) What interpreted information is necessary for rural decision-making?; (3) What are the implications of the planning environment for land evaluation?; (4) What primary information are necessary and feasible to collect or generate?; (5) What models and research methods can be used and which adaptations are necessary considering local conditions?; and (6) How do decision makers evaluate methods, tools and the new information? Is it worth to invest time and resources to further improve information?

This thesis is a collection of papers, all dealing with case studies in Santa Catarina, Brazil and related to demand-driven land evaluation, published or submitted to international peer-reviewed journals. The case studies presented in chapters 4, 5 and 6 were selected according to the main demands of users as identified in the previous chapters.

**Chapter 2** describes and quantifies the use and usefulness of soil surveys and land evaluation reports to land use planners, observe the relation between latent demand and actual supply and suggest improvements on current methods. It is the basis for the thesis, indicating the main directions to be followed. The soil resource inventory and associated land evaluation had some utility, but were not in general used for their intended purpose, namely farm planning. This was mainly because they did not contain crucial information necessary to such planning in the actual context in which the farmer had to take decisions. The primary deficiencies were identified as: (1) no estimate of environmental degradation risk, (2) no financial analysis, (3) no social analysis of decision-makers' attitudes and preferences, (4) no risk assessment for weather, yields, profits and market, and (5)

insufficiently-specific land use alternatives. These deficiencies could have been avoided with a demand-driven approach, evaluating and reporting according to the true needs and opportunities of the decision-makers.

**Chapter 3** explains the farmers' decision environment in Santa Catarina state, Brazil, which is typical of many market-oriented but low-income economies, with respect to the actors, political, legal and social frameworks, interactions and dynamics, how these affect decision makers and implications for land evaluation. It shows that different groups of farmers have different needs for information and should be approached in different manner. Some farmers would welcome any information on improving their current farming systems, whilst others are also interested in innovative crops or agricultural processes. Yet another group might need motivation more than information. It suggests that if the land evaluation process is begun with a careful analysis of the decision environment of rural land users (farmers) and follows a demand-driven approach, the results will likely be more realistic and therefore more useful to both policy/planning institutions and direct land users. This should lead to more demand and a "virtuous cycle" where planning, land evaluation and clients' needs and possibilities are increasingly inter-linked.

**Chapter 4** describes the applicability of a data-intensive watershed erosion and water quality model (AGNPS) in a relatively data-poor environment, reporting on the steps necessary to apply the model in a GIS setting, including data preparation, cell size selection, sensitivity analysis, model calibration and application to different management scenarios at small watershed scale in an area of intensive swine production. We calibrated the model by making a best guess for model parameters and performed a pragmatic sensitivity analysis using optimistic and pessimistic settings of these. It was not possible to calibrate over the entire rainfall range, which was thus divided into three (<25 mm, 25-60mm, >60 mm). Predicted sediment concentrations were consistently six to ten times higher than actual, probably because of sediment trapping by vegetated channel banks. Predicted N and P concentrations in stream water, adjusted by this empirical sediment concentration factor, ranged from just below to well

above regulatory norms. The study shows that expert knowledge of the area, in addition to experience reported in literature, was able to compensate for poor calibration data. It was possible to apply the model for relative ranking of scenarios (actual, recommended, and excessive manure applications; point source pollution from pig farming) in comparative studies. Finally, we suggest that this methodology could also be useful as a starting point for calibration in a data rich environment.

**Chapter 5** shows that visualization of scenarios with community participation was useful to increase participants' understanding of the water pollution problem, improve their perceptions, stimulate the search for solutions and generate new demands. This was the case even taking into account that rural decision makers are not well educated and not used to visualizing scenarios. In this, Santa Catarina is similar to many areas of the world. This study also addresses decision makers' opinions about the provided information.

**Chapter 6** evaluates the potential of a participatory approach for integrating risk analysis into decision making for rural land use and decision makers' view of the supplied information. It particularly focuses on two of the main risk-oriented information demands in the region: (1) yield predictions for maize on different planting dates and (2) economic information for different land use options. It also investigates decision makers attitudes towards risk, and the degree to which these could be changed by objective information, in Santa Catarina State, Brazil, typical of transitional economies, where neither direct (farmers) nor indirect (extensionists) decision makers had been exposed to concepts of risk. Different groups had markedly different levels of knowledge, analytic capacity, economic conditions, perspectives and needs, and therefore should be approached differently and with group-specific information. Farmers were mostly moderately or extremely risk averse. However, at the end they declared themselves willing to take risks if they have adequate information. Despite their lack of previous exposure to these concepts, participants were able to understand the presented information. It finally suggests that a participatory approach, by gathering, presenting and periodically discussing

demanded information with decision makers is certainly a practice to be further explored to effectively integrate risk assessment into rural decision making.

**Chapter 7:** Demand driven land evaluation has been suggested by several authors as an attempt to make the information more relevant and useful to rural decision makers for land use planning. This research showed that this approach is possible in practice and should be further explored, but its effectiveness needs time to be definitely confirmed.



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## SAMENVATTING

De hoofddoelstelling van deze thesis is om het gebruik en de bruikbaarheid van informatie voor de besluitvorming aangaande ruraal landgebruik te verbeteren door middel van een benadering die gebaseerd is op een operationele vraaggestuurde methode van landevaluatie, met case studies in de staat Santa Catarina, Brazilië.

Om dit doel te bereiken werden de volgende onderzoeksvragen geformuleerd: 1) zijn de bestaande landevaluatie rapporten nuttig voor de besluitvormers van het rurale gebied?; 2) welke geïnterpreteerde informatie is nodig ten aanzien van deze besluitvorming?; 3) wat zijn de implicaties van het planningskader voor landevaluatie?; 4) wat is de voornaamste informatie die nodig is en tevens verzameld en/of gegenereerd kan worden?; 5) welke modellen en onderzoeksmethoden kunnen gebruikt worden en welke aanpassingen zijn nodig met betrekking tot lokale condities: en 6) hoe evalueren de besluitvormers methoden, technieken en nieuwe informatie? Is het de moeite waard om tijd en middelen te investeren om informatie te verbeteren?

Deze thesis is gebaseerd op een verzameling onderzoeksartikelen aangaande vraaggestuurde landevaluatie in Santa Catarina, Brazilië, die gepubliceerd of ingediend werden in internationaal georiënteerde “peer-reviewed” tijdschriften. De case studies die gepresenteerd worden in hoofdstuk 4, 5 en 6 werden geselecteerd op basis van de voornaamste vragen van de landgebruikers, die vastgesteld werden in de voorafgaande hoofdstukken.

**Hoofdstuk 2** beschrijft en kwantificeert het gebruik en de bruikbaarheid van bodemkarteringen en landevaluatie rapporten voor besluitvormers van het landgebruik, observeert de relatie tussen de latente vraag en het actuele aanbod en stelt verbeteringen voor van bestaande methoden. Het vormt de basis voor de thesis en geeft aan welke richtingen gevolgd zullen worden voor het onderzoek.

De bodeminventarisatie en daarmee verbonden landevaluatie hadden enig nut, maar werden in het algemeen niet gebruikt waar ze voor bedoeld waren, namelijk planning van het boerenbedrijf. Dit werd voornamelijk veroorzaakt door het feit dat ze geen doorslaggevende informatie bevatten nodig voor dit soort planning, i.e. aan de boer in zijn actuele situatie voorbijgingen. De voornaamste geïdentificeerde tekortkomingen waren: 1) geen inschatting van het milieu en mogelijke degradatie daarvan; 2) geen financiële analyse; 3) geen sociale analyse met betrekking tot de standpunten en voorkeuren van de besluitvormers; 4) geen risico beoordeling aangaande het weer, oogst, winst en markt situatie en 5) onvoldoende gespecificeerde keuzes voor landgebruik. Deze tekortkomingen hadden voorkomen kunnen worden door een vraaggestuurde benadering, gebaseerd op een evaluatie en rapportage van de werkelijke behoeften en kansen van de besluitvormers.

**Hoofdstuk 3** behandelt het kader van besluitvorming in Santa Catarina, dat typisch is voor veel markt georiënteerde maar laag inkomen economieën. Het betreft de deelnemers, politieke, wettelijke en sociale regelgeving, en interacties tussen deze en hoe de besluitvormers hierop reageren m.b.t. de landevaluatie. De studie toont aan dat verschillende groepen boeren niet dezelfde behoefte hebben aan informatie en benaderd moeten worden op een eigen wijze. Sommige boeren zouden graag informatie willen hebben om hun huidige landbouwbedrijf te verbeteren, terwijl anderen meer geïnteresseerd waren in alternatieve gewassen of landbouwkundige processen. Terwijl weer een andere groep meer behoefte heeft aan motivatie dan aan informatie. Het toont aan dat als het landevaluatieproces wordt begonnen met een zorgvuldige analyse van het kader van besluitvorming van de boeren en een vraaggestuurde benadering wordt gevolgd, de resultaten meer realistisch en daarom nuttiger zullen zijn voor zowel de instituties die zich bezig houden met politiek en planning, als wel voor de directe landgebruikers. Dit zou kunnen leiden tot meer vraag en een heilzame cirkel van iteratie waarin planning, landevaluatie en de noden en mogelijkheden van de cliënten in toenemende mate onderling verbonden worden.

**Hoofdstuk 4** beschrijft de toepasbaarheid van een op veel data gebaseerd erosie- en waterkwaliteitsmodel (AGNPS) in een stroomgebied waar weinig gegevens voorhanden zijn. Het brengt verslag uit van de te ondernemen stappen die nodig zijn om het model in een GIS toe te passen, inclusief voorbereiding van de data, grootte van de spatiale cel, precisie analyse, kalibratie van het model en toepasbaarheid op verschillende bedrijfs-scenario's in een klein stroomgebied met intensieve varkenshouderij. Het model werd gekalibreerd door middel van een "best guess" voor de model parameters en een pragmatische gevoeligheidsanalyse, gebruik makend van een optimistische en een pessimistische instelling van de parameters. Het was niet mogelijk om een kalibratie uit te voeren voor de totale variatie in regenval, die daarom werd verdeeld in drie hoeveelheden (<25mm, 25-60mm en >60mm).

De voorspelde sediment concentraties waren consequent zes tot tien maal groter dan in werkelijkheid, waarschijnlijk omdat veel sediment werd opgevangen in de oevervegetatie. De voorspelde concentraties van N en P in het rivierwater, bijgesteld door deze empirische sediment concentratie factor, varieerden van net beneden tot ver boven de voorgeschreven waarden. Dit onderzoek toont aan dat we met specialistische kennis van het gebied, samen met soortgelijke ervaringen uit de literatuur, in staat zijn om voor slecht gekalibreerde data te compenseren. Het was mogelijk om het model toe te passen voor een relatieve rangorde van scenario's (huidige, aanbevolen en buitensporige bemesting in de varkenshouderij) in vergelijkend onderzoek.

Tenslotte wordt aanbevolen dat deze werkwijze nuttig kan zijn als een uitgangspunt voor kalibratie in een gegevens arme omgeving.

**Hoofdstuk 5** toont aan dat het zichtbaar maken van de scenario's met de deelnemers nuttig was om hun begrip te vergroten op het gebied van problemen van watervervuiling, hun algemeen voorstellingsvermogen te verbeteren, als stimulatie voor het zoeken naar oplossingen, en het genereren van nieuwe vragen. Dit alles met inachtneming van het niet gewend zijn aan deze gewoonte en betrekkelijke lage graad van voorbereiding, zoals zoveel voorkomt in vergelijkbare gebieden als die in

Santa Catarina. Ook worden de meningen van de rurale besluitvormers gegeven over de aangedragen informatie.

**Hoofdstuk 6** evalueert het potentieel van de participatieve benadering voor een geïntegreerde risico-analyse bij besluitvorming over ruraal landgebruik en de opinie van de besluitvormer met betrekking tot de beschikbare informatie. Het gaat in het bijzonder om twee vragen aangaande risico georiënteerde behoeften in het gebied, viz. 1) oogst voorspelling van maïze voor verschillende zaaidata en 2) economische informatie voor verschillende keuzes in landgebruik. Ook wordt de houding besproken van de besluitvormers aangaande risico, en de mate waarin deze zou kunnen veranderen door meer objectieve informatie. Dit alles toegepast in Santa Catarina dat een typisch voorbeeld is van een economie in de overgang, waar noch de boeren, noch de voorlichters te maken hebben gehad met het begrip risico. Het bleek dat de verschillende groepen uiteenlopende niveau's hadden op het gebied van kennis, analytisch vermogen, de economie, toekomstmogelijkheden en behoeften, en daarom verschillend benaderd zouden moeten worden en met groeps-specifieke informatie. De boeren hadden in het algemeen een matige tot overdreven afkeer van risico, alhoewel zij tenslotte bereid waren om risico's te lopen indien zij voldoende informatie hadden gehad. Ondanks hun gebrek aan voorafgaande blootstelling aan deze concepten, waren de deelnemers in staat om de voorgedragen informatie te begrijpen. Tenslotte wordt gesuggereerd dat een participatieve benadering zeker de moeite van nader onderzoek waard is om een effectieve risico analyse mee te nemen in de rurale besluitvorming.

**Hoofdstuk 7:** Vraaggestuurde landevaluatie werd door verschillende auteurs voorgesteld als een poging om informatie meer relevant en nuttig te maken voor besluitvorming van en in het landelijk gebied. Dit onderzoek toont aan dat deze benadering in de praktijk mogelijk is en verder onderzocht moet worden, maar dat zijn doeltreffendheid tijd nodig heeft om zich te bewijzen.

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## RESUMO

O principal objetivo desta tese é o de propiciar melhor uso e utilidade das informações existentes, tais como: inventário das terras, dados climáticos e mapas de solos, para tomada de decisão em relação ao uso e manejo das terras no meio rural, por meio de uma metodologia de aptidão de uso das terras por demanda. Para atingir este objetivo, as seguintes perguntas de pesquisa foram formuladas: (1) Os inventários das terras elaborados atualmente são realmente úteis para os tomadores de decisão no meio rural?; (2) Que informações secundárias são necessárias para tomada de decisão; (3) Que influência poderia ter o ambiente no qual as decisões quanto ao uso e manejo das terras são tomadas, nos métodos de avaliação das terras?; (4) Que informações primárias são necessárias e viáveis de serem coletadas ou geradas? (5); Que modelos e métodos de pesquisa podem ser usados e que adaptações são necessárias para sua aplicação, considerando-se as condições locais?; e (6) Qual é a opinião dos tomadores de decisões sobre os métodos, ferramentas e novas informações oferecidas? Vale a pena investir tempo e recursos para melhorar estas informações?

Esta tese é composta por artigos científicos publicados ou submetidos a revistas científicas internacionais, todos referentes a estudos de casos em Santa Catarina, Brasil e relacionados com a proposta de uma metodologia de avaliação das terras por demanda. Os estudos apresentados nos capítulos 4, 5 e 6 foram selecionados de acordo com as principais demandas dos usuários, previamente identificadas nos capítulos 2 e 3.

**Capítulo 2:** descreve-se e quantifica-se o uso e a utilidade dos inventários das terras para os planejadores (extensionistas rurais), observa-se a relação entre a informação potencialmente demandada e aquela efetivamente oferecida e sugerem-se melhorias nos métodos utilizados atualmente. Este capítulo é a base para o trabalho descrito nesta tese, indicando as principais direções a serem seguidas. Os inventários das terras tiveram alguma utilidade, mas em geral não foram usados para seu propósito principal, ou seja, planejamento do uso e manejo das terras, principalmente pelo fato de não conterem as informações mais importantes para este tipo de

planejamento, considerando o contexto real no qual os agricultores têm que tomar suas decisões. As principais deficiências identificadas foram: (1) ausência de estimativas dos riscos de degradação ambiental; (2) inexistência de análises econômicas; (3) falta de uma análise social, principalmente relacionada às preferências e atitudes dos tomadores de decisões; (4) não havia avaliação dos riscos climáticos, produtivos, econômicos e de mercado; e (5) as alternativas de uso apresentadas eram muito abrangentes (ex: culturas anuais, fruticultura e pastagens). Estas deficiências poderiam ter sido evitadas caso o enfoque fosse direcionado pelas principais demandas, com os relatórios apresentando informações e recomendações levando-se em conta as reais necessidades e condições dos tomadores de decisões.

**Capítulo 3:** descreve-se o ambiente onde os agricultores tomam suas decisões considerando as condições do Estado de Santa Catarina, Brasil, similares a outras regiões no mundo, no que diz respeito aos atores, aspectos políticos, legais e sociais, interações e dinâmicas. Este capítulo explica como este ambiente afeta os tomadores de decisões e quais são suas implicações para os métodos de avaliação das terras. Demonstra ainda que diferentes grupos de agricultores necessitam de informações diferentes e conseqüentemente, deveriam ser abordados de maneira distinta. Alguns agricultores gostariam de qualquer informação para melhorar seus sistemas produtivos atuais, enquanto outros estariam também interessados em culturas ou processos agrícolas alternativos. Um outro grupo necessitaria mais de motivação do que informação. Os resultados encontrados sugerem que se o processo iniciasse com a análise cuidadosa do ambiente onde vivem os usuários das terras agrícolas, e seguisse uma metodologia direcionada pelas demandas, as informações seriam provavelmente mais realistas e portanto, mais úteis tanto para as instituições de planejamento, quanto para os tomadores de decisão finais (agricultores). Este procedimento geraria mais demandas, chegando-se a um “ciclo virtuoso” onde planejamento, inventários das terras e as necessidades e condições dos clientes estariam cada vez mais interligadas.

**Capítulo 4:** avalia-se a possibilidade da aplicação de um modelo altamente exigente em dados (AGNPS) integrado a um sistema geográfico

de informações, para estimar a qualidade da água em bacias hidrográficas, em ambiente relativamente pobre em dados. Descrevem-se os passos necessários para que o modelo possa ser aplicado neste ambiente, incluindo: preparação de dados, seleção do tamanho de células, análise de sensibilidade, calibração e aplicação em diferentes cenários em uma área de produção intensiva de suínos. O modelo foi calibrado usando-se uma “tentativa realista” na determinação dos valores dos parâmetros necessários, e realizando-se uma análise de sensibilidade pragmática utilizando-se possíveis limites para os referidos parâmetros considerando-se cenários otimistas e pessimistas. Não foi possível calibrar o modelo para toda a série de chuvas considerada, a qual foi então dividida em três faixas (<25mm, 25-60mm e >60mm). As previsões de concentração de sedimentos em água foram consistentemente seis a dez vezes maiores que as medidas, provavelmente devido à captura de sedimentos pela vegetação próxima aos drenos e rios. As estimativas de concentrações de N e P, ajustadas conforme as proporções empíricas encontradas para os sedimentos, variaram desde pouco abaixo até bastante acima dos padrões de qualidade de água estabelecidos em lei. O estudo demonstrou que o conhecimento técnico da área, somado às experiências relatadas na literatura disponível, foi capaz de compensar a deficiência dos dados para calibração. Foi possível aplicar o modelo para uma classificação relativa dos diferentes cenários (ex: aplicações de esterco conforme recomendações técnicas, exageradas e próximas das quantidades aplicadas na prática; poluição pontual a partir de esterqueiras fluindo diretamente para os drenos) em estudos comparativos. Finalmente, sugere-se que a metodologia aplicada pode ser útil também como ponto de partida para calibração do modelo em ambientes ricos em dados.

**Capítulo 5:** demonstra-se que a visualização de cenários com a participação da comunidade foi útil para melhorar o entendimento e a percepção dos problemas de poluição da água, estimular a busca de soluções e gerar novas demandas, mesmo considerando-se a falta de preparo e hábito dos participantes com esta prática. Neste sentido Santa Catarina é bastante similar a muitas áreas no mundo. O estudo também avalia as opiniões dos tomadores de decisões sobre as informações e ferramentas apresentadas.

**Capítulo 6:** avalia-se o potencial de uma proposta participativa para integrar análise de riscos ao processo de tomada de decisões relativas ao uso e manejo das terras, bem como a opinião dos tomadores de decisões sobre as informações apresentadas. Este capítulo refere-se particularmente às duas principais informações relacionadas a risco solicitadas na região: (1) previsão de produtividade do milho para diferentes épocas de plantio; e (2) informações econômicas para diferentes alternativas de uso das terras. Também investiga as atitudes dos tomadores de decisões em relação ao risco, e até que ponto estas atitudes podem ser mudadas com o uso de informações objetivas. O estudo foi realizado no Estado de Santa Catarina, Brasil, que pode ser considerado representativo de economias em transição, onde nem os tomadores de decisões diretos (agricultores) nem os indiretos (extensionistas) estão habituados aos conceitos formais de riscos. Os três diferentes grupos de participantes (agricultores periféricos, agricultores consolidados e extensionistas) demonstraram marcantes diferenças em nível de conhecimento, capacidade analítica, condições econômicas, perspectivas e necessidades, e portanto devem ser contatados de maneiras diferentes e com informações específicas. Os agricultores foram considerados principalmente moderada a extremamente avessos a riscos. Entretanto, ao final das reuniões eles consideraram que poderiam correr riscos caso tivessem informações adequadas. Apesar da falta de costume com o uso destes conceitos, os participantes foram capazes de entender as informações apresentadas. Finalmente, os resultados deste capítulo sugerem que esta proposta participativa, reunindo, apresentando e periodicamente discutindo informações demandadas com os tomadores de decisões, é com certeza uma prática a ser mais explorada, para efetivamente integrar a avaliação de riscos ao processo de tomada de decisões no meio rural.

**Capítulo 7:** avaliação de terras por demanda tem sido sugerida por diversos autores como uma tentativa de tornar as informações mais relevantes e úteis para os tomadores de decisões no meio rural, no que se refere ao planejamento do uso e manejo das terras. Esta pesquisa demonstrou que a proposta é possível na prática e deveria ser amplamente explorada, porém, sua efetividade necessita mais tempo para ser definitivamente confirmada.



**Appendix A**

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**ITC PhD dissertations**



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## *Appendix A – ITC PhD dissertations*

1. **Akinyede**, 1990, Highway cost modelling and route selection using a geotechnical information system
2. **Pan He Ping**, 1990, 90-9003757-8, Spatial structure theory in machine vision and applications to structural and textural analysis of remotely sensed images
3. **Bocco Verdinelli, G.**, 1990, Gully erosion analysis using remote sensing and geographic information systems: a case study in Central Mexico
4. **Sharif, M.**, 1991, Composite sampling optimization for DTM in the context of GIS
5. **Drummond, J.**, 1991, Determining and processing quality parameters in geographic information systems
6. **Groten, S.**, 1991, Satellite monitoring of agro-ecosystems in the Sahel
7. **Sharifi, A.**, 1991, 90-6164-074-1, Development of an appropriate resource information system to support agricultural management at farm enterprise level
8. **Zee, D. van der**, 1991, 90-6164-075-X, Recreation studied from above: Air photo interpretation as input into land evaluation for recreation
9. **Mannaerts, C.**, 1991, 90-6164-085-7, Assessment of the transferability of laboratory rainfall-runoff and rainfall - soil loss relationships to field and catchment scales: a study in the Cape Verde Islands
10. **Ze Shen Wang**, 1991: 90-393-0333-9, An expert system for cartographic symbol design
11. **Zhou Yunxian**, 1991, 90-6164-081-4, Application of Radon transforms to the processing of airborne geophysical data
12. **Zuviria, M. de**, 1992, 90-6164-077-6, Mapping agro-topoclimates by integrating topographic, meteorological and land ecological data in a geographic information system: a case study of the Lom Sak area, North Central Thailand
13. **Westen, C. van**, 1993, 90-6164-078-4, Application of Geographic Information Systems to landslide hazard zonation
14. **Shi Wenzhong**, 1994, 90-6164-099-7, Modelling positional and thematic uncertainties in integration of remote sensing and geographic information systems
15. **Javelosa, R.**, 1994, 90-6164-086-5, Active Quaternary environments in the Philippine mobile belt

16. **Lo King-Chang**, 1994, 90-9006526-1, High Quality Automatic DEM, Digital Elevation Model Generation from Multiple Imagery
17. **Wokabi, S.**, 1994, 90-6164-102-0, Quantified land evaluation for maize yield gap analysis at three sites on the eastern slope of Mt. Kenya
18. **Rodriguez, O.**, 1995, Land Use conflicts and planning strategies in urban fringes: a case study of Western Caracas, Venezuela
19. **Meer, F. van der**, 1995, 90-5485-385-9, Imaging spectrometry & the Ronda peridotites
20. **Kufoniya, O.**, 1995, 90-6164-105-5, Spatial coincidence: automated database updating and data consistency in vector GIS
21. **Zambezi, P.**, 1995, Geochemistry of the Nkombwa Hill carbonatite complex of Isoka District, north-east Zambia, with special emphasis on economic minerals
22. **Woldai, T.**, 1995, The application of remote sensing to the study of the geology and structure of the Carboniferous in the Calañas area, pyrite belt, SW Spain
23. **Verweij, P.**, 1995, 90-6164-109-8, Spatial and temporal modelling of vegetation patterns: burning and grazing in the Paramo of Los Nevados National Park, Colombia
24. **Pohl, C.**, 1996, 90-6164-121-7, Geometric Aspects of Multisensor Image Fusion for Topographic Map Updating in the Humid Tropics
25. **Jiang Bin**, 1996, 90-6266-128-9, Fuzzy overlay analysis and visualization in GIS
26. **Metternicht, G.**, 1996, 90-6164-118-7, Detecting and monitoring land degradation features and processes in the Cochabamba Valleys, Bolivia. A synergistic approach
27. **Hoanh Chu Thai**, 1996, 90-6164-120-9, Development of a Computerized Aid to Integrated Land Use Planning (CAILUP) at regional level in irrigated areas: a case study for the Quan Lo Phung Hiep region in the Mekong Delta, Vietnam
28. **Roshannejad, A.**, 1996, 90-9009284-6, The management of spatio-temporal data in a national geographic information system
29. **Terlien, M.**, 1996, 90-6164-115-2, Modelling Spatial and Temporal Variations in Rainfall-Triggered Landslides: the integration of hydrologic models, slope stability models and GIS for the hazard zonation of rainfall-triggered landslides with examples from Manizales, Colombia
30. **Mahavir, J.**, 1996, 90-6164-117-9, Modelling settlement patterns for metropolitan regions: inputs from remote sensing

31. **Al-Amir, S.**, 1996, 90-6164-116-0, Modern spatial planning practice as supported by the multi-applicable tools of remote sensing and GIS: the Syrian case
32. **Pilouk, M.**, 1996, 90-6164-122-5, Integrated modelling for 3D GIS
33. **Duan Zengshan**, 1996, 90-6164-123-3, Optimization modelling of a river-aquifer system with technical interventions: a case study for the Huangshui river and the coastal aquifer, Shandong, China
34. **Man, W.H. de**, 1996, 90-9009-775-9, Surveys: informatie als norm: een verkenning van de institutionalisering van dorp - surveys in Thailand en op de Filippijnen
35. **Vekerdy, Z.**, 1996, 90-6164-119-5, GIS-based hydrological modelling of alluvial regions: using the example of the Kisaföld, Hungary
36. **Pereira, Luisa**, 1996, 90-407-1385-5, A Robust and Adaptive Matching Procedure for Automatic Modelling of Terrain Relief
37. **Fandino Lozano, M.**, 1996, 90-6164-129-2, A Framework of Ecological Evaluation oriented at the Establishment and Management of Protected Areas: a case study of the Santuario de Iguaque, Colombia
38. **Toxopeus, B.**, 1996, 90-6164-126-8, ISM: an Interactive Spatial and temporal Modelling system as a tool in ecosystem management: with two case studies: Cibodas biosphere reserve, West Java Indonesia: Amboseli biosphere reserve, Kajiado district, Central Southern Kenya
39. **Wang Yiman**, 1997, 90-6164-131-4, Satellite SAR imagery for topographic mapping of tidal flat areas in the Dutch Wadden Sea
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41. **Ceccarelli, T.**, 1997, 90-6164-135-7, Towards a planning support system for communal areas in the Zambezi valley, Zimbabwe; a multi-criteria evaluation linking farm household analysis, land evaluation and geographic information systems
42. **Peng Wanning**, 1997, 90-6164-134-9, Automated generalization in GIS
43. **Lawas, C.**, 1997, 90-6164-137-3, The Resource Users' Knowledge, the neglected input in Land resource management: the case of the Kankanaey farmers in Benguet, Philippines
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45. **Farshad, A.**, 1997, 90-6164-142-X, Analysis of integrated land and water management practices within different agricultural systems under semi-arid conditions of Iran and evaluation of their sustainability
46. **Orlic, B.**, 1997, 90-6164-140-3, Predicting subsurface conditions for geotechnical modelling
47. **Bishr, Y.**, 1997, 90-6164-141-1, Semantic Aspects of Interoperable GIS
48. **Zhang Xiangmin**, 1998, 90-6164-144-6, Coal fires in Northwest China: detection, monitoring and prediction using remote sensing data
49. **Gens, R.**, 1998, 90-6164-155-1, Quality assessment of SAR interferometric data
50. **Turkstra, J.**, 1998, 90-6164-147-0, Urban development and geographical information: spatial and temporal patterns of urban development and land values using integrated geo-data, Villaviciencia, Colombia
51. **Cassells, C.**, 1998, Thermal modelling of underground coal fires in northern China
52. **Naseri, M.**, 1998, 90-6164-195-0, Characterization of Salt-affected Soils for Modelling Sustainable Land Management in Semi-arid Environment: a case study in the Gorgan Region, Northeast, Iran
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55. **Wang Donggen**, 1998, 90-6864-551-7, Conjoint approaches to developing activity-based models
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60. **Wolski, Piotr**, 1999, 90-6164-165-9, Application of reservoir modelling to hydrotopes identified by remote sensing

61. **Acharya, B.**, 1999, 90-6164-168-3, Forest biodiversity assessment: A spatial analysis of tree species diversity in Nepal
62. **Akbar Abkar, Ali**, 1999, 90-6164-169-1, Likelihood-based segmentation and classification of remotely sensed images
63. **Yanuariadi, T.**, 1999, 90-5808-082-X, Sustainable Land Allocation: GIS-based decision support for industrial forest plantation development in Indonesia
64. **Abu Bakr**, Mohamed, 1999, 90-6164-170-5, An Integrated Agro-Economic and Agro-Ecological Framework for Land Use Planning and Policy Analysis
65. **Eleveld, M.**, 1999, 90-6461-166-7, Exploring coastal morphodynamics of Ameland (The Netherlands) with remote sensing monitoring techniques and dynamic modelling in GIS
66. **Yang Hong**, 1999, 90-6164-172-1, Imaging Spectrometry for Hydrocarbon Microseepage
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71. **Kaymakci, Nuri**, 2000, 90-6164-181-0, Tectono-stratigraphical Evolution of the Cankori Basin (Central Anatolia, Turkey)
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73. **Schetselaar, Ernst**, 2000, 90-6164-180-2, Integrated analyses of granite-gneiss terrain from field and multisource remotely sensed data. A case study from the Canadian Shield
74. **Mesgari, Saadi**, 2000, 90-3651-511-4, Topological Cell-Tuple Structure for Three-Dimensional Spatial Data
75. **Bie, Cees A.J.M. de**, 2000, 90-5808-253-9, Comparative Performance Analysis of Agro-Ecosystems
76. **Khaemba, Wilson M.**, 2000, 90-5808-280-6, Spatial Statistics for Natural Resource Management

77. **Shrestha, Dhruva**, 2000, 90-6164-189-6, Aspects of erosion and sedimentation in the Nepalese Himalaya: highland-lowland relations
78. **Asadi Haroni, Hooshang**, 2000, 90-6164-185-3, The Zarshuran Gold Deposit Model Applied in a Mineral Exploration GIS in Iran
79. **Raza, Ale**, 2001, 90-3651-540-8, Object-oriented Temporal GIS for Urban Applications
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83. **Alfestawi, Y.**, 2001, 90-6164-198-5, The structural, paleogeographical and hydrocarbon systems analysis of the Ghadamis and Murzuq Basins, West Libya, with emphasis on their relation to the intervening Al Qarqaf Arch
84. **Liu, Xuehua**, 2001, 90-5808-496-5, Mapping and Modelling the Habitat of Giant Pandas in Foping Nature Reserve, China
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90. **Abadi, Abdulbaset M.**, 2002, 90-6164-205-1, Tectonics of the Sirt Basin – Inferences from tectonic subsidence analysis, stress inversion and gravity modelling
91. **Geneletti, Davide**, 2002, 90-5383-831-7, Ecological Evaluation for Environmental Impact Assessment
92. **Sedogo, Laurent G.**, 2002, 90-5808-751-4, Integration of Participatory Local and Regional Planning for Resources Management using Remote Sensing and GIS



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93. **Montoya, Lorena**, 2002, 90-6164-208-6, Urban Disaster Management: a case study of earthquake risk assessment in Carthago, Costa Rica
  94. **Ahmad, Mobin-ud-Din**, 2002, 90-5808-761-1, Estimation of Net Groundwater Use in Irrigated River Basins using Geo-information Techniques: A case study in Rechna Doab, Pakistan
  95. **Said, Mohammed Yahya**, 2003, 90-5808-794-8, Multiscale perspectives of species richness in East Africa
  96. **Schmidt, Karin**, 2003, 90-5808-830-8, Hyperspectral Remote Sensing of Vegetation Species Distribution in a Saltmarsh
  97. **Lopez Binnquist, Citlalli**, 2003, 90-3651-900-4, The Endurance of Mexican Amate Paper: Exploring Additional Dimensions to the Sustainable Development Concept
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  100. **Campos dos Santos, Jose Laurindo**, 2003, 90-6164-214-0, A Biodiversity Information System in an Open Data/Metadatabase Architecture
  101. **Hengl, Tomislav**, 2003, 90-5808-896-0, PEDOMETRIC MAPPING, Bridging the gaps between conventional and pedometric approaches
  102. **Barrera Bassols, Narciso**, 2003, 90-6164-217-5, Symbolism, Knowledge and management of Soil and Land Resources in Indigenous Communities: Ethnopedology at Global, Regional and Local Scales
  103. **Zhan, Qingming**, 2003, 90-5808-917-7, A Hierarchical Object-Based Approach for Urban Land-Use Classification from Remote Sensing Data
  104. **Daag, Arturo S.**, 2003, 90-6164-218-3, Modelling the Erosion of Pyroclastic Flow Deposits and the Occurrences of Lahars at Mt. Pinatubo, Philippines



**Appendix B**

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**Curriculum Vitae**



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## *Appendix B – Curriculum Vitae*

Ivan Luiz Zilli Bacic was born on the 19<sup>th</sup> of November 1961 in São Paulo/SP, Brazil. He obtained his degree in Agronomy at the Santa Catarina Federal University (UFSC) in 1983. From March to December 1988, he followed a specialization course on “Interpretation of remote sensing images applied to soil surveys” at the Geographic Institute “Agustin Codazzi” in Bogota, Colombia. He started his MSc. studies at ITC in March 1997, and graduated with distinction in February 1998, presenting the thesis entitled “Development of a land evaluation method for the southern agro-ecological zone of Santa Catarina State, Brazil”. He worked for Mannesmann Agro-Florestal LTDA in Minas Gerais State, Brazil, from 1984 to 1986. During this time, he was researcher and head of the Pedology and Forest Nutrition Division. Since 1986, he has been working for the Agricultural Research and Rural Extension Agency of Santa Catarina State (EPAGRI), Brazil as a researcher in land evaluation and soil survey and mapping. He was the head of the Soils Division from November 1989 to November 1991, Natural Resources State Manager from December 1991 to February 1995 and Sectorial Manager of the Soil Monitoring, Planning and Mapping Component of the Microcatchment Project supported by the World Bank, from March 1992 to February 1994. In November 1999, he started his PhD research at ITC and Wageningen University in The Netherlands.



Cover designed by Iasmine R. Bacic, Karoline Y. R. Bacic and Thiago I. R. Bacic.

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