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The *Journal of Environmental Management* is a journal for the publication of peer reviewed, original research for all aspects of management and the managed use of the environment, both natural and man-made. Critical review articles are also welcome; submission of these is strongly encouraged.

As governments and the general public become more keenly aware of the critical issues arising from man's use of his environment, this journal provides a forum for the discussion of environmental problems around the world and for the presentation of management results. It is aimed not only at the environmental manager, but at anyone concerned with the sustainable use of environmental resources.

Research Areas Include, but are not exclusive to:

- resource quality, quantity and sustainability • economics of environmental management • transport and fate of pollutants in the environment • spill prevention and management • remediation of contaminated sites • process modification for pollution prevention • improved energy efficiency • waste treatment and disposal

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Journal of **Environmental** *Management*

Editor-in-Chief

A. GILL

**Our Shared Landscape: Design, Planning and Management of
Multifunctional Landscapes**

Guest Editor: Eckart Lange

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Editorial

Our shared landscape: Design, planning and management of multifunctional landscapes

This special issue of the *Journal of Environmental Management* includes 10 selected papers presented at the 'Our Shared Landscape' conference which was held at the Centro Stefano Franscini on Monte Verità (translated: the mountain of truth) in Ascona, Switzerland, 2–6 May 2005 (Fig. 1). The abstracts of all accepted papers and posters that were presented at the conference can be downloaded from the conference website (Lange and

conflicts between aesthetic, ecological, socio-economic and land-use aspects of landscape planning and management and concentrated on how to integrate these issues from both a theoretical and practical perspective.

Individual sessions at the 'Our Shared Landscape' conference focused on 'Visualization and Decision-Making', 'Perceived Ecological and Aesthetic Quality', 'Ecological Aesthetics', 'Landscape Modelling', 'Landscape Abandonment and Rehabilitation', 'Scenario-Based Approaches', 'Infrastructure and Landscape', 'Landscape Policy and Landscape Economics', 'Landscape, a Matter of Scale', 'Analysis and Processes of Landscape Change', 'Integrative Approaches', 'Management of Rivers and Catchments', 'Agricultural Use and Landscape', 'Indicating Landscape Quality', 'Issues in Landscape Ecology' and 'Sustainability and Multifunctional Landscape'.

The notion of our shared landscape also requires shared values (Haber, 2005) in order to protect, plan and manage the landscape for future generations. Valuation and assessment techniques are a common thread within all contributions in this special issue. In several of the papers 3D visualization techniques are integrated in the evaluation by visualizing future landscapes and different management options, also, often taking advantage of using these visualizations as a mirror to reflect public opinion on the effects of different landscape management strategies on landscape aesthetics.

In an overview of how economic thinking is incorporated into the valuation of landscapes Peter V. Schaeffer ('Thoughts concerning the economic valuation of landscapes', 89 (3), 146–154) explores and discusses the uses and limitations of economic valuation of landscapes from different perspectives. He provides the context for several of the contributions that address landscape economics and use economic valuation methods.

Katrin Bernath and Anna Roschewitz ('Recreational benefits of urban forests: explaining visitors' willingness to pay in the context of the theory of planned behavior', 89 (3), 155–166) examine the potential of the theory of planned behavior to explain willingness to pay (WTP) in a contingent valuation survey of the recreational benefits of the Zürich forests.

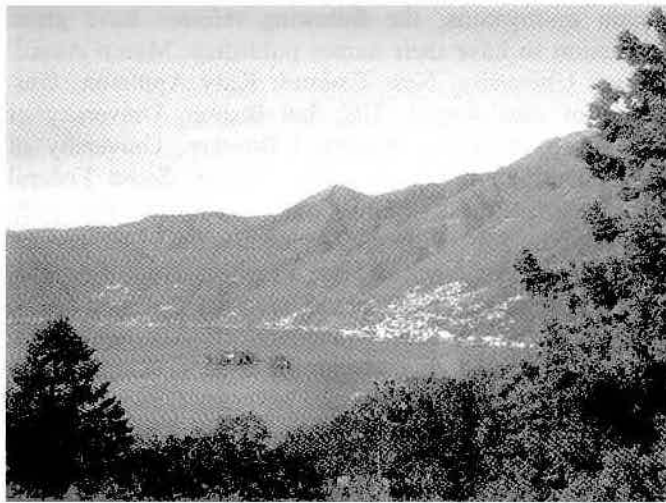


Fig. 1. View from the inspiring location of the Monte Verità conference venue towards the surrounding landscape with Lago Maggiore and Brissago Islands.

Miller, 2005). At the same venue, in 1999, we held the highly influential 'Our Visual Landscape' conference. While the 'Our Visual Landscape' conference concentrated on the analysis, modeling, visualization and protection of the visual landscape only (Lange and Bishop, 2001), the 'Our Shared Landscape' conference in 2005 broadened the topic, including landscape aesthetics and visual resources as well as ecological and socio-economic factors. In this context, we were especially addressing human influence in generating landscape through a wide range of land uses, among them agricultural and silvicultural land-use, and its impact on landscape aesthetics and landscape ecology. The conference tried to explore the common ground and the

James F. Palmer ('The perceived scenic effects of clearcutting in the White Mountains of New Hampshire, USA', 89 (3), 167–183) investigates the scenic perception of alternative forest management systems.

Ulrike Wissen, Olaf Schroth, Eckart Lange and Willy A. Schmid ('Approaches to integrating indicators into 3D landscape visualizations and their benefits for participative planning situations', 89 (3), 184–196) explore the potential of 3D visualization in participative landscape management processes to show complex relationships in the landscape of the Entlebuch UNESCO Biosphere Reserve by integrating visual and non-visual landscape information.

Adrienne Grêt-Regamey, Peter Bebi, Ian D. Bishop and Willy A. Schmid ('Linking GIS-based models to value ecosystem services in an Alpine region', 89 (3), 197–208) present a GIS-based procedure to value ecosystem goods and services, i.e. avalanche protection, timber production, scenic beauty and habitat quality, in Davos in the Swiss Alps, by linking existing process-based models with economic valuation.

Christina von Haaren and Manfred Bathke ('Integrated landscape planning and remuneration of agri-environmental services. Results of a case study in the Fuhrberg region of Germany', 89 (3), 209–221) propose a management concept that enhances the ecological and cost efficiency of agri-environmental measures linked with new remuneration models.

In a contribution from Switzerland that also focuses on the management of agricultural landscapes Beatrice Schüpbach, Kurt Zraggen and Erich Szerencsits ('Incentives for low-input land-use types and their influence on the attractiveness of landscapes', 89 (3), 222–233) apply a spatially explicit economic land-use model to predict land-use changes caused by agricultural policy and their effects on landscape aesthetics.

Philip Paar, Wieland Röhrich and Johannes Schuler ('Towards a planning support system for environmental management and agri-environmental measures—the Colorfields study', 89 (3), 234–244) present a planning support system (PSS) consisting of a bio-economic modeling system that is linked with a 3D-visualization system permitting a virtual implementation of Colorfields and blooming strips illustrating agri-environmental measures on model farms in northern Germany.

Eckart Lange, Sigrid Hehl-Lange and Mark J. Brewer ('Scenario-visualization for the assessment of perceived green space qualities at the urban-rural fringe', 89 (3), 245–256) pursue a prospective approach to green space planning, using a case study in Zürich by combining 3D visualization of future landscape scenarios and survey techniques to facilitate improved participation of the public.

Raffaele Laforteza, Robert C. Corry, Giovanni Sanesi and Robert D. Brown ('Visual preference and ecological assessments for designed alternative brownfield rehabilitations', 89 (3), 257–269) describe an integrative method for quantifying and analyzing the effects of alternative

brownfield rehabilitation in southern Italy by comparing ecological attributes with visual preference.

The conference at Monte Verità provided an opportunity for experts from all over the world to present and discuss new ideas on past, present and future landscapes from an aesthetic, ecological and socio-economic perspective. The challenge is now to apply this knowledge to land-use planning practice, landscape planning as well as landscape management.

Acknowledgments

First of all, I would like to thank the editor of the *Journal of Environmental Management* for her kind invitation to publish the papers of this special issue on 'Our Shared Landscape'.

Also, I am very grateful to the referees who have devoted a considerable share of their time and who gave very valuable and detailed input to the manuscripts. Without the help of the referees this special issue would not have been possible. While some of the referees preferred to remain anonymous, the following referees have given permission to have their names published: Marco Amati, Massey University, New Zealand; Katy Appleton, University of East Anglia, UK; Ian Bishop, University of Melbourne, Australia; Reinhard Boecker, University of Hohenheim, Germany; Matthias Buerger, Swiss Federal Institute of Forest, Snow and Landscape Research, Switzerland; Jon Burley, Michigan State University, USA; Bruce Chetwynd, Forest Practices Authority Tasmania, Australia; Peter Clinch, University College Dublin, Ireland; Terry Daniel, University of Arizona, USA; Wenche Dramstad, Norwegian Institute of Land Inventory, Norway; Susana Ferreira, University College Dublin, Ireland; Paul Gobster, USDA Forest Service, USA; Wolfgang Haider, Simon Fraser University, Canada; Tomohiro Ichinose, University of Hyogo, Japan; Jochen Jaeger, ETH Zürich, Switzerland; Simon Jude, University of East Anglia, UK; Ulrich Kias, University of Applied Sciences Weihenstephan, Germany; Tom Klingl, Swiss Federal Office for the Environment, Switzerland; Andrew Lovett, University of East Anglia, UK; Andreas Muhar, University of Natural Resources and Applied Life Sciences Vienna, Austria; Asa Ode, Macaulay Institute, UK; Harmen Oppewal, Monash University, Australia; Andreas Roehring, Leibniz-Institute for Regional Development and Structural Planning, Germany; Hans-Georg Schwarz-von Raumer, University of Stuttgart, Germany; Stephen Sheppard, University of British Columbia, Canada; Carys Swanwick, The University of Sheffield, UK and Simon Swaffield, Lincoln University, New Zealand.

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Thoughts concerning the economic valuation of landscapes

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Abstract

The incorporation of economic thinking into the valuation of landscapes is still relatively new. It is an approach that yields valuable new insights and can help with prioritizing the use of scarce resources to improve and/or preserve landscapes. This paper explores and discusses the uses and limitations of economic valuation of landscapes from market failure, policy process, and theoretical and philosophical perspectives.

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Keywords: Non-market valuation; Market failure; Rationality; Externalities; Allocation efficiency; Amenities; Open space; Land use

1. Introduction

Landscape architects and planners are increasingly using tools from economics to assess the value of and inform decision makers about land and its resources. In this process, to do their part well, they have to understand not only the properties of economic non-market valuation methods, but also their theoretical and philosophical foundations because they determine their limitations. An understanding of the foundations is also important for comparing alternative approaches and understanding and interpreting results. We are interested in economic valuation because scarce resources force us to choose or compromise between competing ends and economic valuation is well suited for assessing trade-offs among feasible alternatives and setting priorities.

Economic non-market valuation estimates often serve as inputs in policy processes designed to allocate land resources efficiently, whereas competitive markets rely on prices to accomplish this task. Market prices are attractive measures of the value of resources because they are usually readily available and, if certain conditions are met, have desirable characteristics. Specifically, competitive market prices send signals about scarcity to suppliers and consumers so that the eventual allocation of resources

among competing uses and users is a Pareto optimal outcome. Such an allocation cannot be changed to make someone better off without causing harm to someone else. An allocation that does not satisfy this criterion does not make the best possible use of available resources and is socially inefficient or wasteful. This explains economists' interest in finding ways to achieve Pareto optimal outcomes or, put differently, their interest in allocation efficiency.

Although market prices can help bring about Pareto optimal outcomes, they fail to do so under the following circumstances: (1) The market for a resource is not competitive, (2) a resource has the characteristics of a public good or a common pool good,¹ or (3) the market for a resource does not exist. These circumstances are referred to as market failures. Economists have developed a number of tools to deal with instances of such failures, which include economic non-market valuation.

The purpose of this paper is to provide background in three areas. (1) Because economic non-market valuation is applied almost exclusively because of market failure, we look at major reasons for market failure. (2) Since value estimates often serve as inputs into policy, we comment on

¹A pure public good has non-rival and non-exclusion characteristics, that is, once it is produced, one person's consumption of the good does not diminish its availability to others. The lighthouse is a classic example of a public good. A common pool good has only non-exclusion characteristics, that is, it is too expensive or it is against the law to exclude others from the good.

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the policy process. (3) Finally, we discuss aspects of the theoretical and philosophical background related to the application of economic non-market valuation methods.

Because of space limitations, this article will not focus on a specific method and for information about specific economic non-market valuation methods and their applications we recommend King and Mazzota, with the assistance of Markowitz (not dated).² Many other excellent surveys and reviews of the economic non-market valuation literature exist, and the following references provide entry points: Freeman III (2003), Peterson et al. (1988), and Kopp and Smith (1993). Mitchell and Carson (1989) present a thorough explanation of the contingent valuation method (CVM), which has emerged as one of the most popular approaches for assessing aesthetic resources. CVM is a direct method, that is, it asks individuals directly for their values of a resource. By contrast, the travel cost model (TCM) is an indirect method (revealed preferences) that relies on observing how individuals behave to draw conclusions about their valuations of amenities. Shaw (2005) provides a non-technical review of TCM. For practical guidelines for preparing analyses, see US Environmental Protection Agency (2000), and for a critique of these guidelines, see Knetsch (2005).

The remainder of this article is organized as follows. In Section 2 we define property rights, analyze their central role in determining socially optimal land use outcomes, and explain why and how poorly defined property rights can cause market failure. Section 3 is a discussion of the possible policy uses of economic non-market valuation methods and introduces two pragmatic criteria to help decide how to apply such methods. Then, in Section 4, distinguishing between theoretical and philosophical issues, we look at possible limitations that may prevent the use of economic non-market valuation tools. The last section presents conclusions.

2. The importance of property rights and other institutional factors

Without market failure there would be no need for economic non-market valuation methods.³ Because market failure is often caused by missing or incomplete property rights, we focus on their role for the functioning of markets (Barzel, 1989; Libecap, 1989). Property rights consist of the three distinct rights to (1) exclude others from one's property, (2) transfer all or part of one's property, permanently (sale, trade, gift) or temporarily (rent, lease, lend), and (3) all benefits that accrue from owning the

property. When any of these rights is missing we say that we have incomplete property rights. As the following examples show, incomplete property rights explain some of the most important causes of Pareto inefficient land and other resource use outcomes.

In western societies property rights are usually well defined, and for most types of property the owners alone decide their use. Land is different, however, in that government significantly influences land use decisions. Use rights in land are usually constrained by zoning, environmental, and safety laws and regulations because land uses can have significant effects on others besides the land owner.

Fischel (1985) has interpreted zoning as a publicly held property right. It is an example of an incomplete property right, however, because the government is not legally permitted to transfer the right to regulate land uses. The resulting separation of the benefits from the costs of regulation frequently causes Pareto inefficient land use outcomes (Fischel, 1985, 2000, 2004). Consider the example of community residents who are enjoying open space amenities of farmland. They may oppose that land's development since they currently receive, at no charge to them, the benefits of having open space close to where they live, which may also enhance the market value of their homes. Furthermore, if the proposed development does not generate new tax revenues sufficient to at least cover the required additional local government services, then current residents and real estate property owners have to make up the difference through increased taxes paid by them. Thus, residents who oppose the development act to protect their interests. The problem is that such pursuits of self-interest can result in a smaller supply of developments than is socially desirable and/or their construction in suboptimal locations.

To illustrate how the outcome might differ if zoning rights could be traded, assume that community residents would loose \$1 million if the development occurred. If the developer finds it cheaper to pay current residents at least \$1 million rather than build elsewhere, then the benefits of the site exceed those of any available alternative and the development would increase society's welfare. Alternatively, the refusal to pay \$1 million would demonstrate that the site's benefits are insufficient to compensate the losses suffered by current residents and therefore lower total social welfare.

Sometimes property owners may find it legally impossible or otherwise infeasible (e.g., because of high transaction costs) to obtain all returns, or be held responsible for all costs, generated by their efforts. Cases of positive (owner does not receive all returns) externalities result in underinvestment relative to the socially optimal level and negative (owner does not bear all costs) externalities result in overinvestment. Occasionally the problem can be solved by creating a market for the externality. The purchase of development rights (PDR) to preserve open space amenities is an example of the creation of a market to solve a

²Their review discusses the range of common approaches without getting embroiled in technical details. They consider the advantages and disadvantages of each method for particular purposes and their article is therefore a particularly useful resource for scholars in the early stages of exploring the use of economic non-market valuation methods.

³However, the absence of market failure does not address the argument of those who oppose economic valuation. Such critics may therefore still argue for non-economic, non-market valuation methods.

social problem (externality). For a short history of PDRs in the United States see Buckland (1987). In the United States PDRs have also become a relatively popular tool for farmland preservation,⁴ (e.g., Daniels, 1991; Daniels and Bowers, 1997; Steiner, 1999). However, high transaction costs usually prevent the establishment of markets for externalities and the competing interests of owners of different properties may require government regulation and/or a court decision to resolve them.

Coase's (1960) framing of such issues as "the problem of social costs" ranks among the most influential contributions to applied economics and alerted us to the importance of property rights. In his celebrated contribution he showed that (1) if property rights are completely defined, (2) if the originator of the externality can be identified, and (3) if the cause and effect of the externality are certain, then externalities will not be a problem because they would be compensated, provided that (4) the transaction costs of doing so are not prohibitive.

Consider the case of a view. If the four conditions hold and a builder who proposes a project that would impact the view were liable for damages, then the builder would either build so that there is no impact or offer compensation. If paying compensation makes building unprofitable, the builder would move the project elsewhere or quit.

What if the builder were not liable for damages? If Coase's four conditions are met, then those whose view would be affected will either have to accept the loss, pay to alleviate the impact of the new building, or buy out the developer who will then either quit or build elsewhere.⁵ Since the cost of remedy does not depend on who pays, the most cost effective option and therefore the outcome will be Pareto optimal and the same in either case.

However, this result, known as Coase's Theorem, holds only if the assignment of liability (that is, of rights) has no significant wealth effect. If the law holds the agent who causes the externality liable, the outcome depends on the "willingness-to-accept" (WTA) of those affected. The WTA is the minimum they would have to be paid to accept the environmental loss. Alternatively, if the agent is not liable the "willingness-to-pay" (WTP) determines the outcome. The WTP is the most that those who are adversely affected are willing to pay to avoid the environmental loss (of the view).

WTA and WTP should be equal. To see this even more clearly, consider a numerical example. Assume that the builder wants to build a new house which would block the view of one home owner. He offers \$50,000 in compensation, which the home owner rejects because she believes that the property value would be diminished by more than that amount. Rather than offering more, the builder

changes the plans and builds the new house in such a way that home owner's view is not impacted. This means that the change of plans either reduced the value or increased the cost of the new house by at most \$50,000. Otherwise the builder would have to offer more compensation as the cheaper alternative. Hence, if the situation had been different and the home owner had no legal rights to the view, then, if she were a skilled negotiator, she should be able to get the builder to change his plans for about \$50,000. In either case, although the wealth effects are clearly different, the eventual outcome is Pareto optimal.

The distinction between WTA and WTP is critical in applications of CVM. The US Environmental Protection Agency (2000) suggests substituting WTP for WTA, based on the assumption that the two measures will be close in practice (see Knetsch, 2005 for a critique). The measures are rarely equal in practice, however, or even close, because of reference dependence and endowment effects (Kahneman and Sugden, 2005; Knetsch, 2005). While the wealth (endowment) effect can be important, what is more important is that individuals treat losses differently from gains (e.g., McFadden, 1999; Kahneman and Sugden, 2005). This results in violations of underlying assumptions about the economic rationality of economic agents that underlie economic models. For those who are interested in this literature, we recommend Simon (1986) which contains an excellent discussion of the different meaning of rationality in economics and psychology, respectively. It is a useful background for an understanding of the literature.

In practice, endowment and reference effects significantly affect outcomes and the values obtained using WTP are smaller than those using WTA. This has led to the recommendation that WTP should be used as the more conservative measure. Alheim and Bucholz (2000) present a theoretical argument against this practice and conclude that a preference for WTP is likely to result in the systematic underestimation of environmental improvements and amenities (see also Knetsch, 2005).⁶ They recommend that the choice of WTA vs. WTP should be dictated by the political and socio-economic circumstances of each case. We agree, and in many instances WTP is the preferred measure. For example, if we want to elicit information to charge a fee for a currently free amenity, WTP is more pertinent than WTA. Second, since WTP yields lower values, the eventual policy recommendation is more likely to overcome possible political resistance. On the other hand, WTP has the disadvantage of eliciting more protest responses. Such responses are usually in the form of zero bids and/or non-responses and we often do not know

⁴Farmland preservation, particularly at the urban-rural fringe, tends to generate externalities.

⁵In resort towns, where views tend to be particularly highly valued, the author has witnessed several instances of home owners paying someone who was planning to build a home that would have blocked their view to alter their plans to minimize the impact.

⁶Part of the reason is that the two measures do not exactly measure the same thing. In the example given above, WTA measures the amount of money required for the homeowner to regain her initial utility if she loses her view. The reference point is her initial state with the view intact. By contrast, the WTP is defined as the amount of money that she would be willing to pay to avoid the loss of the view. The reference point is the state with the view lost, even if the loss can be avoided (Knetsch, 2005).

if they are true zero valuations or protest votes (Jorgensen et al., 1999) and are therefore difficult or impossible to interpret.

Sometimes institutional arrangements also create incomplete property rights and thus contribute to inefficiencies. For example, in West Virginia the Division of Forestry (DOF) is responsible for forest management, while the Division of Natural Resources (DNR) is in charge of wildlife management. The DNR derives revenues from selling hunting licenses and therefore benefits from maintaining deer herds that attract hunters. The negative impact of large herds on reforestation may not be given full consideration because this cost is born by the DOF and forest owners. Thus, the separation of benefits and costs may result in socially inefficient deer herd management. A recent news article describes another institutional problem resulting in land use inefficiencies in conjunction with development near national forest and park lands. The developments increase the losses from fires, but the federal government, which has no voice in determining the size and nature of, or choice of materials in, these developments, has been paying for the costs of fighting the fires (Johnson, 2007). Thus, sometimes we can deal with market failure either by changing institutional responsibilities so as to align benefits with costs to avoid externalities or by using non-market estimates of the social value of a resource in conjunction with policy measures to achieve the same outcome.

3. Economic non-market valuation and policy considerations

3.1. Policy applications of economic non-market valuation

In principle, economic non-market valuation can be used whenever markets do not exist or when significant externalities distort the usefulness of prices as signals for the allocation of scarce resources. In practice, they are mostly used when markets fail to form. There are two general reasons for estimating dollar values when markets fail. First, governments or non-governmental organizations may want to determine priorities for projects, such as the acquisition of land or rights in land or environmental improvements.

Second, market prices signal the relative scarcity of a commodity. When there is no market to serve this function and something is available free of charge, there is a tendency to underestimate its value. This in turn can lead to underinvestment into and/or overuse of the commodity (Hardin, 1968). The purpose of using non-market valuation techniques in such instances is to make the public and government officials aware of the potentially significant value of and/or to determine the price to be charged for

- business activities on public lands for which no fee is charged or the fee does not reflect the activities' value;
- the protection provided by a forest of built-up areas against avalanches;
- a beautiful view that is being threatened by development; and/or
- ecological services provided by land for which no fee is or can be charged.

This is not a complete list and only serves to illustrate types of potential applications. Note that while for the above purposes values are needed, for others purposes rankings to establish priorities might be sufficient.

3.2. Two pragmatic criteria for the application of non-market valuation

Non-market valuation methods are often inputs into policy making for better land use decisions. If the decision is to occur within a democratic process, then the method should satisfy the following two pragmatic criteria. The method(s) used to estimate a dollar value should (1) yield persuasive results and (2) be based on reliable information.

3.2.1. Persuasive results

The best estimates of the value of land or a landscape may be ignored if citizens, politicians, and other decision makers do not find them persuasive (see Steinitz, 2005 for an application of this criterion). The bigger the potential impact of a decision, and the more difficult it is to reverse the decision, the less decision makers should rely on estimates they cannot explain and defend, or they will effectively leave the decision to experts who have no public mandate and are not held accountable. The need for accountability to the public is implied, for example, by the code of ethics of the American Institute of Planners (American Planning Association, 2005).

The proposed solution is to supplement non-intuitive estimates with values obtained using intuitive approaches that can serve as reference points. For example, Lange and Schaeffer (2001) compared the prices charged for and occupancy rates of rooms in the same hotels, identical except for their views. Using simple discounting, they estimated how much the hotel gained from having a side with a great view, in one case the river and old city and the mountains in the background, and in the other case the lake with the mountain panorama as a backdrop. The method can be easily explained and there is a good chance that lay persons may have had comparable experiences while vacationing at the beach or in the mountains. Those who ultimately decide the fate of land or amenities will be more ready to accept a value estimate they do not intuitively understand if it is supplemented by intuitive value information that supports it.

One of the advantages of CVM is also that it is easy to explain and understand (Shaw, 2005). By contrast, Shaw argues, indirect valuation methods such as TCM are more

- recreational activities on public lands for which no fee is currently charged or the fee does not reflect the activities' value;
- recreational activities on public lands which are being considered for alternative uses;

difficult to explain and this may be one of the reasons why they are not used more frequently.

3.2.2. *Reliable information*

Deciding how much to ask or pay for something can be a daunting task if the commodity is complex, expensive and if the prospective seller and/or buyer has scant previous experience. Most home sellers and buyers are in this situation. Because the value of a home depends on a variety of factors, sellers and buyers usually work with real estate professionals to advise them. Lenders may require an inspection before they issue a mortgage to protect their investment, as well. Buyers and sellers are willing to pay for information to reduce their risks because the high price of real estate makes even small percentage errors costly.

Landscapes are complex systems and not easily understood.⁷ The results of the first gap analysis, conducted in Hawaii in the 1980s to protect these islands' many endangered bird species, illustrate how easily even experts can err. Gap analysis is a systematic approach based on overlay mapping (see McHarg, 1967/1992) for assessing land areas (for a description of gap analysis see USGS, 2004). The purpose of the Hawaii study was to identify areas that provide valuable habitats for several endangered species, since setting aside such areas would yield protection on the least amount of land. When the areas identified through the gap analysis were compared to areas previously set aside, the overlap was distressingly small. Less than 10% of the ranges of the endangered forest birds were included in the protected areas (Scott et al., 1987). A recent study by Corry and Nassauer (2005) found that even a systematic approach may not result in the reliable evaluation of ecological consequences for small mammal habitat.

Complexity may therefore limit the reliability of some non-market valuation techniques, particularly when we consider the value of whole systems. When even the term used to designate a system is ambiguous, as for example in "landscape" (for a discussion of the importance of language in planning see Guttenberg, 1993), then laypersons may not provide reliable estimates. Complexity may thus determine the method or methods to be used and the target population (experts or citizens).

For democratic decision-making it is less important who provides the information than who makes the decision, as long as the decision-maker can evaluate the information. Thus, both reliable information and reference points are important to make estimates persuasive and understandable.

This criterion may limit the applicability of some economic non-market evaluation methods. For example, Lazo et al. (1992) argue that CVM is better suited to the estimation of environmental use than non-use values since the knowledge of the respondents about the latter could be

too limited to provide meaningful responses. Fortunately, Lazo et al. (1992) also discuss ways to mitigate the problem. Without mitigation, the CVM results for non-use values might be too unreliable.

4. Issues and limitations

In the previous sections we discussed technical issues that may limit applications of economic non-market valuation methods. In this section we consider limitations to the use of economic valuation that stem from either (1) theoretical or (2) philosophical issues. In addition, (3) scarcity of resources may render expensive economic analysis socially suboptimal.

4.1. *Theoretical issues*

A global Pareto optimum represents an ideal that is achieved if all markets are in a competitive equilibrium. Since reality always falls short of this ideal, a global Pareto optimum is unattainable. If some markets are not competitive or not in equilibrium, will maintaining a competitive equilibrium in all other markets result in the second-best possible outcome for society? In their *General Theory of the Second Best*, Lipsey and Lancaster (1957) answered this question in the negative. Thus, pursuing a policy that includes estimated market values to address market failures does not guarantee a socially superior outcome than might have been obtained by using an alternative approach. Unfortunately, other than this negative result, the *General Theory of the Second Best* provides no guidance at all (Donohue, 1998; Boadway, 1999).

The lack of guidance is one likely reason why we do not very often appeal to the *General Theory of the Second Best*, but continue to rely on markets, which we know how to organize, which tend to make efficient use of relevant information (prices as signals), and which yield local Pareto optima in individual markets. Market approaches also enjoy broad political support, very likely because they are compatible with individualism and democracy (Hayek, 1944).

A second critique is based on the nature of rationality used in most current economic analysis, a critique forcefully put forward in Simon (1986). He criticizes neoclassical economics for "...its silence about the content of goals and values..." (Simon, 1986, p. S210), a sentiment shared by Sen (1987). Simon also questions the validity of the assumption of objective rationality with respect to present and future that is implicit in the economic approach (see also McFadden, 1999). By contrast, other social science disciplines allow for limited information processing capabilities of individuals and the roles of non-rational factors such as emotions, motivations, and sensory stimuli in influencing preferences and, hence, choices made. In economics "...rationality is viewed in terms of the choices it produces", while in other social sciences "...it is

⁷Jude et al.'s (2005) work demonstrates the difficulty of asking laypersons for an assessment of multiple changes in a landscape.

viewed in terms of the processes it employs” (Simon, 1986, p. S210), which he refers to as substantive rationality and procedural rationality, respectively. In other words, economics considers a choice rational if it results in the desired outcome. The process by which this happens is usually ignored. Other social sciences also consider the process that leads to the desired outcomes. Thus, indirectly, Simon’s (1986) critique is a warning against a “the end justifies the means” approach to public policy making. McFadden (1999) provides a more recent review of the meaning of rationality. His tentative conclusion is that seeking to measure stable preferences, the foundation of much of non-market valuation methods, is illusory. Instead, he suggests that consumers learn in an evolutionary and adaptive manner. He bases his conclusions on the growing research in experimental economics that shows human behaviors that are inconsistent with predictions based on established economic theory.

4.2. *Philosophical issues*

Nelson (2001) provides a penetrating analysis of the ethics implicit in modern economics and the pursuit of efficient outcomes through markets. While society generally supports market approaches, there are also many instances where society uses other mechanisms to make decisions about the use and allocation of goods and services. Some commodities are considered so important that all citizens should have access to and/or be able to participate in decisions about them. Markets allocate “votes” relative to how much a participant is willing and able to pay and the outcome therefore depends on the initial allocation of assets among individuals and their earning capacity, whereas political participation in a democratic society is independent of income or wealth. Even if market allocations are Pareto efficient, they may violate our sense of what is fair and equitable. While efficiency is important, it may not be the only goal and will sometimes be trumped by equity considerations. That the individualism represented by the use of markets may sometimes have to be subordinated to considerations for the common good was recognized by Adam Smith (Sen, 1987; see Myers, 1983 for a derivation of the philosophical origins of Smith’s ideas). Modern economics has focused on Pareto efficiency and shied away from making the inter-personal comparisons necessary to deal with equity. Sen (1987) considers this to be a weakness of modern economic theory, a critique that is developed comprehensively by Hinkelammert (2001, particularly in Chapter VI).

Roth (1999) is also critical of the “consequence philosophy” underlying modern welfare economics, which also forms the philosophical basis of economic non-market valuation. Instead of spending so much effort on finding values that enhance economic efficiency, he argues for more effort on building institutions that help society achieve its multiple goals (Roth, 1999). His argument

harks back to an idea we briefly mentioned at the end of Section 2.

Equity, health, and safety concerns are among the reasons why society limits the use of markets. However, society’s standards of what can and cannot be legally traded in markets are not constant. Cocaine could at one time be freely traded while alcohol was outlawed in the United States from 1920 until 1933, and (sin) taxes to discourage consumption of goods such as tobacco and alcohol change frequently.

Firey (1945) persuasively argued that non-economic factors such as “sentiment and symbolism” influence land use outcomes. Because of their history and significance, society considers some lands as sacred and, in some cases, off limits to economic considerations altogether. Hence, some lands remain undeveloped or underdeveloped, even though their economic value would be greater otherwise.

The view of landscape as commodity is particularly well captured in the following statement by Mitchell (1994): “As a medium for expressing value, it⁸ has a semiotic structure rather like that of money, functioning as a special sort of commodity that plays a unique symbolic role in the system of exchange-value. Like money, landscape is good for nothing as a use-value, while serving as a theoretically limitless symbol of value at some other level. At the most basic, vulgar level, the value of landscape expresses itself in a specific price: the added cost of a beautiful view in real estate value; the price of a plane ticket to the Rockies, Hawaii, the Alps, or New Zealand. Landscape is a marketable commodity to be presented and re-presented in “packaged tours,” an object to be purchased, consumed, and even brought home in the form of souvenirs such as postcards and photo albums” (Mitchell, 1994, pp. 14–15).

The economic valuation of landscapes is based on utilitarian philosophy as the basis of society’s relationship with the environment, with economic efficiency as the criterion for what uses are best. This tradition builds on Locke’s liberal philosophy and views private property rights as the foundation of democracy and individual freedom (Barton, 1983; Krueckeberg, 1995). This philosophical underpinning is not universally accepted. Thus, whereas Firey’s “sentiment and value” could be seen as competing in a utilitarian framework with monetary factors to determine land use outcomes, Aldo Leopold rejects the treatment of land as a commodity altogether. “Conservation is getting nowhere because it is incompatible with our Abrahamic concept of land. We abuse land because we regard it as a commodity belonging to us. When we see land as a community to which we belong, we may begin to use it with love and respect” (Leopold, 1966, pp. xvii–xix). A non-utilitarian approach to nature is also part of the traditional American Indian land ethic. “Central to most Indian religions and ethical systems was the idea that humans and other forms of life constituted a single society” (Nash, 1989, p. 117). Other non-utilitarian

⁸Landscape is referred by “it”.

approaches are based on, for example, human rights and animal rights (Barton, 1983; Wenz, 1988, particularly chapters 6 and 7). Finally, Hay (1989) argues against the use of cost-benefit analysis to decide public policy issues because, in his opinion, the underlying values are incompatible with Christian beliefs. Thus, there are different attitudes represented in our societies and even within individuals (Sober, 1995), and they do not remain constant. Which attitudes and values most influence a decision therefore depends on the issue or issues, participants, decision-making process, place, and time. This becomes a practical consideration when we try to understand protest responses in CVM questionnaires. If a respondent rejects the philosophical foundations of CVM and refuses to value environmental resources at all, how do we count or otherwise deal with the (non)response?⁹

4.3. Scarcity

Since economic analysis is a scarce resource, estimating the market value of a landscape is the best use of this resource only if outcomes are sufficiently superior to outcomes based on a cheaper “quick-and-dirty” analysis to compensate for the additional resource used (Leman and Nelson, 1981).

5. Conclusions

Although there is often strong support for economic valuation approaches, the Theory of the Second Best provides a justification for the use of alternatives if society is dissatisfied with the results of the former. Therefore, the appropriateness of an approach or method should not be determined only by how well it meets some criterion of economic or ecological efficiency, but by what it contributes toward achieving society's goals and objectives, in general.

In unregulated markets, individual economic actors, that is, persons and organizations, set their own goals and objectives and express them through their demand and supply. When there are no externalities, the final outcome is socially efficient, making the absence of public discussion irrelevant. In many land use decisions, however, externalities are common, requiring collective action to overcome some of the problems created by them. We must therefore together prioritize goals, depending on the benefits and costs of reaching them. The focus on goals and objectives alerts us to the fact that subjective values often determine what we consider desirable outcomes. Since experience demonstrates that individually and collectively held values can change over time, we should proceed to limit future regret. This is particularly important if decisions have irreversible outcomes (Pearce, 1983; Pindyck, 1991), as is

often the case when a decision impacts a large area and/or historically, culturally, or environmentally significant sites.

Governments are often accused of being inefficient providers of goods and services, and collective ownership is similarly thought to lead to inefficient outcomes (Hardin, 1968). However, we should avoid using economic approaches for ideological reasons and judge each case on its merits. While it is true that collectively held resources may be used inefficiently and that privatization may contribute to their preservation (Demsetz, 1967), Ostrom (1990) has shown that inefficiency of collective ownership is not inevitable, provided certain conditions are met, and Barton (1983) argues that democratic control over land use has benefits that may justify some loss in economic efficiency.

Finally, in the pursuit of its many goals and objectives, society encounters policy resource constraints, and therefore Tinbergen (1952) cautions against ambitions that exceed society's capabilities. In common sense terms, the principle named after him says that the number of goals and objectives must be commensurate with the means dedicated to achieving them. Expressed more formally, Tinbergen's Principle¹⁰ states that to achieve a given number of independent goals, there must be at least the same number of independent policy instruments. Economic non-market valuation estimates can help create new land use policy instruments, and thus enhance society's capability of dealing with land use policy. For this reason alone, economic non-market valuation approaches deserve to be studied and incorporated into our repertoire of policy tools. As long as we respect their shortcomings and limits, they should advance policy making.

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⁹For some guidance, dealing with selection bias only, see Strazzer et al. (2003). They do not deal with the more profound underlying philosophical issues.

¹⁰Tinbergen's Principle bears some analogy to a system of equations that can only be solved if there are at least as many independent equations (goals) as there are variables (policy variables or tools).

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Recreational benefits of urban forests: Explaining visitors' willingness to pay in the context of the theory of planned behavior

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Abstract

The extension of contingent valuation models with an attitude-behavior based framework has been proposed in order to improve the descriptive and predictive ability of the models. This study examines the potential of the theory of planned behavior to explain willingness to pay (WTP) in a contingent valuation survey of the recreational benefits of the Zurich city forests. Two aspects of WTP responses, protest votes and bid levels, were analyzed separately. In both steps, models with and without the psychological predictors proposed by the theory of planned behavior were compared. Whereas the inclusion of the psychological predictors significantly improved explanations of protest votes, their ability to improve the performance of the model explaining bid levels was limited. The results indicate that the interpretation of bid levels as behavioral intention may not be appropriate and that the potential of the theory of planned behavior to improve contingent valuation models depends on which aspect of WTP responses is examined.

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1. Introduction

The importance of forests for recreation and leisure activities is widely recognized. The systematic assessment of recreational and other non-market benefits is essential in order to incorporate these positive externalities of forests into policy and planning decisions. An established method to assess monetary values of non-market commodities is the contingent valuation method (Bateman et al., 2002; Mitchell and Carson, 1989). Contingent valuation (CV) surveys investigate individuals' willingness to pay for the good being valued. Therefore, a hypothetical market for this good has to be constructed. The fact that economic values are derived from individuals' preferences stated within a hypothetical scenario is one of the reasons why there are reservations regarding this method (e.g. Kahneman and Knetsch, 1992). An extensive literature dealing with this and other difficulties with CV studies shows that the method is controversial (e.g. Carson et al., 2001;

Hausman, 1993). One argument raised by critics is that CV models only capture a minor share of the variance of willingness to pay and therefore the reliability and validity of the estimates have to be questioned.

Approaches to improve the model's quality include extending conventional economic models to include attitudes and other psychological predictors (Harris et al., 1989; Mitchell and Carson, 1989). A theoretical framework for this approach is provided by the theory of planned behavior (Ajzen, 1991). According to this theory, the immediate antecedent of a behavior is the intention to perform the behavior. Moreover, behavior depends on the perceived behavioral control, i.e. individuals' perceived capability to perform the behavior. The three stipulated predictors of the behavioral intention are: attitude towards behavior, perceived behavioral control and subjective norm, which represents the social pressure to perform the behavior. This model of attitude-behavior relationships has been applied in CV studies assessing willingness to pay for different types of goods, e.g. leisure activities (Ajzen and Driver, 1992), abatement of forest regeneration cuttings (Pouta and Rekola, 2001) or drugs indicated for the

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treatment of Alzheimer's disease (Werner et al., 2002). In the context of contingent valuation, willingness to pay (WTP) is interpreted as behavioral intention. Impacts of attitudes, perceived behavioral control and subjective norms on WTP are analyzed in order to improve the understanding and explanation of WTP responses.

The overall impact of the psychological predictor variables proposed by the theory of planned behavior on the goodness of fit of models explaining individuals' WTP has been assessed in the following two studies. Luzar and Cossé (1998) analyzed the impact of subjective norms and attitudes towards the good to be valued. The addition of these two variables improved the explanatory power of the models, as indicated by an increase in the adjusted R^2 . Werner et al. (2002) tested the influence of all three predictor variables according to the TPB, and also ascertained an increased adjusted R^2 in the extended model. Both studies concluded that CV models explaining respondents' WTP can be improved by applying an attitude-behavior based framework.

But WTP responses comprise further aspects than the bid levels analyzed in these studies: respondents to a CV survey are, in fact, faced with three decisions. They have to decide whether to accept the hypothetical scenario or not, whether to state a positive or zero bid and how much to bid (Alvarez-Farizo et al., 1999). The presence of individuals who are not willing to pay anything for the good under analysis is frequently observed in CV studies with open-ended question formats (Boyle and Bergstrom, 1999). Genuine zero bids can be separated from protest bids with debriefing questions to find out the reasons for zero WTP (e.g. Freeman III, 2003). In general, those respondents who do not accept the hypothetical scenario are said to be protest voters.

There are different strategies for coping with protest votes in the analysis of WTP responses. Ad-hoc solutions include removing protest votes from the sample. This procedure is problematic as it induces a sample selection bias if the group of protesters differs from the remainder of the sample (e.g. Jorgensen et al., 1999). Therefore, an analysis of protest votes has to be included in a CV study.

Previous studies integrating the theory of planned behavior (TPB) into CV analysis have focused on the explanation of bid levels. The present study additionally implements the TPB into the analysis of protest votes. It has been shown that attitudes towards paying for the good to be valued may also help to explain protest votes (Jorgensen and Syme, 2000). In our study, we extended the analysis of protest votes to take into account other psychological predictors proposed by the TPB. Respondents' decisions whether to reply with a positive bid or a genuine zero bid were not analyzed in this study. In fact, we observed only a few genuine zero bids because we assessed use-values of a resource held by actual users. Therefore, we decided to integrate them into the analysis of the bid levels. Based on these considerations, we split the analysis of WTP responses into two steps. First, we identified protest votes and second, we examined the amount non-protesters were willing to pay.

The main purpose of the research reported here was to explore the potential of the theory of planned behavior to improve the models explaining two different aspects of WTP responses. Taking our survey of the recreational values of an urban forest as an example, we extended conventional models to include the psychological predictors proposed by the TPB. This extension was applied in both steps of our data analysis in order to assess its ability to explain first protest votes and second how much non-protesters would be willing to pay. We tested the contribution of the psychological variables in both steps and compared conventional and extended models by evaluating different indicators of goodness of fit. A further purpose of the study was to determine how WTP responses were influenced by respondents' characteristics, i.e. which variables affected their decisions whether to give a protest vote and how much to bid.

The remainder of this paper is organized as follows. In the next section we present the survey and questionnaire design for our empirical research. General aspects of the theory of planned behavior in the context of contingent valuation and its implementation in our example are outlined. We also describe the statistical methods and hypothesized outcomes of our data analysis. Results are presented in Section 3. Finally, Section 4 offers a discussion of our findings and some conclusions.

2. Methods

2.1. Survey and questionnaire design

Many studies of forest recreation behavior and the economic valuation of forest recreation benefits rely on on-site surveys carried out in the forest region under consideration. Whereas this procedure is very efficient in terms of surveying many forest visitors within a short time, it is subject to sample selection bias. Frequent forest visitors are overrepresented in the sample and the characteristics of non-visitors cannot be detected. Therefore, we decided to combine an on-site survey in the forests around Zurich¹ with an off-site survey among randomly chosen residents of Zurich. In this paper, we report on the off-site mail survey.

The mail survey was carried out in September 2004 among 1500 residents of Zurich. The sample was randomly selected from the municipal population register, and included residents between 18 and 84 years of age. The final sample was reduced to 1472 cases because of 28 undeliverable letters. Data collection employed multiple mailings, according to Dillman's (1978) Total Design Method. The first mailing included the questionnaire and

¹The study area consisted of the forested area of the city of Zurich, which represents about 25% of the total area. The 2250 ha of forest are spread over the hills surrounding the city and can be assigned to three subareas: Uetliberg to the west, Hoenggerberg/Chaefenberg to the north and Zuerichberg/Adlisberg to the east of the city.

a cover letter describing the aim of the study. A reminder postcard was sent 12 days later. With numbered response envelopes we identified non-respondents and sent them the questionnaire again four weeks after the first mailing. In total, 558 filled out questionnaires were returned, which represents a response rate of 38%.

The questionnaire consisted of five parts. In the first part, we wanted to find out how often individuals visited different green spaces in the urban area and if they had visited one of the forests around Zurich during the previous 12-month period. Those who had not visited any urban forests were asked why they had not, and then led directly on to the last part of the questionnaire. The second, third and fourth parts were for forest visitors only.

In the second part, forest visitors were questioned on items regarding their last visit to an urban forest, e.g. when the visit took place, what they had done there and how long they had stayed in the forest. The third part contained the description of the hypothetical scenario and the valuation question. We proposed that the costs of recreational use of forests would have to be paid for through entrance fees and that this would be the case for all forests in Switzerland. Given this scenario, respondents were asked how much they would be willing to pay for an annual permit that would allow them to visit the forests within the city area. Respondents were advised to look at the enclosed payment card. We pointed out that the amounts proposed on the card were given to help them decide on how much they were willing to pay but that any other amount could be chosen.

A debriefing question to identify protest votes was included for respondents who said that they would not pay anything. The question was worded as follows: "What is the main reason why you would not spend any money for an annual visitor permit?" Respondents choosing the first answer option "I prefer not to visit forests rather than paying an entrance fee" were classified as genuine zero bids. Those answering "I generally refuse entrance fees for forest visits" were identified as protest voters. As a third answer option, respondents had the possibility to state other reasons. Most of these reasons, e.g. "I already pay enough taxes", indicated protest against entrance fees.

In the fourth part, forest visitors had to express their agreement with several statements regarding the purchase of a visitor permit or, more generally, regarding an entrance fee and restricted access to forests. These statements were formulated to assess predictors of behavioral intentions according to the theory of planned behavior and are discussed in detail in the next section. In the last part of the questionnaire, we surveyed respondents' socio-economic characteristics.

2.2. *Application of the theory of planned behavior in the CV context*

The theory of planned behavior provides a theoretical framework for explaining human behavior and behavioral

intentions. The application of this theory in the context of contingent valuation intends to improve the explanation of WTP responses. This extension of conventional WTP analysis requires taking into account some features of the TPB with regard to its application in valuation studies.

One aspect concerns how to conceptualize WTP in the context of the behavioral model. In the majority of existing studies, WTP has been interpreted as behavioral intention (e.g. Ajzen and Driver, 1992; Pouta and Rekola, 2001). Accordingly, the corresponding behavior has been seen as equivalent to the real payment of the amount of money individuals stated they were willing to pay. Therefore, there was no real behavior to be explained but a behavioral intention expressed by the stated willingness to pay. The relationship between the intention to pay and real behavior has been analyzed in an empirical study comparing WTP responses with votes on a sales tax increase (Barro et al., 1996). They showed that the strength of the relationship between respondents' WTP and their vote on a sales tax depends on the level of correspondence between the WTP question and the behavior being measured. Furthermore, providing respondents with information on the good to be valued appeared to improve the predictive validity of CVM.

In the study presented here we analyzed the impact of the psychological predictors on WTP responses. This means that we interpreted WTP as behavioral intention in both steps of the analysis of WTP, i.e. in the analysis of protest votes and in the analysis of bid levels. One has to be aware, however, that WTP responses do not contain exactly the same information as do behavioral intentions as they are commonly understood in the TPB context (Ajzen and Driver, 1992): in the latter, behavioral intentions are assumed to indicate how hard individuals are willing to try to perform the behavior under consideration.

In the first step of our approach, we analyzed individuals' decision to state a protest vote or not, i.e. stating a protest vote was interpreted as intention not to pay any money for the good to be valued and the opposite applied to not stating a protest vote. This dichotomous decision does not contain any information on the strength of the intention. In the second step, behavioral intention corresponds to the amount individuals would be willing to pay for a visitor permit. These bid levels contain information regarding individuals' valuation of the good under consideration. Obviously, these values do not necessarily have to be correlated with the strength of the intention to pay the amount (Meyerhoff, 2004).

Another essential aspect to be considered in TPB studies is a clear definition of the behavior under analysis in terms of action, target, context and time (Ajzen and Peterson, 1988). The questions assessing attitudes and other predictor variables have to be compatible with the behavior defined by these four elements. This principle of correspondence has been declared a condition for the correlation between attitudes and behavioral intentions (Fishbein and Ajzen, 1975). In CV studies, the elements

characterizing the behavior of paying for the good to be valued are part of the hypothetical scenario, and refer to the description of the good and the payment scheme. Because individuals may hold different attitudes towards distinct aspects of the hypothetical scenario, it may be advisable to measure their attitudes towards these aspects instead of attitudes towards the behavior “paying for the good to be valued, given the details of the hypothetical scenario”.

The behavior of interest in our study was the hypothetical purchase of a forest visitor permit. Instead of assessing specific attitudes towards the purchase of a permit, we chose to evaluate attitudes towards two aspects related to the implementation of entrance fees for forests. First, *attitudes towards restriction of free access* were measured with the following two statements: “I would support the restriction of access to some parts of the forests for nature conservation purposes” (ATT1) and “I would support the restriction of access to some parts of the forests for safety reasons, if the costs of maintaining forests are otherwise too high” (ATT5). Strictly speaking, only the second statement (ATT5) fits into the hypothetical scenario proposed in the WTP question. With statement ATT1 not only were attitudes towards restriction of free access assessed but so also were attitudes towards nature conservation. Therefore, this item was not included in the analysis of WTP responses.

Second, *attitudes towards financing the recreational use of forests* were measured with three statements concerning the allocation of costs: “It would be fair if all visitors had to pay an entrance fee” (ATT2), “The forest owners should bear the costs of forest recreation” (ATT3) and “Forest recreation is a private affair which should therefore not be publicly funded” (ATT4). The decision to use three items was based on the fact that there seem to be basically three opinions about who should pay for the maintenance of forests: the forest visitors, forest owners or the state. Because only the first of these three items is compatible with the behavior under analysis, it was the only “financing attitude” to be included in our models explaining WTP responses.

The following two statements were intended to measure the *subjective norm* regarding the purchase of a visitor permit for forests: “My friends and family would buy a forest visitor permit” (SN1) and “Most people important in my life would think that I should buy a forest visitor permit” (SN2). By definition, subjective norms refer to the social pressure to perform or not to perform the behavior (Ajzen, 1991). Since only the second statement is consistent with this concept, further analysis of subjective norms referred to this item.

In the context of behavioral intentions represented by WTP responses, the *perceived behavioral control* refers to individuals’ budget constraints and to the independence of the decision to pay a certain amount for the good to be valued. These aspects were measured with two statements: “It would be difficult for me to afford to pay for a forest

visitor permit” (PBC1) and “I would have to discuss the purchase of a forest visitor permit with other persons” (PBC2). Whereas the latter refers to the freedom of decision, the former is intended to measure perceived financial constraints.

These psychological predictor variables were measured using a three-point rating scale (“agree”, “partly agree”, “do not agree”). The answer option “don’t know” was added to distinguish undecided individuals from missing answers. This approach diverges from standard scaling procedures and was chosen because the hypothetical context caused some respondents difficulties in some statements. For example, the assessment of perceived behavioral control required that respondents accepted the hypothetical scenario and therefore these items could not be judged by protest voters. In the regression models, the psychological predictors were incorporated as categorical variables with the levels “agreeing with the statement” (level 1), “partly agreeing” (level 2), “disagreeing” (level 3) and “don’t know” answers (level 4). The deviations of levels 1, 2 and 3 from the overall mean were tested with effects coding.²

2.3. Statistical models and hypothesized influence of predictor variables

Stating willingness to pay in open-ended questions of a contingent valuation scenario involves two aspects. First, respondents decide to accept the hypothetical scenario or not. Second, those accepting the scenario choose the amount of money they are willing to pay for the good to be valued. Considering these two aspects, we split our data analysis into two steps (Table 1). First, we analyzed whether the answers represent “true” willingness to pay or protest against the hypothetical scenario. In order to explore how individuals’ characteristics influence the *probability of stating a protest vote* (PROT), we estimated a logistic regression model. Second, we examined the *amount of money* (WTPA) non-protesters would pay for a visitor permit. The impact of explaining variables on these bid levels was assessed with a linear regression model. In both steps, we first estimated basic models, including socio-economic characteristics and variables related to forest visits as predictor variables. Then we extended the models to include psychological variables according to the theory of planned behavior.

The main purpose of the investigation was to assess the potential of the theory of planned behavior to improve

²The coding of factors determines which effects of factor levels are tested and represented by the parameter estimates in the regression model. With effects coding, the deviation of the first three levels from the overall mean is tested and the parameter value of the fourth category is equal to the negative sum of the estimates for the other three levels (Adamowicz et al., 1997). In Splus, effects coding corresponds to “sum contrasts”. The overall statistical properties of the model, for example, the R^2 value or the Log-Likelihood, are independent of the coding of factors (Venables and Ripley, 1996).

Table 1
Basic and extended models in the two steps of the data analysis

	Basic model	Extended model
First step	$\text{PROT} = \begin{cases} 1 & \text{if } \alpha + \beta X + \gamma Y + \varepsilon > 0 \\ 0 & \text{if } \alpha + \beta X + \gamma Y + \varepsilon \leq 0 \end{cases}$	$\text{PROT} = \begin{cases} 1 & \text{if } \alpha + \beta X + \gamma Y + \delta Z + \varepsilon > 0 \\ 0 & \text{if } \alpha + \beta X + \gamma Y + \delta Z + \varepsilon \leq 0 \end{cases}$
Second step	$\text{WTPA} = a + bX + cY + \varepsilon$	$\text{WTPA} = a + bX + cY + dZ + \varepsilon$

PROT = dichotomous variable indicating protest votes; WTPA = continuous variable representing willingness to pay amounts stated by non-protest voters; X = vector of explanatory variables regarding socio-economic characteristics; Y = vector of explanatory variables related to forest visits; Z = vector of psychological explanatory variables; $\alpha, \beta, \gamma, \delta$ = vectors of parameters to be estimated in the logistic regression models; a, b, c, d = vectors of parameters to be estimated in the linear regression models; ε = error terms.

standard economic models. Therefore, we tested the hypothesis that extending the model to include psychological variables caused no improvement over the basic model. In the first step, this hypothesis is equivalent to $H_0: \delta = 0$ and can be tested with a Likelihood Ratio test, whereas an F -test is appropriate to test $H_0: d = 0$ in the linear regression model in the second step.³ Thereby, δ and d denote the vectors of parameters on the psychological variables (Table 1). In order to analyze the contribution of all psychological predictors together, we calculated different model evaluation criteria taking into account the number of predictor variables in the model. The first was the adjusted R^2 for the linear regression and a modification of this measure for the logistic regression.⁴ An alternative measure to compare the fit of nested models is the Akaike information criterion (AIC). The AIC declines as the model fit increases, i.e. smaller values indicate better models (Greene, 2003).

A further aim of our study was to assess the impact of different parameters on protest votes and willingness to pay. The parameter estimates in the regression models indicate how WTP responses are influenced by explanatory variables reflecting respondents' characteristics, forest visiting behavior, attitudes, subjective norms and perceived behavioral control. For some parameters, we derived a priori hypotheses on the sign of the estimates from economic theory and other considerations (Table 2).

Regarding the first step in the data analysis, i.e. the analysis of protest votes, we had no theoretically founded hypotheses on the impact of the predictor variables in the basic model and they were included in the model for explorative analysis. Regarding the psychological predictor variables added in the extended model, we expected agreement with the statement concerning restricted forest access (ATT5) would have a negative effect on the probability of stating a protest vote. Likewise, a negative correlation was expected from agreement with entrance fees (ATT2). It was anticipated that positive subjective norm (SN2) towards the purchase of a visitor permit, i.e. agreement with the respective statement, would decrease the probability of a protest vote. Furthermore, both variables representing perceived behavioral control (PBC1, PBC2) were not expected to affect protest votes because the decision to give a protest response presumably preceded the decision on how much to bid and thus was considered independent of the respondent's (perceived) capability to buy a visitor permit.

In the second step, non-protest voters' bid levels (WTPA) were expected to correlate positively with their income (INC), as proposed by economic theory. Because we assessed household income, WTPA should be negatively correlated with the number of adult household members (HHAD). Along the same argument, living in a household with children (CHILD) decreased per capita income and therefore should affect WTPA negatively. But this effect could possibly be compensated for by the fact that forest recreation could be more relevant for families with children, providing space to play and to experience nature in the forests. The variables AGE, SEX and employment status were included in the model for explorative analysis without any prior expectations about their possible impact. Based on the results of a model including six categories of employment status, we decided to introduce a dummy variable for retired people (RET) and to omit the other categories. Membership in environmental organizations (ENVO) indicates a general willingness to pay for environmental concerns and can be used as a proxy for general environmental attitudes. Therefore, we hypothesized a positive correlation with the amount individuals would pay for forest recreation. The number of days since the last forest visit (LFVDAYS) and travel time

³The F -statistic to compare the fit of two nested models is calculated as $F = [(RSS_1 - RSS_2) / (df_1 - df_2)] / (RSS_2 / df_2)$, where RSS_1 is the regression sum of squares of the basic model, RSS_2 the regression sum of squares of the extended model, and df_1, df_2 are the corresponding degrees of freedom (Kutner et al., 2004). The Likelihood Ratio test statistic is calculated as $LR = -2(LL_1 - LL_2)$, where LL_1 is the Log-Likelihood of the basic model and LL_2 is the Log-Likelihood of the extended model. LR follows a χ^2 distribution with $(df_1 - df_2)$ degrees of freedom (Kutner et al., 2004).

⁴In analogy with the R^2 for linear models, the Likelihood Ratio R_L^2 (also called Mc Fadden's R^2) measures the proportional reduction in the absolute value of the Log-Likelihood, i.e. $R_L^2 = 1 - LL_M / LL_0$, where LL_M is the Log-Likelihood from the fitted model and LL_0 is the Log-Likelihood from the unparameterized model (Menard, 2002). The adjustments to take into account the number of observations (n) and the number of explanatory variables (k) are analogous to the adjusted R^2 in linear regression models: $\text{adj. } R_L^2 = 1 - (1 - R_L^2)((n-1)/(n-k-1))$. This adjusted measure of deviance for general linear models was proposed by Guisan and Zimmermann (2000).

Table 2
Variable descriptions and hypothesized impacts on protest votes (PROT) and on non-protest voters' willingness to pay (WTPA)

Variable name	Description of the variable	Hypothesized impact on PROT ^a	Hypothesized impact on WTPA ^a
<i>Socio-economic characteristics</i>			
AGE	Respondent's age	?	?
SEX	1 if respondent is male, 0 otherwise	?	?
HHAD	Number of adult household members	?	-
CHILD	1 if children (<18 years) living in the household, 0 otherwise	?	?
INC	Household income	?	+
RET	1 if respondent is retired, 0 otherwise	?	?
ENVO	1 if member of environmental organization, 0 otherwise	?	+
<i>Visiting characteristics</i>			
LFVDAYS	Number of days since respondent's last forest visit	?	-
DUR	Duration of last forest visit	?	+
DURWAY	Travel time to the forest	?	-
ACT	Main activity in the forest (5 categories)	?	?
<i>Psychological predictors (level 1, agreement)</i>			
ATT5	Restricted access for safety reasons	-	no
ATT2	Forest visitors should pay	-	no
PBC1	Perceived financial constraints	no	?
PBC2	Restricted freedom of decision	no	?
SN2	Social pressure to buy a visitor permit	-	no

^a Hypothesized impact: +, positive impact; -, negative impact; no, no impact; ?, no hypothesis

(DURWAY) were expected to negatively affect WTPA, whereas the duration of forest visits (DUR) was hypothesized to have a positive impact on bid levels.

According to the theory of contingent valuation, respondents' willingness to pay expresses their valuation of the good to be valued. These values should not be influenced by the acceptance of the payment vehicle and other details of the hypothetical scenario. Therefore, attitudes and subjective norms towards aspects of the scenario were, theoretically, not expected to affect CV bids. Our expectations about the impacts of perceived behavioral control statements (PBC1, PBC2) were ambiguous. On the one hand, disagreement implies respondents feel confident that they can perform the behavior and consequently should positively affect WTPA. On the other hand, individuals responding with a low WTPA were probably more confident that they could afford the stated amount of money without discussing the expense with other people.

3. Results

The results presented here are based on the off-site mail survey of randomly chosen residents of Zurich. Out of the 558 individuals answering the questionnaire, 65 (12%) reported that they had not visited the forests around Zurich during the previous 12 months. These people then

did not have to answer the questions on forest visiting behavior and on willingness to pay for forest visits.⁵ In the group of forest visitors, eight respondents were excluded from the analysis because they did not give a reason for their missing or zero WTP answer, and 168 respondents (35%) were classified as protest voters because they opposed a visitor fee as a matter of principle.⁶ Only seven respondents stated genuine zero bids, i.e. they would prefer not to visit forests if they had to pay an entrance fee.

3.1. Descriptive statistics of the sample

The analysis of protest votes is based on the sample of all forest visitors, divided into protest voters and non-protest voters, whereas investigations of the WTP amounts rely on

⁵ The analysis of WTP was restricted to actual users because the purpose of this study was to assess *direct use values* (Bateman et al., 2002). Consequently, aggregated values of forest recreation were estimated by extrapolating mean WTP from the sample to the forest visiting population (88% of city residents).

⁶ Relatively high rejection rates of an entrance fee for forest visits were already detected in former studies (e.g. 9–23% in Tyrvainen, 2001), and also in the pretest of our survey. Nonetheless, we decided to retain this payment vehicle first, because of comparability with other studies using entrance fees. And second, because a main purpose of our study was to test whether explanations of protest votes can be improved in the context of commonly used study designs proposing entrance fees.

Table 3

Socio-economic and forest visiting characteristics of forest visitors (incl./excl. protest voters)^a

		Forest visitors	
		Incl. protest voters (n = 315)	Excl. protest voters (n = 231)
<i>Socio-economic characteristics</i>			
AGE	Age	43.8 (15.3)	43.3 (15.2)
SEX	Sex (% females)	55%	54%
HHAD	Adult household members	1.9 (0.7)	1.9 (0.7)
CHILD	Households with children	25%	27%
INC	Household income (in 1000 CHF) ^b	7.9 (4.7)	7.9 (4.7)
RET	Retired individuals	16%	16%
ENVO	Membership in environmental organization	31%	31%
<i>Visiting characteristics</i>			
LFYDAYS	Days since last forest visit	33.7 (57.7)	35.9 (60.4)
DUR	Duration of last forest visit (hours)	1.4 (0.9)	1.4 (0.9)
DURWAY	Travel time (minutes)	15.8 (12.2)	15.9 (12.7)
	Main activity		
ACT_w	Walking, hiking	55%	52%
ACT_d	Walking the dog	6%	5%
ACT_b	Biking	7%	9%
ACT_j	Jogging	18%	18%
ACT_o	Others ^c	15%	16%

^aThe table depicts mean values and standard deviation (in parentheses) for continuous variables. Percentages of the sample are displayed for discrete and factor variables. The total of percentages does not always sum up to 100% due to missing answers and rounding effects.

^b1 CHF ≈ 0.65 € (September 2004).

^cThis category includes visiting a restaurant, having a picnic, playing with children and other activities listed by forest visitors.

the sub-sample of non-protest voters. Observations with missing values in the predictor variables were excluded from the analysis. Consequently, the samples were reduced to 315 forest visitors, of which 231 were classified as non-protest voters. The description of respondents' characteristics in Table 3 reveals no statistically significant differences between these two samples.

Table 4 shows respondents' evaluation of the statements having to do with restricting free access and with visitor permits. Answers from the sample of all forest visitors (including protest voters) were contrasted to those of the subsample of non-protest voters. Noticeable differences between all visitors and the sub-sample of non-protesters concerned the statement that it would be fair if visitors had to pay an entrance fee (ATT2) and the statement assessing the social pressure to perform the behavior (SN2).⁷ Non-protest voters were more likely to (partly) agree with an entrance fee and with the statement that most people important to them would support the purchase of a visitor permit. The answers regarding the statement assessing attitudes towards restricted forest access (ATT5) were equally distributed in the two samples. Furthermore, there were no statistical significant differences between the two samples regarding the statements assessing perceived

Table 4

Agreement with statements assessing psychological variables (%; incl./excl. protest voters; n = 315/231)

Variable	Agree	Partly agree	Disagree	Don't know
ATT5	20/20	21/21	53/53	6/6
ATT2	7/9	23/31	65/55	4/5
PBC1	10/11	13/16	75/72	2/1
PBC2	11/11	10/13	76/73	3/3
SN2	16/21	15/19	33/22	36/39

control over the behavior of purchasing a visitor permit (PBC1, PBC2).

Respondents to CV surveys face an unfamiliar task in stating willingness to pay for a non-market good. As a consequence, they might infer a "fair price" from comparable goods instead of declaring their reservation price. To ensure that respondents expressed the price at which they would be indifferent between visiting the forests or not, we provided opportunities to revise WTP responses. Following the valuation question they were asked if they were confident that they would rather give up visiting forests than pay more than their initial bid.⁸ About one third of the respondents revised the first bid and consequently the

⁷The results of the χ^2 tests indicate that the differences regarding the variable SN2 are statistically significant at the 5%-level ($\chi^2 = 9.2$; p -value = 0.027), and those regarding ATT2 at the 10%-level ($\chi^2 = 6.7$; p -value = 0.082).

⁸The possibility to revise the initial bid encourages respondents to consider their preferences carefully. This approach was used and tested in previous studies assessing recreational values of forests (Elsasser, 1999; Löwenstein, 1994).

Table 5
Forest visitors' willingness to pay for an annual forest visitor permit (CHF)

Sample	Mean	Standard deviation	Median	Minimum	Maximum
<i>Initial bid</i>					
Incl. protest voters ($n = 315$)	64	88	30	0	500
Excl. protest voters ($n = 231$)	88	92	50	0	500
<i>Revised bid</i>					
Incl. protest voters ($n = 315$)	91	127	50	0	1000
Excl. protest voters ($n = 231$)	124	134	100	0	1000

mean WTP increased by roughly 35% (Table 5). Including protest voters as zero answers decreased the mean and median values of WTP considerably. In both samples, the median was lower than the mean, which meant that the distribution of WTP was positively skewed.

3.2. Results of the models explaining protest votes and WTP amounts

The basic models in both steps of the data analysis contained socio-economic characteristics and variables related to forest visits as predictor variables. The decision about which variables to include in the model was primarily based on theoretical considerations. Furthermore, full models were calculated in order to test the impact of variables for which we had no theoretically founded a priori hypotheses. The only significant explanatory variable in the basic logistic regression model explaining protest votes was activity (Table 6). Walkers (ACT_w) were more likely to state a protest vote and the variable representing bikers (ACT_b) had a statistically significant negative impact. This might possibly be due to differences in the awareness of the cost of the services provided to perform the different activities in the forests. Furthermore, walkers might be more likely to oppose entrance fees because their activity has a long tradition, whereas the use of the forests for biking activities emerged within the last two decades.

In the second step we calculated a linear regression model explaining how high the bids were.⁹ Because of the positively skewed distribution, the dependent variable (WTPA) was transformed with the natural logarithm.¹⁰ The signs of the significant predictor variables in the basic model corresponded with our hypotheses. Willingness to pay amounts significantly increased with higher income (INC), membership in environmental organizations (ENVO) and higher frequency of forest visits, represented by the negative impact of the number of days since the last forest visit (LFVDAYS). Furthermore, retired people (RET) gave significantly lower bids. Contrary to expecta-

tions, the duration of forest visits and travel time to the forest were not significantly correlated with WTPA.

The basic models were extended by including the determinants of behavioral intentions specified in the theory of planned behavior, namely attitude, subjective norm and perceived behavioral control. The probability of stating a protest vote was significantly increased by negative attitudes towards an entrance fee (ATT2_disagree) and negative subjective norm towards the purchase of a visitor permit (SN2_disagree). On the other hand, positive subjective norms (SN2_agree) showed a significant negative impact on protest votes, as well as partial agreement with an entrance fee (ATT2_part.agree) and with the statement assessing perceived financial restrictions (PBC1_part.agree). In comparison to the basic model, the impact of the activity was no longer significant at the 5% significance level. In the extended linear regression model, willingness to pay amounts were significantly increased by positive attitudes towards an entrance fee (ATT2_agree) and positive subjective norms (SN2_agree), whereas negative subjective norms (SN2_disagree) significantly decreased bid levels. The impacts of socio-economic and forest visiting characteristics were analogous to the basic model.¹¹

These results show that attitudes towards the behavior, proposed as predictors of behavioral intentions by the TPB, affected protest votes rather than bid levels. On the other hand, membership in environmental organizations (ENVO), as a proxy for general environmental attitudes, affected bid levels but not the probability of stating a protest vote.¹²

The overall effect of adding psychological predictor variables is indicated by the goodness-of-fit estimates. Comparing the basic and the extended model in the first

⁹Individuals' statements on their financial constraints (PBC1) are related to their income. This relationship could influence the estimates regarding the PBC1 variable. In order to test if the income variable affects the coefficients of the PBC1 variable and their standard errors, we additionally estimated models without income as explanatory variable in both steps of the analysis. This procedure did not change the results regarding the PBC1 variable.

¹²A relationship between the general environmental attitudes and the specific attitudes included in our models could affect the estimated coefficients. However, the data showed no statistical relationship between ENVO and every single psychological predictor variable.

⁹The dependent variable in the models presented here was the revised bid for respondents adjusting their initial bid.

¹⁰The dependent variable (WTPA) included the genuine zero bids, therefore we applied the transformation $\log(WTPA + 1)$.

Table 6
Estimated logistic regression model (first step) and linear regression model (second step)

	Logistic regression model (dependent variable PROT)				Linear regression model (dependent variable log(WTPA + 1))			
	Basic model 1 (<i>n</i> = 315)		Extended model 1 (<i>n</i> = 315)		Basic model 2 (<i>n</i> = 231)		Extended model 2 (<i>n</i> = 231)	
	Estimates	Std. error	Estimates	Std. error	Estimates	Std. error	Estimates	Std. error
Intercept	−1.352	0.730	−2.911*	1.140	4.047***	0.392	4.151***	0.449
SEX	−0.078	0.279	0.126	0.363	−0.047	0.152	−0.074	0.153
AGE	0.004	0.012	−0.004	0.016	0.000	0.007	−0.001	0.007
HHAD	0.047	0.191	−0.087	0.248	−0.133	0.111	−0.123	0.113
CHILD	−0.523	0.340	−0.343	0.437	0.111	0.172	0.129	0.178
INC	−0.002	0.032	0.008	0.041	0.055**	0.017	0.058**	0.018
RET	−0.276	0.499	0.581	0.678	−0.544*	0.271	−0.564*	0.272
ENVO	0.111	0.285	0.484	0.381	0.639***	0.156	0.604***	0.158
LFVDAYS	−0.003	0.003	−0.005	0.003	−0.003**	0.001	−0.003*	0.001
DUR	0.095	0.152	0.282	0.200	0.051	0.085	0.022	0.086
DURWAY	−0.009	0.012	−0.014	0.017	−0.005	0.006	−0.003	0.006
ACT								
ACT_w	0.590*	0.292	0.646	0.344	0.094	0.129	0.086	0.129
ACT_d	0.757	0.478	1.058	0.619	−0.132	0.270	−0.218	0.281
ACT_b	−1.761*	0.838	−1.738	0.917	0.018	0.209	0.077	0.211
ACT_j	0.202	0.356	−0.098	0.431	−0.123	0.165	−0.035	0.168
ATT5_agree			−0.184	0.356			−0.134	0.147
ATT5_part.agree			0.017	0.347			0.158	0.156
ATT5_disagree			−0.540	0.304			−0.043	0.125
ATT2_agree			−0.695	0.890			0.458*	0.204
ATT2_part.agree			−1.738*	0.865			−0.107	0.145
ATT2_disagree			1.759***	0.494			−0.154	0.145
PBC1_agree			−0.268	0.496			−0.175	0.250
PBC1_part.agree			−1.278*	0.562			0.338	0.223
PBC1_disagree			0.211	0.402			−0.190	0.198
PBC2_agree			0.166	0.496			0.137	0.209
PBC2_part.agree			−1.117	0.589			0.015	0.202
PBC2_disagree			0.149	0.368			0.118	0.156
SN2_agree			−1.355*	0.612			0.353*	0.140
SN2_part.agree			−0.055	0.469			−0.021	0.147
SN2_disagree			1.562***	0.328			−0.350*	0.144
Adjusted <i>R</i> ²	0 ^a		0.28 ^a		0.16		0.21	
AIC	379.31		298.90		704.78		705.19	
LR, <i>F</i> ^b		110.41				1.83		
<i>p</i> -value ^c		0				0.03		

*Significant at the 5% level.

**Significant at the 1% level.

***Significant at the 0.1% level.

^aAdjusted Likelihood ratio *R*².

^bLikelihood Ratio index (LR) or *F* value for tests of the hypothesis "all parameter estimates of the psychological variables are zero".

^cPr(>χ) for the Likelihood Ratio test of extended model 1 against basic model 1 and Pr(>*F*) for the *F*-test of extended model 2 against basic model 2.

step showed that the psychological predictors enhanced the explanatory power of the model, since the adjusted Likelihood Ratio *R*² increased and the AIC value decreased. The Likelihood Ratio index (LR) confirmed this finding, leading us to a clear rejection of the hypothesis that the inclusion of psychological variables caused no improvement compared to the basic model. The results in the second step were ambiguous. Based on the adjusted *R*², the extended model was preferred while the AIC value suggested the opposite, even though there was only a minor difference between the two models. The *F*-test of the hypothesis "no improvement" reflected this ambiguity.

While this hypothesis was accepted at the 1% confidence level, it was rejected at the 5% level.

4. Discussion and conclusions

Conventional models explaining willingness to pay typically have low explanation power. Mitchell and Carson (1989) proposed an *R*² of at least 15% for reliable results of contingent valuation studies. But even if this benchmark is reached, a large proportion of variation remains unexplained. Therefore, extensions of the conventional approach have been proposed, e.g. developing CV

models based on attitude theory (Harris et al., 1989). A theoretical framework was provided by the theory of planned behavior, an established attitude theory in social psychology.

The main focus of studies combining contingent valuation and the theory of planned behavior has been to explain willingness to pay values (e.g. Luzar and Cossé, 1998; Meyerhoff, 2004; Pouta, 2004). In our study, we additionally investigated how protest votes were influenced by psychological predictors. The payment vehicle “visitor permit” in our hypothetical scenario induced a high share of protest votes because forest visitors are not accustomed to paying entrance fees. In general, green spaces in Switzerland are freely accessible and the right to enter forests is part of Swiss law. Consequently, respondents might reject the hypothetical scenario because this right would be taken away with the proposed entrance fee.¹³ Having 35% protest votes is quite high, but not totally unknown in other CV studies with comparable definitions of protest votes (e.g. 31–32% resp. 18% in Alvarez-Farizo et al., 1999; Strazzer et al., 2003).

The analysis of the basic model in the first step revealed that protest votes were only marginally influenced by respondents’ socio-economic characteristics or by variables related to their forest visits. This result indicates that there were no systematic differences between protest voters and non-protest voters regarding the variables in our models. Therefore, in the analysis of WTP amounts protest votes could be excluded without causing a sample selection bias (e.g. Bateman et al., 2002; Jorgensen and Syme, 2000). In the second step, the influence of socio-economic variables and forest visiting behavior on WTP amounts complied reasonably with economic theory and was in line with previous studies (e.g. Elsasser, 1996). These effects were not affected by the addition of the psychological predictors, i.e. the same variables were significant in both the basic and the extended model.

As to the psychological predictors, attitudes towards entrance fees were highly significant in the model explaining protest votes. This confirms the earlier result that protest votes are related to attitudes toward paying for the good being valued (Jorgensen and Syme, 2000). Moreover, negative subjective norms significantly increased the probability of a protest vote. The third psychological predictor, perceived behavioral control, turned out to be inappropriate for explaining protest votes. This result is in line with the theoretical consideration that the decision to accept the

scenario or not precedes the decision about how much to bid and is therefore independent of (financial) constraints regarding the purchase of a visitor permit. Consequently, our results indicate that the TPB without perceived behavioral control as a predictor, i.e. the theory of reasoned action as a reduced variant of the TPB (Fishbein and Ajzen, 1975), could improve our understanding of protest votes.

Regarding the influence of the psychological variables on bid levels, we observed that the impact of the levels “agree” and “disagree” of the subjective norm variable on WTP bids was significant at the 5% level. This result suggests that respondents with positive (negative) subjective norms would be willing to pay more (less) for a visitor permit. Furthermore, positive attitudes towards payment for forest recreation significantly increased bid levels. These influences of psychological predictors indicate that even non-protest voters’ bids may reveal non-economic motives and have to be interpreted carefully. Our findings are in line with the results of a hierarchical regression analysis including the three TPB predictors in Ajzen and Driver (1992): attitude toward paying and subjective norm were significantly correlated with the amount of money to be paid for different leisure activities, whereas perceived behavioral control was not significant. Luzar and Cossé (1998) also found that subjective norm and attitudes were significantly related to WTP. In contrast to our approach, they assessed attitudes towards the good to be valued and found a stronger relationship between attitudes and WTP, but they did not include perceived behavioral control. Our results differ from those of Pouta and Rekola (2001), who found that subjective norm was not significant in any of the models explaining WTP for abatement of forest regeneration, whereas perceived behavioral control was highly significant. Furthermore, Werner et al. (2002) found that WTP for Alzheimer’s disease drug treatment was significantly influenced by subjective norm and perceived behavioral control but not by attitude toward paying.

Regarding the overall impact of psychological predictor variables, former studies led to the conclusion that extending CV models based on the TPB considerably improved their goodness of fit (Luzar and Cossé, 1998; Werner et al., 2002). Our results show that this conclusion requires some qualification. First, the suitability of the TPB to explain WTP responses depends on which aspects of these answers are considered. Whereas the overall impact of the psychological predictors showed that the TPB had a great potential to improve the models explaining protest votes, the predictors’ ability to explain bid levels was limited. Second, our results suggest that different measures of goodness of fit should be considered. While an increase in the adjusted R^2 would indicate that the extended model explaining WTP bids was better than the basic model, the higher AIC value suggests the opposite. Comparing the two nested models with an F -test provided more detailed information: the hypothesis of no improvement

¹³As one reviewer pointed out, given this legal situation the value of forest recreation could be assessed by eliciting visitors’ willingness to accept (WTA). The formulation and acceptance of a hypothetical scenario for the assessment of WTA, i.e. a scenario proposing compensations for taking away the right of free access to the forest, would be an interesting topic for further research. However, we preferred a WTP question because this approach makes sure that individuals consider their budget constraints. Responses to WTA questions are not restricted by individuals’ income which is one of the sources of disparity between WTP and WTA measures (e.g. Mitchell and Carson, 1989).

by extending the model had to be rejected at the 5% significance level but not at the 1% significance level.

A limitation of our study was that we strictly followed the TPB and only assessed attitudes towards the behavior, i.e. attitudes towards paying for the good “entering the forests”. As has been shown in other CV studies (e.g. Ajzen et al., 1996), WTP amounts can also be related to attitudes towards the good to be valued. Regarding the valuation of forest recreation, it might be difficult to observe variability in the attitudes towards the good to be valued, because respondents generally hold positive attitudes towards urban forests (Tyrväinen, 2001). Further extensions of the original TPB model include additional predictor variables such as past behavior (Bentler and Speckart, 1979) or knowledge about the resource to be valued (Meyerhoff, 2004). Whereas additional predictor variables obviously raise the explanatory power of the models, their assessment increases the complexity of the survey. The length of the questionnaire has to be as short as possible, especially in on-site surveys, and a trade-off has to be attained between the sophistication and practicability of the method. For practical reasons as well we applied a basic approach to assess the psychological variables. Instead of measuring attitudes and the other predictors with a list of items, each variable was represented by a single statement. Therefore, the results have to be interpreted carefully and further research is needed to test whether our results hold in other contexts.

In conclusion, the results of our study show that the potential of the theory of planned behavior to explain WTP responses depends on the focus of the analysis. First, the implementation of the psychological framework was successful in explaining protest votes. This finding supports the assumption that protest votes reflect behavioral intentions and therefore can be explained within the attitude-behavior framework proposed by Fishbein and Ajzen. Second, including psychological predictors only marginally improved the overall performance of the models explaining bid levels. Accordingly, the ability of the TPB to explain how much respondents to a CV survey would pay has to be questioned. Our results corroborate that WTP bids reflect respondents’ valuation of the good and not the strength of their intention to pay for it.

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The perceived scenic effects of clearcutting in the White Mountains of New Hampshire, USA

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Abstract

The scenic effects of clearcutting have been a volatile issue for the American public for much of the past century. A better understanding of the scenic perceptions associated with the cumulative visible effects of clearcutting should contribute to better decisions about its use. This study evaluates the scenic impacts of simulated alternative clearcutting management systems for the White Mountain National Forest. Alternatives represented an unharvested view, and views with removal of 1–5% of the timber every 12 years using either scattered or concentrated clearcut units of 5, 15 and 30 acres in two viewsheds. A random sample of local citizens, four groups of opinion leaders, and US Forest Service employees evaluated these alternatives. Each factor accounts for significant differences in scenic value. All groups rated the scenic value of unharvested scenes very high. All groups find a large drop in scenic value with the introduction of even the least intense harvesting activity. All groups indicated a statistically significant decrease in visual quality as the intensity of harvesting increases. This effect continues throughout the range of harvesting intensities until the level of sustainable yield is reached. In addition, patches 12–15 acres in size were preferred to larger and smaller ones.

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Keywords: Landscape perception; Forest aesthetics; Forest management; Clearcutting

1. Introduction

In the 1993 monitoring report for the White Mountain National Forest, forest supervisor Rick Cables wrote that “there is a wide and increasing interest in the concepts of ecosystem management, a principle which we believe is well addressed in the existing plan although subject to change as our monitoring efforts continue. The growing question, though, is the ‘place’ of the Forest in the wider landscape” (Cables, 1993, p. xi). One of the Forest’s goals in response to this issue of ‘place’ is to conduct all management activities with full recognition of the effect on Forest appearance. The foundation of this sensitivity to scenic value is “realizing the importance to society of a natural (appearing) landscape distinct from the man-made environments otherwise dominant in the East (USA).” As a result, project plans are frequently adjusted. “This is especially true for those areas that have experienced

residential development since completion of the original (forest plan) inventory. Awareness of the concern over clearcutting has led to reduced clearcut acreage or identification of alternative prescriptions for many projects” (Kokx, 1993, pp. 52–53).

Irrespective of its effect on harvesting volume, Rick Cables observes that “with respect to clearcutting, the problem boils down to this: Of the 339 inland animal species in New England, 257 of them have a primary or secondary dependence on a forested habitat. Of these 257 species 90% (233) of them have a primary or secondary dependence on forest vegetation in the regeneration (0–10 years old) or young (from 10 up to 69 years for some species) age classes. Clearcutting is the vegetative management practice that produces these various age classes of the Forest. It is difficult to provide enough of this habitat when the means of doing so is one that so many people find objectionable — clearcutting” (Cables, 1993, p. v).

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Fig. 1. Location of the White Mountain National Forest in the northeastern United States.

Forest Research Station's Chicago Unit. The intention was for this research to "help us better understand viewer response to visual cumulative effect and help in the design of multiple unit, multiple timber sale activities that produce opening contrasts in the landscape over time. This includes both clearcuts under even-age management and group cuts¹ under uneven-aged management. It is anticipated that the results of the work will lead to more inclusive standards and guidelines for visual cumulative effect than what is currently available" (Kokx, 1993, p. 54).

The remainder of this introduction sketches the historical context of opposition to clearcutting in the USA, the situation in upper New England at the time of the study, observations about the visual effects of responding to public pressure to reduce the size of clearcuts, and the research objectives.

1.1. National historical background

During the final quarter of the 19th century, Americans were confronted with "cutover lands in the East, which took on the appearance of wastelands, (and) deeply influenced public opinion" (Hays, 1987, p. 15). There also was concern among national leaders about future sources for timber and the protection of water supplies. In 1891, Congress and President Harrison established the first national forest reserves in response to the public's outrage over this rape of the American landscape. By 1907 there were 150 million acres of public Western timberland set aside as National Forests. The Weeks Act of 1911 authorized the acquisition of private lands in the East. Additions to the eastern National Forests, including the White Mountain National Forest in New Hampshire, were made in earnest during the 1920s and 1930s. Today the National Forest system includes 191 million acres.

The 100 year history of the National Forests, and forest management in general, has seen a sustained struggle

between competing interests and values. Gifford Pinchot, the first chief of the Forest Service, asserted that "the first great fact about conservation is that it stands for development" (Pinchot, 1910, p. 42). Pinchot led the scientific forestry movement to provide the greatest good to the largest number for the longest time. This instrumental or utilitarian perspective of the forest as a source of commodities has dominated official policy from the beginning.

On the other hand, the American public has long expressed a deep interest in rugged forested lands for their intrinsic values, such as scenery, habitat for wildlife, and a place for nature-oriented recreation. John Muir was a leader of the early proponents to preserve wildlands for their intangible values. Often at loggerheads with Pinchot, he pioneered the creation of our National Parks, but lost the battle to protect our National Forests from future harvesting. When the Forest Management Act of 1897 established the Forest Service, only two purposes were mentioned: wood production and water supply.

The issue of how our forests would be managed was not settled so easily, however. The earliest example of citizens insisting that forests satisfy both utilitarian and amenity values dates from 1895. This led to establishing the Society for the Protection of New Hampshire Forests in February, 1901. One of the oldest environmental conservation organizations, it is dedicated to "combining and balancing in its own distinctive way tendencies toward the restoration and management of forests both as sources of wood production and as attractive environments" (Hays, 1987, p. 67). While not specified as an intended use of the National Forests, scenery was an implied benefit from the time of the Organic Act. "Beauty" was first mentioned in the 1903 Annual Report of the Forester. The first documented forest management plan to consider scenic values was in 1908. Landscape architects were first employed to provide for recreation and scenic values in 1916 (USDA Forest Service, 1995, p. G-2).

After World War II, changes came to American society that greatly affected the National Forests. A general affluence spread throughout the country and the standard of living quickly rose. For the first time all strata of society had sufficient discretionary income and time to indulge themselves with attention to environmental amenities. In addition, the new interstate highway system made it possible for people in urban centers to easily and quickly travel to National Forests and National Parks. Hays (1987, p. 35) writes that this "search for amenities became a normal expectation on the part of most Americans." He is thinking in particular of the demand for suburban housing in safe, healthy and pleasant surroundings, the universality of family automobiles taken on Sunday afternoon scenic drives in the countryside, the burgeoning recreational use of public natural areas, and the ever present color snapshot to help us remember those special

¹Group cuts" refers to a group selection harvest cut. In group selection two or more trees are harvested to create an opening with sufficient light to regenerate shade intolerant species.

times. While the booming economy could supply the material goods, “many such amenities could not be purchased... Since the private economy could not supply these environmental amenities, there was increasing demand that public and private non-profit institutions do so” (Hays, 1987, p. 35).

Of course this prosperity fueled a sharp increase in demand for wood products to build the suburban houses, print the newspapers, and provide the furniture. To its great satisfaction, the proponents of scientific forestry had worked out the details of how to provide a sustainable supply of wood in the most efficient manner. “Shortly after World War II (partial cutting) began to be replaced with even-aged management, a mode of organizing the forest area in terms of subunits, each with trees of uniform age” (Hays, 1987, p. 395). “Even-aged regulation was to be carried out through clearcutting... Such clearcutting, in both the East and the West, prompted enormous public outcry because it destroyed the amenity values of the ‘forest as environment’... Even-age management received considerable support from industry... the close relationship between clearcuts and lower costs stimulated a tendency toward larger areas for even-age treatment.”

This set the stage for a confrontation between the modern-day descendants of Pinchot and Muir. “To foresters, a forest was confined to those trees that were valuable for commercial purposes... Environmentalists and ecologists, on the other hand, developed a view of the forest based on direct experience and use” (Hays, 1987, p. 393). While the conflict came to a head in West Virginia on the Monongahela National Forest, it could have occurred in many places. The 1964 management plan prescribed that selection cutting be substantially replaced by even-age management or clearcutting. There was a huge public outcry by the 1970s, when they saw the results of extensive clearcuts (Boerner, 1986). The Forest Service was taken to court and lost. Opposition here and elsewhere led to the National Forest Management Act of 1976 that introduced regulations to the use of clearcutting and increased the public’s opportunity to influence forest management plans.

1.2. Current public opinion

Public concern about clearcutting continues to this day. Surveys during the 1990s have found that 60–70% of the public opposes clearcutting on public forestlands (Bliss et al., 1993; Luloff et al., 1993; Shindler et al., 1993). There is also a wide consensus among 70–80% of the American public that federal forest management place more emphasis on non-timber products (Shindler et al., 1993). When included in surveys of non-industrial private forest owners, scenic value is frequently mentioned as a forest benefit. Butler and Leatherberry (2004) report that family forest owners hold 42% of the woodlands in the USA. In a national sample survey, they found that “enjoyment of

beauty and scenery” was the number one reason for this group to own forestland.

There is a significant literature grounded in empirical research concerning people’s perceptions and preferences for forest management activities (Hoffman and Palmer, 1996; Ribe, 1989; Ryan, 2005). While much of this research includes clearcut harvest scenes, it is based primarily on views within or near to the forest activity (e.g., Brunson and Shelby, 1992; Karjalainen, 1996; Kellomäki, 1975; Ribe, 1990; Savolainen and Kellomäki, 1984; Vodak et al., 1985). The “beauty strip” is an effective and often mandated means to screen the public from the effects of harvests that might otherwise be seen along roads or next to other public lands. However, it is often not possible to screen harvesting activities from public places with more distant views, such as those investigated in the study reported here.

Another feature of much of the literature is its focus on recently implemented management activities (Brunson and Shelby, 1992; Karjalainen and Komulainen, 1999; Ribe, 2005). Much of the negative impact is due to the raw nature of a fresh clearcut (Karjalainen, 1996), which diminishes over time (Silvennoinen et al., 2002). Shelby et al. (2003) returned annually for a decade with students to rate six different silviculture treatment sites. Right after harvest, the scenic ratings of the clearcut site was substantially below the other five treatments (Brunson and Shelby, 1992). However, a decade later they reported that ratings for all sites had both improved and converged; the clearcut site no longer had the lowest scenic rating. Rudis et al. (2004) report similar findings after 4 years. A related issue is that when viewed from a distance the landscape is a montage of management activities that have occurred at different times, and this cumulative effect needs to be considered. For instance, Ribe et al. (2002) evaluated existing vistas of forest management activity on public land in the Pacific Northwest and compared them to simulated views after 20 years of “ecosystem management.” The interpretation of their results are complex, but the fundamental basis of their study is clear—it is difficult but very important to investigate cumulative effects if we are to understand the implications of forest management decisions.

Much of this research has been an attempt to identify approaches to mitigate the large drop in scenic value that occurs immediately after a clearcut harvest. Ribe (2005, p. 289) found that “a harvest area of completely cut-over areas of any size, number or form is enough to elicit perceptions of ugliness, when seen looking directly at slopes in vista views.” He concluded that retaining 25% of the pre-harvest trees was necessary to provide adequate mitigation. However, others have found that the size, intensity and pattern of clearcuts does have a significant effect on viewer perceptions.

Size of the clearcut opening is one of the more common attributes that have been investigated. Karjalainen (1996) found that the size of clearcut openings was the most

important attribute in determining scenic value; larger openings had lower scenic value. Schroeder et al. (1993) found that while the smaller sizes were slightly more preferred, differences in this size range (2–15 acres) were relatively unimportant compared to the amount and treatment of slash. There is some evidence to suggest that recreationists do not even recognize the smaller clearcut openings commonly used now as “clearcuts.” For instance, Becker (1983) interviewed state park visitors who had passed through 4–6 acre areas that were four to five years old and just under half of the visitors recognized the areas as clearcuts.

In general, increasing intensity of clearcutting leads to decreasing scenic value (Brunson and Shelby, 1992; McCool et al., 1986; Ribe, 1999; Vodak et al., 1985). Paquet and Belanger (1997) found that even a small clearcut caused a measurable scenic impact, and that the impact increased as intensity increased. However, they also found that the public would accept one large clearcut that occupied 25% of the visible forest. If smaller dispersed clearcuts were used, some groups found it acceptable to harvest as much as 50% of the view.

The pattern in which clearcuts are placed in the landscape relative to the viewer also influences their scenic impact. The closer the clearcut is to the viewer, the greater its impact. In addition, the impact is greater when clearcuts are concentrated together, rather than dispersed throughout the view (Brush, 1979; Schuh, 1995).

1.3. Controversy in northern New England

These broad public sentiments are seeking expression in public policy. New England may seem distant from the politicized controversy surrounding the spotted owl in the Pacific Northwest or the pileated woodpecker in the Southeast. However, at the time of this study clearcutting controversies were flourishing in the three northeasternmost states of Vermont, Maine and New Hampshire.

Forest products are the second largest industry in the state of Vermont and a valued part of the state economy. However, the regional planning commission in Vermont's Northeast Kingdom recently joined a statewide environmental organization in an effort to further regulate forestry practices. They released a study documenting extensive clearcutting in four towns over the past 15 years. Their hope is to avoid the boom-and-bust harvesting cycles of the past. The regional commission's planning coordinator observed that “nearly every town I have worked with in the past four years has voiced concern about the increasing amount of clearcuts” (Caledonian-Record, 1994b). An industry representative replied that “clearcutting is the buzz word that offends the public, clearcutting is a very small percentage of the type of sound forest management that is occurring in Vermont's forestland” (Caledonian-Record, 1994a).

In the early 1980s, extensive clearcutting in Maine was initiated in response to a spruce budworm epidemic. This

led in 1989 to the passage of the Forest Practices Act that limits clearcuts to 125 acres. However, in 1996 the state's Green Party submitted enough signatures to force a referendum on banning clearcutting from the North Woods and severely restrict other forestry practices. The former Green Party gubernatorial candidate believes that “this is the last vestige of a great forest that is being destroyed... this is as important as saving the ancient forests of the Northwest” (Rimer, 1996). Faced with polls that indicated upwards of 70% public support, Maine's forest products industry and the state government proposed a compromise alternative known as the Compact. It would reduce the maximum size of clearcuts throughout the state to 75 acres. On November 5, 1996, voters were asked to decide whether the state should keep the existing forest practices law, ban clearcutting altogether, or institute the compromise proposed in the Compact. The vote split roughly into thirds. Without a majority vote, the current law remained in effect. However, the issue is one that has remained active in Maine.

In New Hampshire, many of the laws that regulate forest practices were written early in the century. Incremental revisions have led to outmoded regulations and created inconsistencies. There are now three different state departments with the responsibility to supervise forestry practices. In 1993 the state legislature directed that an advisory group be established to review the forestry laws (Roundtable, 1994). This group, the Roundtable on Forest Law Recodification and Revision, brought together representatives from government, industry and environmental organizations. The director of the New Hampshire Timberland Owner's Association characterized the group as “taking a century's worth of forestry laws, a crazy quilt put together without regard, giving it a very logical flow and structure” (Feingold, 1994). The group made great strides in forming a consensus from initially disparate positions. When they submitted their report the disposition of only one major issue was still unclear — clearcutting (Roundtable, 1994).

These positions clearly represent the context within which this study was undertaken. The Roundtable's representative from the Appalachian Mountain Club believes “there are legitimate reasons for clearcutting, but it's something that has the greatest potential for abuse ... regulation is needed to prevent the kind of indiscriminate liquidation of extensive tracts that have become common ... (with) no intention for long-term, intelligent management.” The representative from the New Hampshire Timber Harvesting Council characterized “support for clearcutting regulations as coming from those who see it as an esthetic problem ... [regulation] should be based on a scientific forest management point of view.” He worries that regulating clearcutting is just another example of the individual's rights being sacrificed to what some consider the public good (Feingold, 1994). Both perspectives are a real concern for the North Country where timber products and tourism are the two largest industries.

1.4. Visualizing the problem

The days of clearcut mountainsides are in the past on US Forest Service lands, though it may still occur in some areas on private lands. However, smaller clearcut openings are still common. Fig. 2 illustrates the cumulative effect of harvest patch size for a 500 acre property under even-age management with a rotation length of 120 years. Every 10 years, 40 acres are harvested; it can take up to 40 years for a clearcut patch to regenerate sufficiently to be indistinguishable when viewed in the middle distance. Scenario A represents the effect of a single large cut as visually coherent and unified — a single new impact each decade.

Contrast this with Scenario B in Fig. 2, in which the harvests are made in eight separate 5 acre patches every decade. The visual effect of these harvests also takes 40 years to recover completely. During that time, the many individual small patches accumulate. They create a scattered and fragmented pattern that appears “moth-eaten” from the middle distance.

As these two simple visualizations demonstrate, the public’s pressure to reduce the size of clearcuts may not have the visual quality effects that they hoped to achieve.

1.5. Objectives

The purpose of this study is to provide guidance for the scenic value management of clearcutting on National Forests. This goal is addressed from the perspective of three important interest groups: local citizens, opinion leaders, and forest managers. The specific objective is to

investigate the relation of clearcut intensity, size and pattern to forest scenic value.

2. Methods

2.1. Reconnaissance and photography

Members of the study team conducted a field reconnaissance of the situation in the White Mountains in August 1992. This gave the team an opportunity to become familiar with the visual conditions of forest management in the White Mountain National Forest.

The Forest Landscape Architect selected the two viewpoints used in this study. The view from Middle Sugarloaf Mountain is taken at 115° from north down the Zealand River valley. The management area within which the clearcuts are located is approximately 2.0 square miles. Mount Field on the right side of the photo is 6.0 miles away. Mount Washington is to the left, just outside the photograph. The second photo is taken at 147° from north on a ledge just below the peak of Welch Mountain. The Mad River is at the foot of the view and Sandwich Notch is in the center of the photo (though obscured from view). The clearcuts are located within a 2.8 square mile management area. Both viewpoints are accessible from popular hiking trails that receive seasonally high use. Both views are predominately in the middle ground, a zone 1–3 miles from the viewer, and lack a visible foreground. There is recent clearcutting activity apparent in both views.

The views were photographed with Kodak Ektar 35 mm color print film on a sunny day with a light haze. This was a very dry year in the White Mountains, and the forest

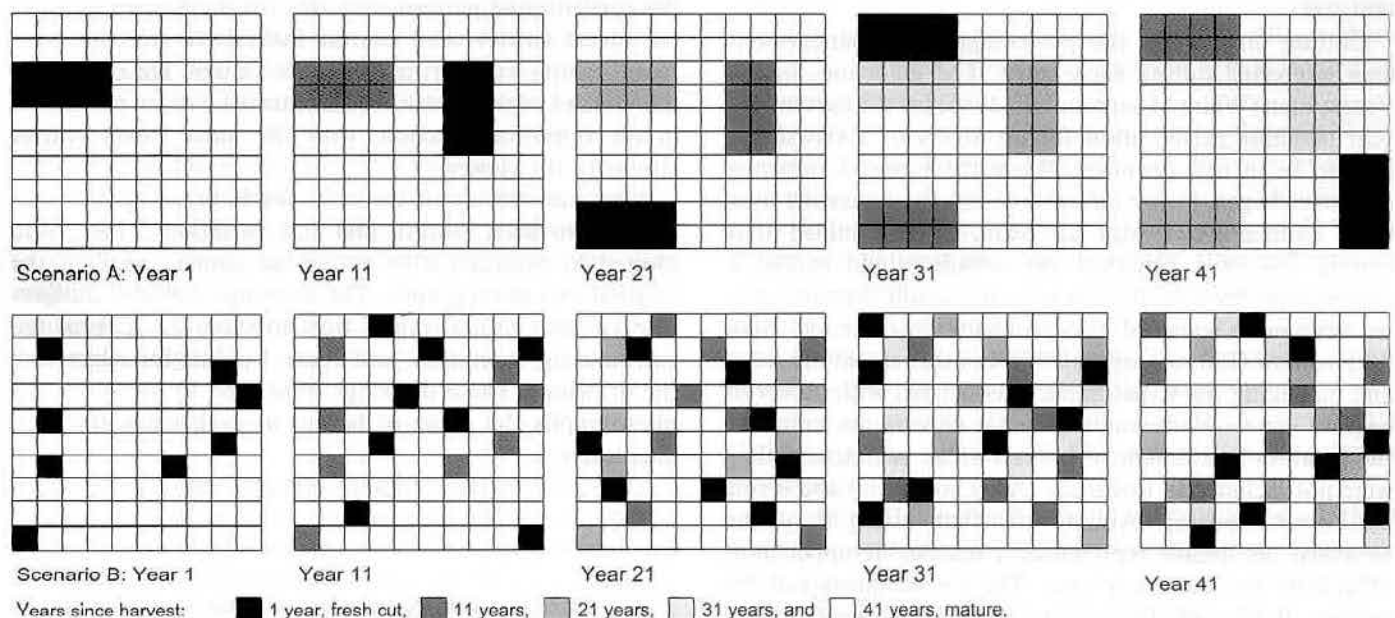


Fig. 2. This 500 acre site is divided into 100 equal sized stands. The trees are managed on a 120 year rotation. The harvest plan calls for 40 acres to be harvested every 10 years. It is assumed that from a distance, a clearcut patch appears mature in 40 years. In Scenario A the harvest is one 40 acre patch; in Scenario B there are eight separate 5 acre patches.

colors were more brown and yellow than in years with average rainfall. A 50mm lens with an ultraviolet filter was used to approximate a viewer's normal cone of focal vision and keep optical distortion to a minimum. Additional middle ground photographs were taken of other areas representing the types and ages of regeneration described by possible alternative management scenarios. These would provide information about the patterns and textures necessary to create accurate visual simulations.

2.2. Alternative scenarios

While many forest studies simulating environmental factors are conventionally based on checkerboard patterns (e.g., Li et al., 1993), this simplification is inappropriate for a visual study. It was decided that the most realistic approach would imitate the way the Forest Landscape Architect actually allocated and designed areas for harvest cuts. Cutting entries are normally made between 10 and 12 years apart on the White Mountain National Forest. Therefore, the decision was made to simulate three entries showing clearcut openings representing approximately 1 year, 12 years and 24 years of regeneration growth. Showing more than three entries was not necessary, since at this distance the visual effect of the original clearcut normally disappeared after 30–35 years. All harvest openings were irregular in shape, but like a single blob than one with many fingers. There were no visible groupings of trees retained within the harvested area. These attributes reflected the current practice on the Forest at the time of the study. Three additional variables were identified as being important to consider in creating the alternative scenarios: cutting intensity, cutting pattern, and cutting unit size.

Cutting *intensity* is the percentage of a management area harvested during each entry. The guidelines in the Forest Plan (White Mountain NF, 1986) for the current 10-year planning period allow for up to 7% of a viewshed's area to be in new openings. When the Forest Landscape Architect began to lay out and design the scenarios over three cutting cycles with his team, he determined that cutting 7% of a viewshed per decade would exceed a comfortable level of disturbance, and could therefore not be sustained. Some of the problems encountered were keeping new clearcuts separated from other recent harvests, and managing the visual impacts associated with access to harvest areas. While environmental constraints influence the location and design of harvest areas in practice, they were not included in this study. After some trial and error, the Forest Landscape Architect felt that cutting 5% of the viewshed per decade represented a reasonable upper limit of activity for the study area. The six scenarios call for cutting 0–5% of the study areas per decade. The simulations show 25 years of cumulative effect where 0%, 3%, 6%, 9%, 12% and 15% respectively, of the view has been harvested.

Two design concepts or *patterns* were used.² The first distributed or scattered the cutting units throughout the viewshed; the second concentrated the units for each entry into the front, middle or background as seen from the viewpoint. The Forest Plan assumes that cutting would be scattered randomly throughout a view. However, to implement projects it is common to concentrate sale units into a smaller portion of a viewshed. This is a tricky proposition in any case, since what appears scattered from one viewpoint, may appear clustered from another. When this occurs, the percentage of the view affected around the sale is substantially higher, but it will be lower in other parts of the viewshed.

The *size* of the cutting units is based on the current guideline in the Forest Plan (White Mountain NF, 1986). It provides that harvested areas in zones with level 1 sensitivity and moderate variety have 10 or fewer observable acres (USDA Forest Service, 1995). Since some portion of a unit may not be seen, this translates to an average unit size between 10 and 14 acres. The maximum unit size allowed in the Forest Plan is 30 acres. This establishes an upper range in size for units from 20 to 30 acres. The minimum unit size used for the simulations is 4–5 acres.

The process of designing the scenarios was similar to that normally used in laying out harvest areas. Landscape architects on the White Mountain National Forest used Perspective Plot software. They designed and located several appropriate units to create each possible combination of viewpoint, pattern and size. For each simulated alternative, the appropriate units were selected that would produce the required acreage for each entry period and that would present an acceptable design, both for that individual entry and for the cumulative effect. In designing the concentrated pattern scenarios for the Sugarloaf view, the oldest entries were nearest the viewer and the most recent entries were farthest from the viewer. The design for the Welch Ledge scenarios' concentrated pattern proceeded in the opposite direction, with the most recent entries closest to the viewer.

A master overlay of the units for both viewpoints was created for each pattern and size variation. These were plotted in perspective to match the camera view of the original two photographs. The drawings included outlines of each unit, with a ring of trees to show the scale of the surrounding vegetation, and control points for registering the drawings. These drawings were used to locate on the photographs the areas to be cut at each entry for each alternative.

²As used in this study "pattern" refers to the location of clearcut patches in the landscape, and not the shape of the patches themselves. It was not until the year after this study began that clearcut patches with islands of residual trees or convoluted shapes were used on the White Mountain National Forest.

2.3. Visual simulations

The original 3.5×5 in photographs from the two viewpoints were scanned at 400 dots per inch to create full color (24-bit) digital images. The existing scenes were first edited using Photoshop software to simulate mature revegetation in areas where existing harvesting was apparent. Natural openings were left unchanged.

Overlays locating the harvest units for each alternative were used as guides to insert the clearcut areas into the scenes. The appropriate regrowth was digitally painted into the clearcut areas using image material scanned from photographs of harvested areas of the appropriate age at different sites. Care was taken to match the tones and textures that highlight the visual contrast between the old and new vegetation. Particular attention was paid to light and shadow patterns. A site visit to the White Mountain National Forest was made when the first simulations were being created to field check the quality of the simulation techniques. The final images were therefore of a consistent high quality. Examples of the simulations are shown in Fig. 3, and further details concerning their creation are provided by Shannon et al. (1994).

The resulting 64 scenes, (2 views $\times$ 2 patterns $\times$ 5 intensities $\times$ 3 sizes = 60 scenarios, plus the 2 revegetated and 2 original scenes), ranged in size between 2.5 and 4 MB. They were printed to 35 mm slides in 24-bit color with a resolution of 4000 dots per inch and were used to survey the North Country Advisory Board members.

High quality color copies of the simulations were printed with a four-color web offset process for the questionnaires used by all other groups. Each image was 3.2×2.1 in with a fine-line black border. The 32 images from a single viewpoint were arranged into a four-page booklet with eight images per page. The first page contained the scene without any clearcuts and a series of six scenes representing scattered clearcuts of all three sizes with 6% and 15% of the area visibly harvested. These seven scenes provided a representative subset of the simulations for possible use in special questions or surveys. The final image on the first page was the concentrated pattern of smaller clearcuts covering 15% of the view; it was repeated on the third page to provide a check on the validity of the ratings. The original view was not included. Other than the selection of images to put on the first page, the order of the images was randomly assigned.

2.4. Respondents

There are three separate samples used in this study: a random sample of local citizens, four groups of opinion leaders responsible for making forestry-related decisions, and environmental professionals working on National Forests.

2.4.1. North Country citizens

A random sample of households was drawn from a digital telephone directory of towns served by the North

Country Council (ProCD, 1994). The first mailing was in mid-January, with a follow-up mailing on February 6, 1995. The US Postal Service returned as undeliverable all the envelopes for some towns. The residents at some of these addresses replied to the second mailing, indicating that there was a postal service delivery problem, possibly because of the season. It is possible that there were additional unknown delivery problems. A total of 77 usable surveys were returned, representing a 24% response. While this response is modest, there is no apparent reason to suspect that non-delivery introduces bias into the effective sample.

2.4.2. Opinion leaders

Four groups of opinion leaders were selected to represent a broad range of forest-related interests. The Appalachian Trail Conference represents environmental groups. The North Country Council Advisory Board represents their constituent communities. Two specially convened advisory groups, the Roundtable on Forest Law Recodification and the Forest Resources Plan Steering Committee, represent the diversity of stake holders in the future management and regulation of New Hampshire's forests. They both include representatives from environmental groups, the forest industry, and the public.

An Appalachian Trail Conference (ATC) working meeting was held October 29, 1995 at the Hubert Outdoor Center in Fairlee, Vermont. The ATC is made up of trail clubs and interested citizens responsible for managing the Appalachian Trail. This National Scenic Trail runs 2000 miles from Springer Mountain in Georgia to Mount Katahdin in Maine and passes through the White Mountain National Forest. They used the printed simulations and completed the standard opinion leaders questionnaire as part of the scheduled meeting. All members present at the time agreed to participate, which yielded 24 usable responses.

The North Country Council Advisory Board (NCC) is composed of citizens appointed to provide oversight and policy review for the North Country Council, Inc., a regional planning agency. They evaluated slides of the simulations and completed the standard opinion leaders questionnaire at their normally scheduled quarterly meeting on November 10, 1994. Their evaluation was followed by a presentation on managing forest aesthetics and the findings from the pilot study in which hikers were interviewed at the two study viewpoints (Palmer et al., 1995). All 43 members in attendance participated.

The Roundtable on Forest Law Recodification (RT) is a group convened to make recommendations to change New Hampshire's forestry law. They completed their charge in the fall of 1994. All 17 members were sent a questionnaire by mail in January with a second follow-up mailing in February 1995. Eleven returned the survey completed.

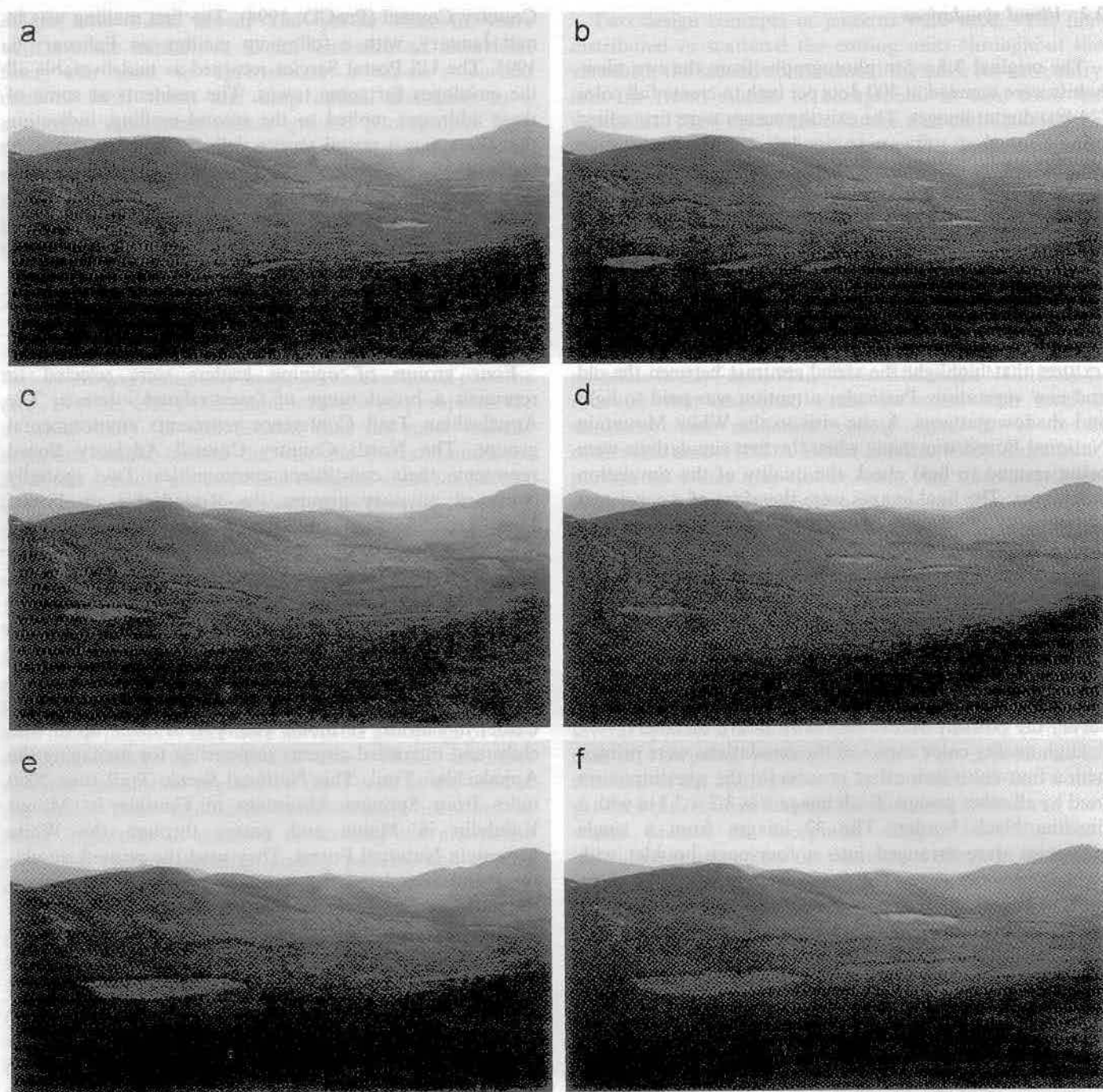


Fig. 3. Examples of the Sugarloaf simulations. The left column shows 6% and the right column 15% of the area view being harvested in the past 25 years. The top row shows 4–5 acre harvest patches, the middle row shows 10–14 acres patches, and the bottom row shows 20–30 acre patches.

The Forest Resources Plan Steering Committee (FRC) is a New Hampshire state government committee charged with looking at the statewide Forest Resources Plan. All 27 members were sent a questionnaire by mail in January with a second follow-up mailing in February 1995. Nineteen completed surveys were returned.

2.4.3. Forest Service employees

A directory was obtained containing e-mail and office addresses for employees with professional job titles

stationed on National Forests or in district offices in Region 9 of the US Forest Service (USFS). Region 9 is composed of the Northeastern and North Central states from Maine to West Virginia and Minnesota to Missouri. The final sample includes 364 forest-oriented professionals working at 71 sites. They were mailed the survey on April 30, 1995 with an e-mail follow-up on May 9. Overall, 56% of the USFS employees responded, including nine archeologists, 13 engineers, 87 foresters, 10 landscape architects, 30 rangers or forest

supervisors, 20 recreation specialists, and 36 wildlife biologists.

2.5. Response Formats

Respondents completed a questionnaire with the following instructions:

Many of us receive great enjoyment from forest scenery. The accompanying color photographs show possible timber management alternatives from an actual viewpoint in the White Mountain National Forest... Rate the scenic quality of each forest view by assigning it a number between 1 and 10. Assign forest scenes judged low in scenic quality a low number; a rating of 1 is for the very lowest scenic quality. Those judged high in scenic quality are assigned a high number; a rating of 10 is for the very highest scenic quality. Remember to evaluate the quality of the forest scenes rather than the quality of the photography. Use the full range of numbers if you possibly can and rate each view.

Numbered spaces follow for the respondent to write the scenic quality rating for each of the simulations. It was emphasized to the Forest Service employees that their ratings should be "from their own perspective."

2.6. Validity and reliability

Comparability of Sugarloaf and Welch Ledge views: The unharvested (i.e., control) simulations from the two viewpoints were anticipated to be of similar high scenic quality. In most cases, Welch Ledge receives a modestly higher rating, though paired-*t* tests indicate significant ($p < 0.05$) differences for only two of the 12 subgroups studied. Therefore ANOVA results indicating differences between the two sites can be attributed primarily to differences in the harvesting treatments. In particular, the most recent clearcuts are in the background of the concentrated pattern Sugarloaf simulations, while they are in Welch Ledge's foreground.

Validity of simulations: A pilot study evaluated the validity of the simulations used in this study (Palmer et al., 1995; Palmer and Hoffman, 2001). Both sites provided extensive panoramic views. The scenic ratings from these viewpoints, even when the hikers were directed to only consider the valley shown in the photograph, were substantially higher than the ratings of the photograph which shows only a portion of the panoramic view. However, the overwhelming acceptance of the simulations as real photographs by these hikers, their ability to identify the photography that matched their view from among the simulations, and the consistency in their ratings suggest that their use is appropriate for studying alternative clearcutting intensities and patterns.

Intraclass reliability: There is very high agreement over the scenic value ratings within each group. Intraclass

reliability is 0.960 for the residents, 0.979 for the opinion leaders, and 0.994 for the USFS employees (Palmer and Hoffman, 2001).

Inconsistent methods: There are two instances of inconsistent methods that must be accepted as limitations to this study. First, the North Country Council members evaluated slides, while all other groups evaluated printed simulations. Second, while they responded to the same questions, the North Country Council and Appalachian Trail Conference participated as a scheduled part of a meeting, while all the other groups participated through mailed surveys. The possible effects of these differences cannot be evaluated, though there is no reason to believe that they introduce any significant bias.

Table 1

Citizens' and opinion leaders' mean scenic value for levels of harvesting intensity, size of clearcuts, cutting pattern, viewpoint

Factor	Means scenic value				
	Citizens	ATC	NCC	FRC	RT
<i>Percent view harvested</i>					
0	9.01	9.17	9.36	8.24	8.95
3	6.75	5.70	7.22	6.80	7.57
6	5.53	4.52	6.17	5.85	6.43
9	4.76	3.49	4.76	5.34	5.33
12	4.30	3.06	4.19	5.06	4.90
15	3.93	2.84	3.84	4.63	4.46
<i>Size of clearcuts (acres)</i>					
4–5	4.84	3.69	4.76	5.44	4.80
10–14	5.52	4.50	5.39	5.79	6.47
20–30	4.80	3.58	5.56	5.36	5.95
<i>Pattern of clearcuts</i>					
Concentrated	4.78	3.64	4.99	5.27	5.39
Distributed	5.32	4.20	5.48	5.78	6.08
<i>Viewpoint</i>					
Sugarloaf	5.28	4.17	5.76	5.77	5.87
Welch Ledge	5.08	4.00	4.98	5.46	5.81

Table 2

Citizens' ANOVA of the effects from viewpoint, cutting pattern, percent of area cut, cutting guidelines, and their second order interactions on scenic value

Source	df	Sum of squares	Mean square	F	p
Viewpoint	1	43.3	43.3	7.0	0.0083
Control	1	4252.1	4252.1	685.2	≤0.0001
Intensity	4	4351.0	1087.8	175.3	≤0.0001
Size	2	479.7	239.8	38.6	≤0.0001
Pattern	1	314.9	314.9	50.7	≤0.0001
Intensity*Size	8	115.5	14.4	2.3	0.0172
Intensity*Pattern	4	15.4	3.9	0.6	0.6466
Size*Pattern	2	295.1	147.5	23.8	≤0.0001
Error	4604	28,571.3	6.2		
Total	4627	38,434.5			

3. Results

3.1. Citizens' scenic quality evaluation

The citizens' mean ratings for the percent of the view harvested, the size of the clearcuts, the pattern of the three harvest entries, and the viewpoint are given in Table 1. Table 2 provides the results of an analysis of variance (ANOVA) for the citizens' data summarized in Table 1. There are very significant differences found for all the main effects. However, since there is no significant difference between the fully reforested simulations of Sugarloaf and Welch Ledge (paired $t = 1.32$, $p = 0.193$), the differences between the two viewpoints will not be discussed. The interaction of size with pattern, and intensity with size are also significant. Intensity and pattern do not show a significant interaction. Fig. 4 presents plots

of the main effects and their interactions to assist in their interpretation.

Control: These tables and figure clearly show that the unharvested control condition has a much higher scenic value than any of the harvested conditions. This is the most significant difference in Table 2's ANOVA summary. It indicates that the spectacular view from either site is severely impacted by the introduction of any harvesting treatments.

Intensity: The greatest impact to scenic value occurs with the first introduction of harvesting. While the intensity of harvesting increases in equal increments, the increment of scenic impact is less with each step. While there may be a point where additional harvesting does not cause an increased visual impact, it is beyond the rate of a sustainable harvest at these sites. Tukey's test for least significant difference (LSD) indicates that the decrease in

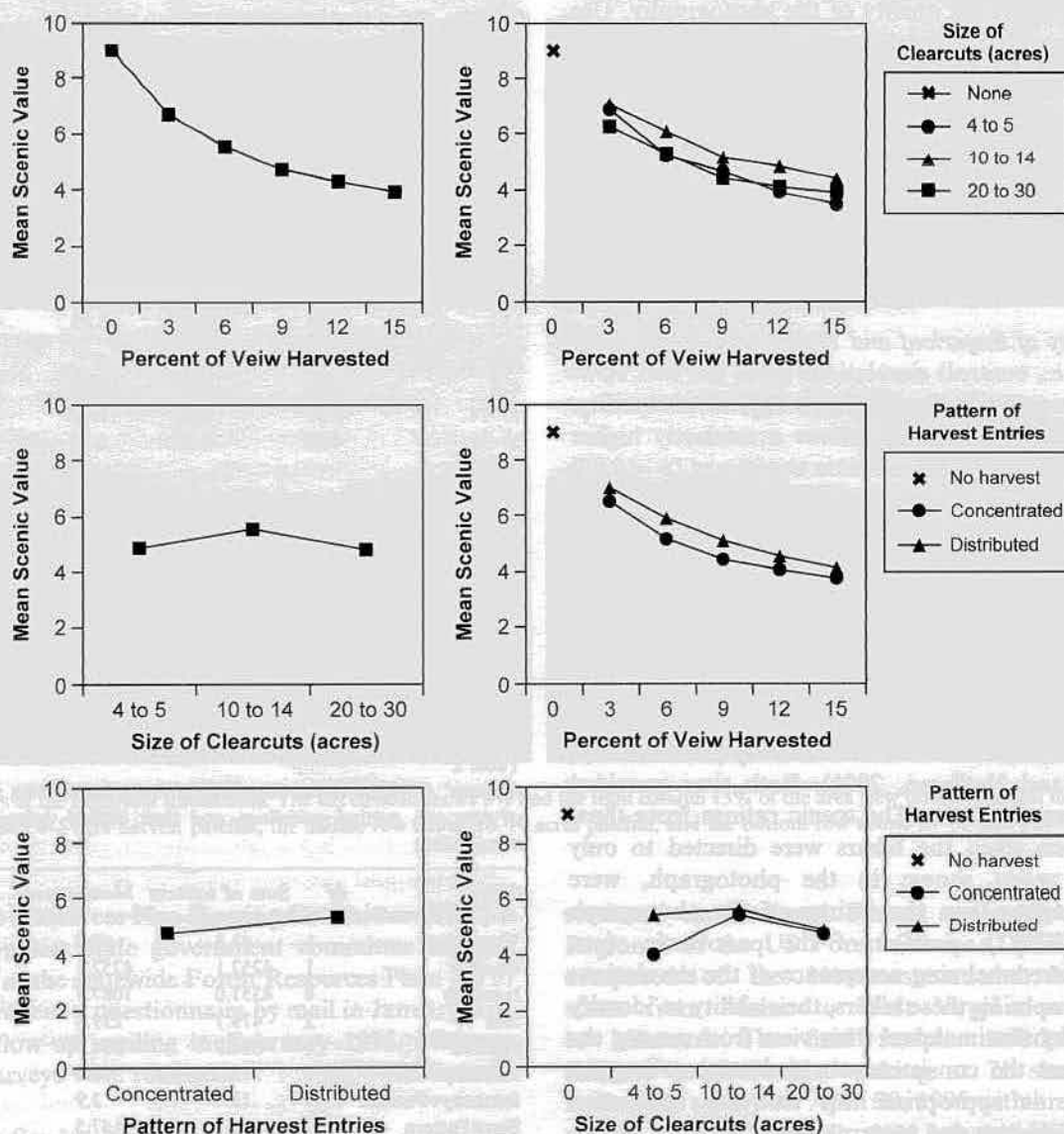


Fig. 4. Plots of the mean scenic value perceived by North Country citizens with the percent of view harvested, size of clearcuts, pattern of harvest entries, group, and their interaction.

scenic quality with each increment of harvest intensity value is significant.

Size. The ANOVA indicates that differences among the size of clearcuts also have a significant effect on scenic value. Table 2 and Fig. 4 show that clearcuts in the 10–14 acres range are preferred to those both half the size and twice as large. Tukey's LSD test shows that preference for the medium sized clearcuts is significantly higher than for the other sizes. There appears to be no significant difference between the smaller or larger clearcuts.

Pattern. The pattern of locating harvest areas also has a significant effect on scenic value. Dispersing the recent harvest areas throughout the viewshed lessens the overall visual impact. While forest managers may find it operationally desirable to concentrate harvesting activity in a smaller area, this leads to a greater perception of scenic impact.

Interaction of size and intensity: The scenic value of the medium size clearcuts is approximately 0.7 units above the larger clearcuts for all intensities of harvesting. The smaller clearcuts begin within 0.2 units of the medium clearcuts. However, their impact is slightly greater than the other sizes, so that they are 0.9 units less than the medium sized clearcuts at the highest intensity of harvesting. This result may reflect the public's sensitivity to the undesirable moth-eaten appearance of many small clearcuts.

Interaction of size and pattern: There is not a significant difference between the concentrated and distributed patterns for the standard and larger sized clearcuts. However, the visual impact of smaller clearcuts is more severe when the harvest areas are clustered together.

3.2. Opinion leaders' scenic quality evaluation

The mean scenic values of the four groups of opinion leaders are presented in Table 1 for each harvesting intensity, size, pattern, and viewpoint. The ANOVA results reported in Table 3 includes group membership as one of the major effects. For three of the groups, there is no

significant difference between the mean scenic values for the unharvested condition at the two viewpoints. Only for the NCC is there a significant difference (paired $t = 2.23$, $p = 0.031$). Fig. 5 shows the main effects and paired interactions plotted for each group of opinion leaders. The following discussion interprets these results.

Control: The contrast between the unharvested control scene and all the harvest treatment simulations is the most significant difference in the ANOVA for the opinion leaders groups.

Intensity: The initial impact associated with introducing a harvest into the scene is greater than any of the other incremental harvest intensities. However, Tukey's LSD indicates that the decrease in scenic value with each increment in Fig. 5 is significantly different from the preceding value ($p < 0.05$). This indicates that there is no threshold within the limits of sustainable yield where harvesting impacts flatten out. Further inspection shows that though there are some differences, each group of opinion leaders follows this general pattern. The ATC respondents are most sensitive to the initiation of harvesting and their scenic judgments at each intensity are at least a full unit lower than each of the other groups. The result is that ATC members do reach the point where Tukey's LSD does not find a difference between 12% and 15% of the view being harvested. In contrast, the FRC members rate the unharvested view lower than the other groups, and are less sensitive to the incremental impacts of harvesting at each intensity level. The slope of their curve is much flatter than any of the other groups, though the incremental decrease in scenic value is significant at each level except between 9% and 12%.

Size: The effects of clearcut size on scenic value are also very significant. The general pattern in Fig. 5 indicates that the 10–14-acres clearcuts are preferred to larger ones, which are in turn preferred to smaller ones. Tukey's LSD finds significant differences among each pair of sizes. The same general pattern is apparent when the four groups are plotted separately. However, the NCC participants show a slight preference for the larger clearcuts to the standard size, though it is not a significant difference. Tukey's LSD does not indicate a significant difference between the larger and smaller sizes for the ATC and FRC respondents.

Pattern: There is a significant preference for distributing clearcuts throughout the view rather than clustering them together at each harvest period. This result is the same for each of the four opinion leaders groups.

Interaction of intensity and size: The top of Fig. 5 shows how the size of clearcuts affects scenic value as the intensity of harvesting increases. At low intensities, the size of clearcuts is not significant. However, with approximately 6–9% of the view in visible clearcuts, the larger and smaller clearcuts have distinctly lower scenic value than the standard size of 10–14 acres. With the higher intensity harvesting, the smaller size has distinctly lower scenic value than the standard size.

Table 3
Opinion leaders' ANOVA of the effects from viewpoint, cutting pattern, percent of area cut, cutting guidelines, and their second order interactions on scenic value

Source	df	Sum of squares	Mean square	F	P
Viewpoint	1	311.6	311.6	75.5	≤ 0.0001
Control	1	3015.4	3015.4	731.2	≤ 0.0001
Intensity	4	6905.1	1726.3	418.6	≤ 0.0001
Size	2	517.3	258.7	62.7	≤ 0.0001
Pattern	1	402.4	402.4	97.6	≤ 0.0001
Intensity*Size	8	115.1	14.4	3.5	0.0005
Intensity*Pattern	4	32.2	8.1	2.0	0.0990
Size*Pattern	2	138.6	69.3	16.8	≤ 0.0001
Leaders' group	3	2356.6	785.5	190.5	≤ 0.0001
Error	5919	24,410.8	4.1		
Total	5945	38,203.5			

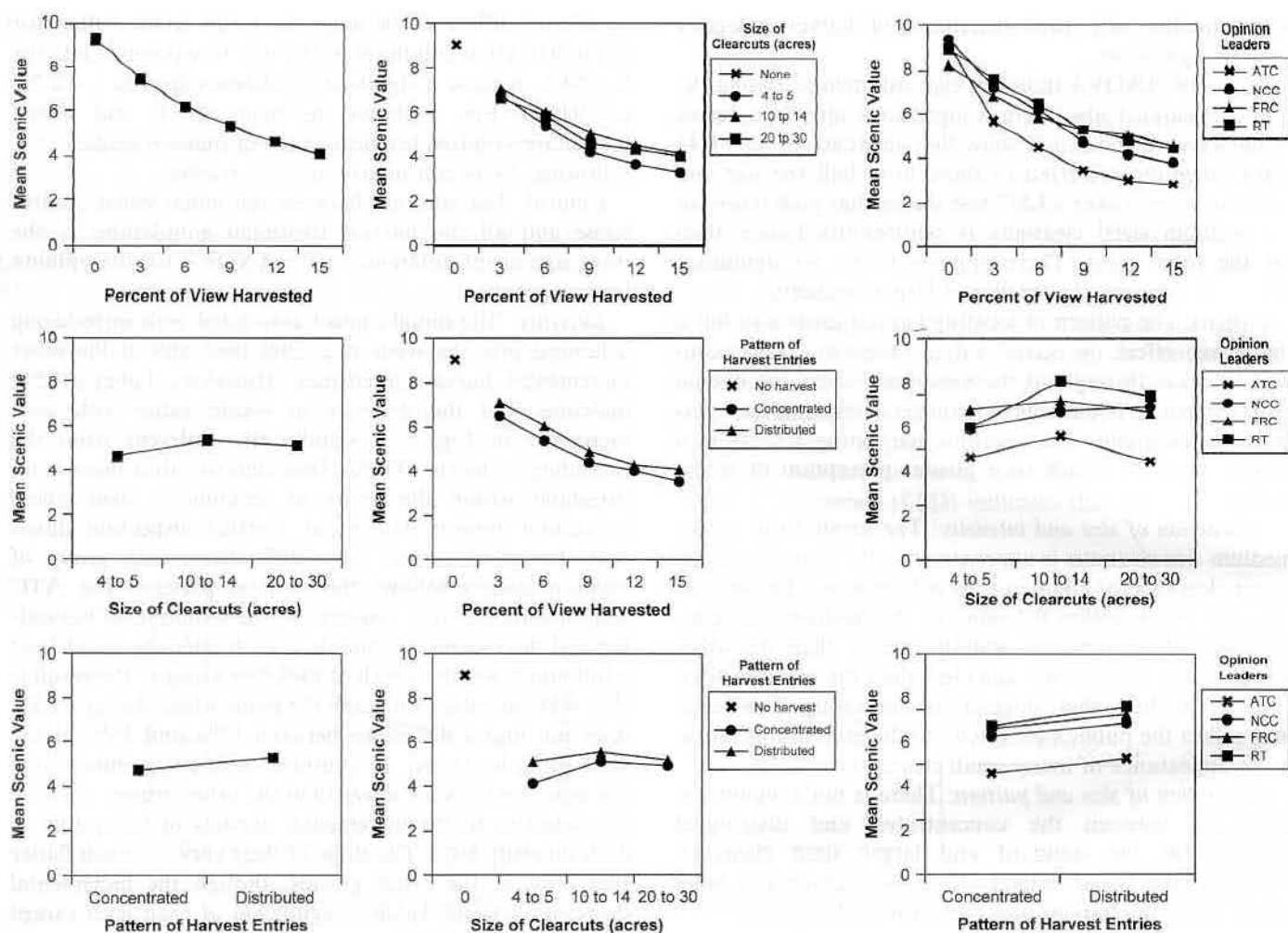


Fig. 5. Plots of the mean scenic value perceived by four groups of opinion leaders with the percent of view harvested, size of clearcuts, pattern of harvest entries, group membership, and their interaction.

Table 4

Forest Service employees' mean scenic value for levels of harvesting intensity, size of clearcuts, cutting pattern, viewpoint, and profession

Effects	Mean scenic value							
	USFS	Archeologist	Engineer	Forester	Land. Arch.	Management	Recreation	Wildlife biologist
<i>Percent view harvested</i>								
0	9.23	9.83	9.27	9.17	9.85	9.00	9.20	9.24
3	7.47	7.49	6.92	7.71	7.50	7.41	7.36	7.22
6	6.23	5.59	5.91	6.66	5.90	6.10	6.02	5.82
9	5.32	4.44	5.21	5.72	4.85	5.25	5.05	4.94
12	4.68	3.74	4.46	5.08	3.97	4.74	4.37	4.34
15	4.14	3.17	3.94	4.59	3.26	4.11	3.85	3.79
<i>Size of clearcuts(acres)</i>								
4–5	5.07	4.16	4.78	5.45	4.89	5.28	4.81	4.51
10–14	6.25	5.48	5.74	6.63	6.00	6.26	6.11	5.87
20–30	5.38	5.01	5.34	5.77	4.41	5.04	5.08	5.28
<i>Pattern of clearcuts</i>								
Concentrated	5.19	4.36	4.99	5.58	4.73	5.16	4.96	4.82
Distributed	5.95	5.41	5.87	6.32	5.46	5.89	5.71	5.62
<i>Viewpoint</i>								
Sugarloaf	5.78	5.11	5.40	6.16	5.33	5.74	5.46	5.47
Welch Ledge	5.60	4.98	5.43	5.95	5.16	5.53	5.45	5.23

Interaction of size and pattern: A shallow peaked pattern for both the concentrated and distributed arrangements of clearcuts is apparent in the bottom-center plot. However, the smaller concentrated arrangement is significantly lower in scenic value when compared to its distributed counterpart.

3.3. USFS employees' scenic quality evaluation

The mean scenic value judgments for the Forest Service respondents reported in Table 4 for percent of view harvested, size of clearcuts, pattern of harvesting, viewpoint, profession and their interactions are charted in Fig. 6. The interaction effects of the respondent's profession are summarized for three groups: (1) archaeologists and landscape architects, (2) engineers, managers, recreation specialists and wildlife biologists, and (3) foresters. The professions within each group had similar overall visual assessment patterns. The ANOVA reported in Table 5 finds that all the effects are significant.

Control: The unharvested scenario has significantly higher scenic value than any of the harvest treatments. The landscape architects and archaeologists find these two scenes substantially more scenic than the other professions.

Percent of view harvested: The intensity of harvesting activity is the most significant management factor effecting

scenic value. A threshold to the visual impacts from increased harvesting is not evident within the sustainable yield constraints of this study. Each increment in the amount of the view that is harvested adds a significant decrease in scenic value. Separate Tukey's LSD analyses indicate that this is also true for each group of professionals.

Size of clearcuts: The 10–14 acres clearcuts that are normally used in the White Mountain National Forest

Table 5

USFS employees' ANOVA of the effects from viewpoint, cutting pattern, percent of area cut, cutting guidelines, and their second order interactions on scenic value

Source	df	Sum of squares	Mean square	F	p
Viewpoint	1	100.2	100.2	29.2	≤0.0001
Control	1	5315.3	5315.3	1547.0	≤0.0001
Intensity	4	17151.6	4287.9	1248.0	≤0.0001
Size	2	3081.3	1540.6	448.4	≤0.0001
Pattern	1	1748.4	1748.4	508.9	≤0.0001
Intensity*Size	8	728.7	91.1	26.5	≤0.0001
Intensity*Pattern	4	147.2	36.8	10.7	≤0.0001
Size*Pattern	2	719.8	359.9	104.8	≤0.0001
Profession	6	1464.9	244.2	71.1	≤0.0001
Error	12,673	43,541.4	3.4		
Total	12,702	74,001.5			

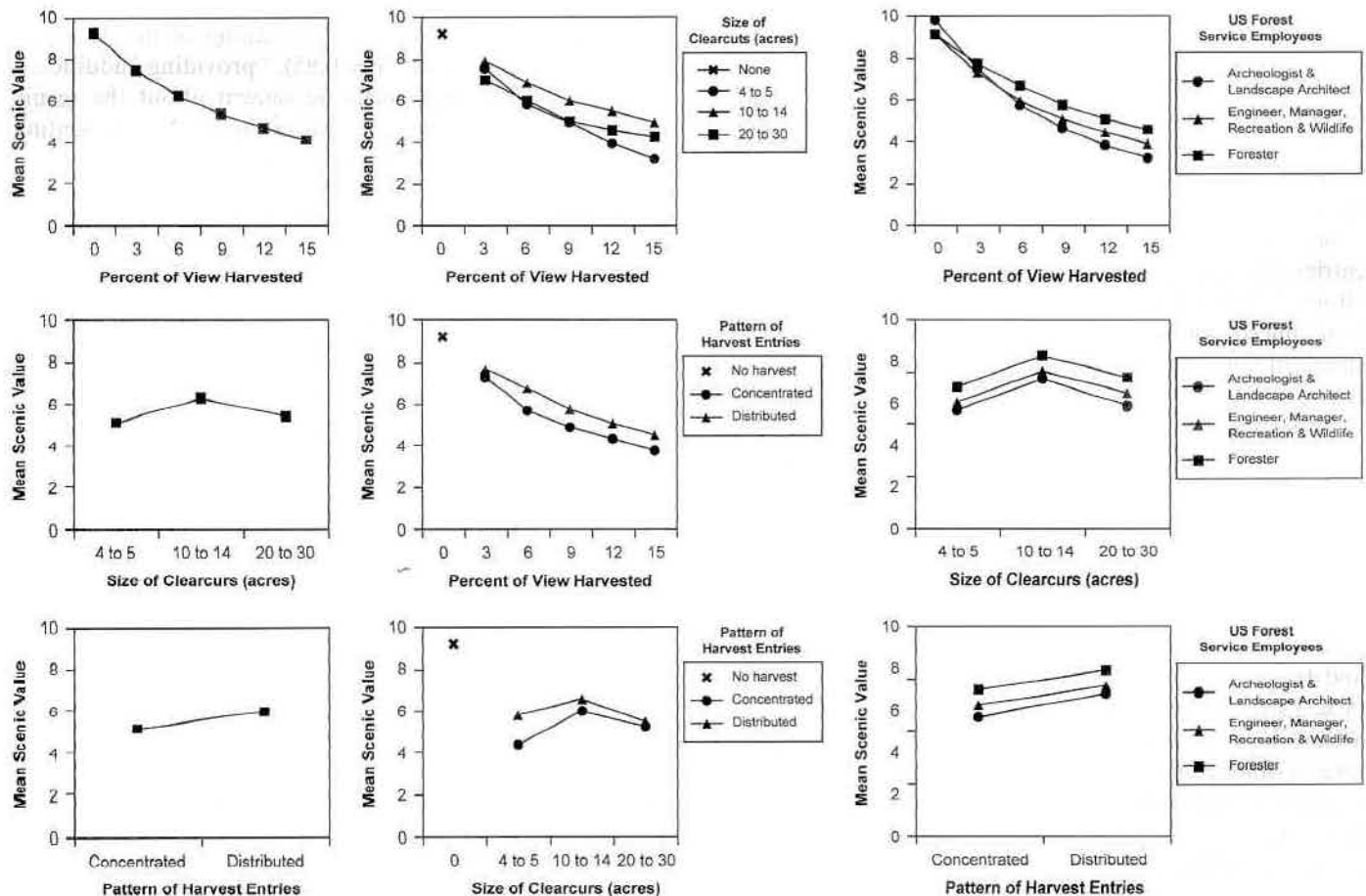


Fig. 6. Plots of the mean scenic value perceived by Forest Service employees with the percent of view harvested, size of clearcuts, pattern of harvest entries, profession, and their interaction.

have significantly higher scenic value than the smaller or larger clearcuts. This result is found for each professional group. In general, the scenarios with the largest clearcuts are preferred to these with the smallest ones. There is a significant difference for the respondents as a whole. However, when separate Tukey's LSD analyses are conducted for each profession, there is no significant difference between the scenic value of larger and smaller size clearcuts for the archaeologists, managers and recreation specialists. Landscape architects have a significant preference for the smaller clearcuts. Engineers find no significant difference between the standard and larger clearcuts.

Pattern of harvest entries: Forest Service respondents find a distributed pattern of harvest entries has a significantly higher scenic value than a concentrated pattern. This is also the case when each profession is considered separately.

Interaction of intensity and size: The 10–14 acre clearcuts have significantly higher scenic value at all harvesting intensities. The smaller clearcuts have significantly higher scenic value than the larger ones when 3% of the view is harvested. There is no significant difference between the smaller and larger clearcuts when 6% or 9% of the view is harvested. At higher intensities, the larger size clearcuts have significantly higher scenic value than the smaller ones.

Interaction of intensity and pattern: Concentrating the pattern of harvest entries leads to significantly lower scenic value at all harvesting intensities. However, at the lowest harvesting intensity the difference is quite small. For intensities at 6% of the view and above, the difference between the distributed and concentrated patterns is relatively constant.

Interaction of size and pattern: The distributed pattern of entries receives significantly higher scenic value ratings for all sizes of clearcuts. However, the difference is particularly pronounced for smaller clearcuts, is much reduced for standard size cuts, and is rather modest for larger harvest areas.

Profession: There are significant differences in the scenic evaluations made by the different professional groups. Archeologists give the lowest overall ratings to the harvest simulations ($\bar{x} = 4.89$) and the second highest ratings for the unharvested control scene ($\bar{x} = 9.83$). Tukey's LSD shows their judgments are significantly ($p < 0.05$) different from all but the landscape architects. Landscape architects gave the highest ratings to the unharvested scene ($\bar{x} = 9.85$) and the second lowest ratings for the harvested scenarios ($\bar{x} = 5.10$). While these evaluations are very close to the archaeologists, they are also not significantly different from several other professions. Wildlife biologists, engineers and recreation specialists have very comparable ratings for both the harvested ($\bar{x} = 5.27$) and unharvested ($\bar{x} = 9.23$) scenarios. Tukey's LSD indicates that managers' ratings are significantly different from all the other groups. They gave the lowest rating to the unharvested scene ($\bar{x} = 9.00$) and next to the highest ratings to the harvested scenes

($\bar{x} = 5.52$). Finally, Tukey's LSD shows that foresters are also significantly different from all other groups. Overall, they give the most positive scenic ratings to the harvested scenes ($\bar{x} = 5.95$).

These patterns are simplified in Fig. 6, where the professions are placed into three groups. These groups clearly show very similar patterns of ratings. The only important difference is seen in the graph of mean scenic value by percent of view harvested. In this graph, the archaeologists and landscape architects are seen to give higher ratings to the unharvested scene and react more negatively to the harvesting scenarios. This leads to a substantially greater overall sensitivity to visual impact from increasing harvesting intensity, as reflected in the steeper curve describing their ratings.

The greater tolerance of foresters for the visual impacts of the harvesting scenarios is easily seen in the graphs of mean scenic value by size of clearcuts and pattern of harvest entries. While the overall pattern of their ratings is similar to the other groups, their ratings of harvested scenes are clearly higher.

3.4. Relations among respondent groups

It is instructive to look at patterns of similarities among the respondent groups. The correlations among the respondent groups based on their ratings of the 62 scenes are very high (mean $r = 0.95$), providing additional evidence for the high social agreement about the scenic effects of clearcutting. A cluster analysis representing the overall pattern among the groups based on these mean ratings is shown in Fig. 7. Three groups are apparent at the point where the distance curve begins a steep ascent. These clusters are more easily interpreted by considering Table 6, which lists for each group the mean scenic value of the two unharvested scenes and all the harvested scenes combined. The difference between these values is a measure

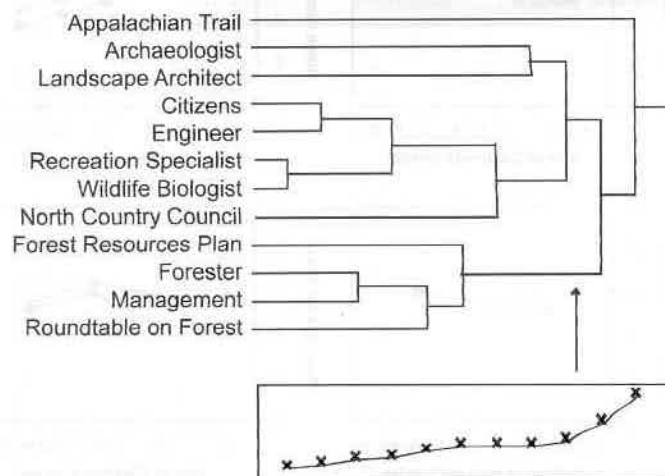


Fig. 7. Clustering of respondent groups based on mean scenic value evaluations of the 62 simulations using Ward's method.

Table 6

The mean scenic value of the unharvested and harvested scenarios, and the difference between them for the respondent groups

	Mean scenic value		
	Unharvested	Harvested	Impact
Citizens	9.01	5.06	3.93
Appalachian Trail Conference	9.17	3.92	5.25
North Country Council Board	9.36	5.24	4.12
Forest Resources Plan Committee	8.23	5.36	2.78
Roundtable on Forest Law	8.95	5.74	3.21
Forest Service employees	9.24	5.55	3.70
Archaeologist	9.83	4.88	4.95
Engineer	9.27	5.25	3.96
Forester	9.17	5.92	3.29
Landscape Architect	9.85	5.10	4.76
Management	9.00	5.52	3.48
Recreation Specialist	9.20	5.33	3.87
Wildlife Biologist	9.24	5.22	4.02

Table 7

Effects of percent area cut, size of clearcuts, cutting pattern, viewpoint, and respondent group on scenic value judgments

Source	df	Sum of squares	Mean square	F	p
Viewpoint	1	378.3	378.3	90.2	≤0.0001
Control	1	10504.9	10504.9	2505.3	≤0.0001
Intensity	4	28237.2	7059.3	1683.6	≤0.0001
Size	2	3728.7	1864.4	444.6	≤0.0001
Pattern	1	2398.3	2398.3	572.0	≤0.0001
Intensity*Size	8	857.4	107.2	25.6	≤0.0001
Intensity*Pattern	4	119.6	29.9	7.1	≤0.0001
Size*Pattern	2	1112.5	556.2	132.7	≤0.0001
Respondent group	11	5405.0	491.4	117.2	≤0.0001
Error	23,097				
Total	23,131				

of average scenic impacts attributable to harvesting. Overall, there are no significant differences among the respondent groups in how they evaluated the unharvested scenes ($F(11, 361) = 1.28, p = 0.239$). However, there are differences in the ratings for the harvested scenes, and therefore the overall scenic impacts attributable to clear-cutting.

The two committees charged to review forest management practices in the state of New Hampshire join with Forest Service foresters and managers. Their rating of the unharvested scenes is slightly lower than the other groups, and they rate the harvest scenarios much higher. These four respondent groups form a cluster that shares a utilitarian perspective on forest management. They are less sensitive to the scenic impacts caused by harvesting. A second large cluster includes the random sample of citizens and North Country Council advisory board. They are joined by Forest Service engineers, recreation specialists, wildlife biologists, archaeologists and landscape architects. This

cluster shares what may be termed a largely experiential perspective toward the forest and its management. They tend to give higher scenic ratings to the unharvested scenes and are substantially more critical of the scenic impact from harvesting. Finally, there are the Appalachian Trail conference members, who form a cluster by themselves. They seem to have more of a preservation orientation toward the forest. While their scenic rating of the unharvested scenes is similar to the experiential group, they are substantially more critical of the scenic impacts from harvesting activity.

An ANOVA including data from all the respondent groups is reported in Table 7. The results mirror those previously reported: increasing harvest intensity is associated with decreasing scenic value; 10–14 acres clearcut patches are preferred to smaller and larger ones; distributed entries are preferred to concentrated ones. While there are statistically significant (though slight in magnitude) differences among the respondent groups, these patterns are robust and occur in varying degrees for each group. A comparison of the respondent groups using Tukey's LSD indicates affinities similar to the cluster analysis in Fig. 7.

4. Conclusions

This study has several important methodological and forest management implications. First, there is very strong similarity among all respondent groups in the pattern of responses to the harvesting scenarios. All groups rate the scenic value of unharvested scenes very high. All groups find a large drop in scenic value with the introduction of even the least intense harvesting activity. All groups indicate a statistically significant decrease in visual quality as the intensity of harvesting increases. This effect continues throughout the range of harvesting intensities that provide for sustainable yields.

Second, all groups share a similar pattern evaluating the scenic effects of different size clearcuts. There is a substantial preference for clearcuts in the 10–14 acres range when seen in the middle distance. This preference is apparent across all intensities of harvesting. Small 4 or 5 acres clearcuts have substantially less scenic value. This effect is increased when they are clustered together. The scenic value of larger 20–30 acres clearcuts is evaluated somewhere in between the smaller and standard size, though usually closer to the smaller clearcuts.

Third, the pattern of harvest entries also influences scenic value. The clustering of clearcuts increases their impact. A dispersed pattern is more desirable. However, what may appear to be dispersed from one viewpoint, may appear clustered from another. Forest managers must carefully consider the impacts of pattern from each major viewpoint.

Fourth, this study demonstrates that there are significant differences in the sensitivity to scenic impacts from clearcutting. The most important insight from these

differences is that those most involved in forest management—foresters, managers, and representatives rewriting the forest law—have the highest tolerance for scenic impacts. The general public is significantly more sensitive, and there are special interest groups that are even more sensitive to the visual impacts of harvesting.

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Approaches to integrating indicators into 3D landscape visualisations and their benefits for participative planning situations

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Abstract

In discussing issues of landscape change, the complex relationships in the landscape have to be assessed. In participative planning processes, 3D visualisations have a high potential as an aid in understanding and communicating characteristics of landscape conditions by integrating visual and non-visual landscape information. Unclear is, which design and how much interactivity is required for an indicator visualisation that would suit stakeholders best in workshop situations. This paper describes the preparation and application of three different types of integrated 3D visualisations in workshops conducted in the Entlebuch UNESCO Biosphere Reserve (CH). The results reveal that simple representations of a complex issue created by draping thematic maps on the 3D model can make problematic developments visible at a glance; that diagrams linked to the spatial context can help draw attention to problematic relationships not considered beforehand; and that the size of species as indicators of conditions of the landscape's production and biotope function seems to provide a common language for stakeholders with different perspectives. Overall, the of the indicators the functions required to assist in information processing. Further research should focus on testing the effectiveness of the integrated visualisation tools in participative processes for the general public.

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1. Introduction

Current planning processes aimed at the management of landscape change should include local stakeholders in order to enhance the acceptance of the outcome and the implementation of measures (Healey, 1997; Fürst, 2005). One problem of participative planning processes is communicating the relevant planning information among all the stakeholders in an understandable way (Demuth and Fünkner, 2000). For an integrated analysis of landscape change, the characteristics of landscape conditions such as the productivity of the soil, water supply and retention, climatic regeneration as well as geological and biological diversity or the scenic view have to be evaluated. In

practice, indicators are used to measure the impact of landscape change on these conditions with regard to economic, ecological and social requirements (v. Haaren, 2004).

Traditional planning tools such as maps, diagrams, tables or texts often fail to communicate the results to lay people (Tress and Tress, 2003; Appleton and Lovett, 2005). Compared to these tools, GIS-based 3D landscape visualisations show a high potential for contributing to a better understanding of the information (Orland et al., 2001; Al-Kodmany, 2001; Heißenhuber et al., 2004). By integrating indicators, 3D visualisations offer the opportunity to link all the dimensions, the visual and non-visual parts of the landscape, and may even provide a new planning tool (Bishop and Lange, 2005). However, only single studies exist that are suggesting possible designs of integrating indicators in these visualisation tools (e.g., Hehl-Lange, 2001). Beyond, the impacts of the integrated tools in real planning situations have not been tested yet.

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To link visual qualities to production, ecological, cultural and amenity functions was one objective of the EU project VisuLands—Visualisation Tools for Public Participation in the Management of Landscape Change (<http://lrg.cthz.ch/visulands>). In the VisuLands project, tools were developed to improve understanding of what people consider important in the visual landscape and to assist in the assessment of different landscape development scenarios. This paper describes the research into how to represent landscape indicators in 3D visualisations, and their application in public participation processes. First, three ways to display indicators in 3D landscape visualisations are classified with respect to the type of visualisation and interactive requirements. Second, results from psychological and media-pedagogical research on using images for information communication are applied in the design of 3D visualisations with regard to human information processing. Third, based on the principles derived from the literature review, integrated 3D landscape visualisations are used in real planning situations to collect feedback from end users with regard to understanding and utility. The results reveal what qualities the respective designs and the mode of interactivity of the three types of integrated 3D visualisations had for the participants' information processing and for the planning process. Thus, they should provide a component for a standardised 3D visualisation method for landscape indicators.

2. Literature review

2.1. Integrating indicators into 3D landscape visualisations

Today, rapid development in computer technologies has extended the possibilities of visualisation in landscape planning enormously: geographic information systems (GISs) make it possible to base visualisations on real-world geo- and vegetation data and advanced rendering methods allow the photorealistic representation of scenes in real-time. Interactive landscape visualisations may facilitate the communication of landscape related issues by raising people's attention, by demonstration, by putting them in context, and by the construction of mental models (Dransch, 2000). Technically, virtual landscapes are composed of the terrain, a geotexture, which is usually created from satellite data or orthophotos, vegetation and built structures (Lange, 2001), possibly extended by water, animals, people, atmosphere and light (Ervin, 2001).

Different types of landscape visualisations can be distinguished with regard to the level of realism, ranging from abstract to realistic representations of the landscape (Lange, 2001), and secondly, with regard to perspective and scale, ranging from an overview to close local views. Third, the ability to interact with landscape visualisations is important for their use as a communication tool. Different levels of interactivity are available (Schroth et al., 2005), so that changes of the visual landscape can be assessed by experts as well as community members in an intuitive way

by switching between alternative scenarios and timeframes (Lange et al., 2003). If parallel windows are used, the landscape model can be linked to abstract scientific visualisations, e.g., diagrams, by hyperlinking objects in the landscape to them. Finally, real-time movement makes it possible to view the landscape model from different perspectives and to zoom into areas of interest or zoom out to the overview.

For a comprehensive landscape assessment, ecological, economic, social and aesthetic criteria have to be evaluated. Aesthetic can be assessed by the visual landscape quality expressed mainly by visual elements (Nohl, 2001) that can be displayed in the 3D visualisation. However, in evaluating ecological and socio-economic aspects, complex systems have to be analysed (v. Haaren, 2004). These systems cannot be mapped themselves and therefore, must be illustrated by indicators, i.e., measurable characteristics reflecting the state of the system. Visualising smaller entities of the whole system that indicate the extent of specific functional relations or their spatial dimension for a particular issue are challenging but have proven to be practical (Hehl-Lange, 2001). Three different types of indicator visualisation in three dimensions are classified in this paper with regard to their representation and interactive features.

First, thematic maps show objects or topics that are not part of the topography, e.g., economic or social data on economy (Hake et al., 2002). Cartographic projections of thematic maps onto the terrain as an overlay are suitable for showing indicators in relation to elevation, slope or orientation (Sieber, 2001). Traditional two-dimensional thematic maps usually have a rather low level of realism, i.e., they abstract reality considerably. However, different target groups prefer different representations, e.g., it has been suggested that realistic representations are more suitable for lay people (Buziek et al., 2000). Therefore, one great potential of interactive visualisations is that they allow diverse target groups to view, combine and explore the underlying geodata individually.

Second, non-visual processes with respect to the geological or biological impact of a landscape change can be uncovered indirectly by visual indicators. For example, the ecological needs of different plant species can be used as an indicator value for the sensitivity of and adverse effects on a biotope (Böcker and Stöhr, 2004). Thus, vegetation species can demonstrate harmful consequences of a landscape change on the landscape's ecological quality that are not necessarily visible at a glance. The question is how these indicator species could be meaningfully visualised in more realistic looking 3D models for different stakeholders. In using interactivity, time series seem to be an appropriate feature for the representation of landscape change.

Third, most of the economic and social indicators are hard to express, as they are neither visual nor spatially explicit. Their assessment is not formalised yet with regard to landscape assessment and the relationships are rather

complex' (v. Haaren, 2004). Socio-economic data can be shown in additional windows with abstract scientific visualisations, e.g., diagrams or tables, which are linked to the realistic landscape model by hyperlinks. In this way, the spatial relationship between data and location becomes explicit. However, empirical knowledge about the effectiveness of this approach is still rare.

The three identified approaches of indicator visualisation were further elaborated to enhance their potential for communicating specific information. Therefore, the individual cognitive dimension of presenting and using visual information as well as modes of interactivity and their potential in the communication of indicators were investigated.

2.2. Individual cognitive dimension of presenting and using visual information

Successful information delivery in the participative planning of landscape change should rely on the principles of communication theory (Orland et al., 2001). The communication process is characterised by information, the extraction of information from a medium and the individual information processing that leads to the comprehension of the message (Luhmann, 1987). This means that individual cognitive performance is finally responsible for the information delivery's degree of completeness. Therefore, the theoretical background of image reception, cognition and functions of images as an aid in learning can build a framework to explain the effects of visual information on the recipient and to derive advice for an effective design of the information in 3D visualisations (Wissen et al., 2005; Wissen, 2007).

Cognitive theories are based on an information processing paradigm that explains the attraction of interest to and the processing of media messages (Bonfadelli, 2004a). The idea is that people confronted with new information activate a cognitive pattern to integrate the new impressions (Scheufele, 2001). Assisting in the consecutive phases of this information processing, the design of images functions mainly to motivate and thus focus the attention of the viewer to support the extraction of information by pointing to relevant attributes, contextualising information, facilitating scenario building, and assisting in the comprehension of the message by giving links between the reality and the cognitive concept of an issue that has to be built up or extended (Weidenmann, 2002a; Bonfadelli, 2004a). In cartography, Buziek et al. (2000) summarises the implications of the major cognitive approaches by Neisser (1976), Paivio (1986) and Pylyshyn (1981) for the use of dynamic and interactive features in visualisation. Buziek et al. (2000) shows that such features are a means to highlight specific visualisation objects, to support the perception of space, and to facilitate learning processes. A brief overview of recommendations drawn from literature for the presentation of the information in images that help fulfil these functions is given in Table 1.

Conclusions from the fields of media-psychology and media-pedagogic point out that perception, recognition and cognition are multi-sensory patterns of events (Luders, 2001; Fabler, 2002). For this reason, many factors have to be taken into account when trying to optimise the design of 3D visualisations for information communication, and a simple mechanical application of design and application rules would not be sufficient either. The research results instead provide an orientation aid to refer the different principles to each other so that the 3D visualisations can be designed to accommodate the psychological principles of information processing (Schnotz, 2002).

3. Overview of case study site and methodological issues

3.1. Social-empirical testing

A social-empirical research design was set up to provide a structure for collecting and analysing end-users' feedback on the utility of the integrated visualisation tools. Because the impact of the 3D visualisations had to be assessed in the complex context of participative landscape planning, it was not possible to control all the influencing factors in a quantitative experiment. Therefore, an explorative case study analysis with a mix of qualitative methods was seen as most suitable (Flick et al., 2003).

The data was collected over three thematically different series of workshops related to landscape development and with different groups of stakeholders. Two of these workshop series are discussed here in detail, the third had a slightly different participatory setting. The methods for data collection comprise observation of and group discussions with the workshop participants, as well as in-depth interviews with key actors. In order to ensure an objective observation, two researchers conducted independent observations, following structured observation guidelines, and compared the results afterwards. These have been documented in protocols and, when possible, on audiotape. Later, the interviews were transcribed on the basis of these tapes. The data was then analysed by coding and clustering, using a combined method of grounded theory and qualitative content analysis (Strauss, 1998; Diekmann, 2005). The coding was applied by two researchers, who then compared the results. This approach of carefully combining different data sources, researchers, and methods should lead to more comprehensive results as conclusions are based on different levels and thus can be more extensive than with one access only (Kelle and Erzberger, 2003; Flick, 2004).

3.2. Case study site—Entlebuch UNESCO Biosphere Reserve

The Entlebuch UNESCO Biosphere Reserve (UBE) was chosen as the case study site for testing the integrated visualisation tools because the Biosphere management had

Table 1
Results from the literature review on possible functions of 3D visualisations as an aid to human information processing and recommendations for the presentation of the information to fulfil the functions

Function	Design recommendations for representation and interactivity
Triggering the attention of the viewer (cognitive and affective) and raising his awareness which enhances his chance of perceiving the information	High attention • Visualisations that integrate new aspects of already known issues (Bonfadelli, 2004a; Klimsa, 2002; Weidenmann, 1994) • Areas with a lot of information presented (Hearnshaw, 1994; Schierl, 2001) Attention can be evoked by • Dynamics (Buziek et al., 2000) • Conciseness (Bonfadelli, 2004b) • Closeness and relevance; comprehensibility; credibility (Weidenmann, 2002b; Bonfadelli, 2004b) • Emotional contents (Strzebkowski and Kleeberg, 2002) • Opportunities to interact with the representation (Buziek et al., 2000) • Originality (Meckel, 2001) • Colour and size (Weidenmann, 2002b)
Pointing to the relevant attributes to help the viewer in the extraction of information	Organising complex issues/providing for transparency by • Objective simple designs (Weidenmann, 2002a) • Didactical presentation of the elements, e.g., with chosen display detail and perspective; colour and size distortion (Weidenmann, 2002a; Schnotz, 2002)
Contextualising the information to aid the viewer in getting familiar with a situation	Providing for • An overview on the area of investigation and data for comparison (Dransch, 2000) • Realistic and complex situations (Weidenmann, 2002b) • A combination of realistic and abstract elements to be suggestive about the situation (Weidenmann, 2002a)
Giving links between the reality and the cognitive concept of an issue to assist the viewer in the development of his perception	Providing for • A medium level of reality and a medium degree of complexity (Lewalter, 1997) • Symbolic images (Weidenmann, 1994) • A design according to the representation form (e.g., topographic information or spatial arrangements in an abstract design; appearance of elements in a realistic design) (Weidenmann, 2002b) • Interactive navigation between overviews and focused zooms to help the viewer developing his own mental model (Buziek et al., 2000) • An arrangement of different information windows to increase access to the desired information (Weidenmann, 2002b)

already initiated various collaborative planning forums (Schroth et al., 2006). The site is located in central Switzerland, in the main valley between Lucerne and Bern, and is famous for its cultural landscape of national and international significance. The diverse, agricultural landscape contains important habitats for plants and animals, e.g., karst areas, forests and unique moorlands. As with similar regions throughout Europe, the Entlebuch area faces problems in maintaining its agricultural farms and in losing inhabitants, which in turn can cause major impacts on the landscape over the long term. Biosphere reserves are sites recognised under the UNESCO's Man and the Biosphere Programme that innovate and demonstrate approaches to conservation and sustainable development (UNESCO, 2006). Therefore, the Entlebuch serves as a model region and a 'living laboratory' where solutions for these problems are developed in participative planning processes.

3.3. Characterisation of participative planning at the case study site

Healey (1997) observed a paradigm shift, the so-called "communicative turn" in planning participation. In addition to Healey's (1997) most influential book *Collaborative Planning*, Forester (1989) has determined the discussion in planning theory, while both authors refer to Habermas' (1981) *Theory of Communicative Action* as the basis of their arguments. Forester (1989) adopts Habermas' theory to planning in order to understand planning as a communicative process and to derive ethical norms for communication in planning, i.e., comprehensiveness, objective truth, normative correctness and subjective truth, in other words: transparency and credibility. Because transparency and credibility are key principles in collaborative planning, it is necessary to assess the indicator visualisations not only with regard to their communication functions (Table 1),

but also how far they enhance transparency of the process. From his analysis of current planning processes, Forester concludes that communication in this specific context is biased by structural inequalities and he sees the role of planners in transferring Habermas' ethics to planning as a way to facilitate a consensus-oriented communication. Like Forester, Healey (1997) also refers to Habermas (1981) and she emphasises that today, planning is shaped by a multi-stakeholder society. She asks how planning could achieve sustainable results in such a context and her answer is a planning approach that she describes as "collaborative planning", characterised by the sharing of power, group learning, transparency and a consensus-oriented style of communication. All the workshops and forums established in the Entlebuch area attended to the suggestions of Forester and Healey in practice and provided a very good basis for testing the visualisation tools and gathering feedback on their usability.

3.4. Access to the planning situations and choice of 3D visualisation scenarios

Landscape development is a central topic in most of the projects carried out in the Entlebuch because a beautiful and ecologically stable landscape is recognised as the basis for a healthy life, and, furthermore, provides natural capital for tourism and a powerful mechanism for promoting regional products (Ruoss et al., 2002). These are crucial aspects as one third of the local people work in the tourism and agriculture sectors. Among the most important regional employers are the cable car companies in Soerenberg and Marbach (Schnider, 2005).

Access to real planning situations was made possible by one of the Biosphere's regional managers who coordinated scientific research and education in the Entlebuch Reserve. He arranged for the VisuLands team to apply the integrated 3D visualisations in different workshops. All of the workshops described in this paper were facilitated by him and took place locally. The workshops followed a standard workflow shown in Table 2 that was elaborated for the participatory processes in the Entlebuch Reserve (Schmid, 2004). The application of the 3D visualisations was integrated in this workflow. In all cases, the content of the indicators was discussed beforehand with the experts involved and the facilitator conducting the workshops. In the following, the application and effects of the integrated 3D visualisations used in the two case studies are described in detail.

Table 2
Standard workflow with different phases in the moderation of a workshop

Factual phases	Introduction	Collecting	Choosing	Editing	Planning	Conclusion
Emotional phases	Orientation	Working				Finishing

Source: Schmid (2004, p. 85).

4. Case study 1: tourism

4.1. Concept

At that time, the main problem for local tourism in the Entlebuch area was the lack of an up-to-date infrastructure in comparison to its national and international competitors. Therefore, the owners of cable car and skiing facilities, as well as some hoteliers, were planning new investments. According to the principles of the Biosphere Reserve, the investments were aimed at a sustainable regional tourism development, but a long-term strategy that would ensure synergetic effects among the different investments was missing. Therefore, the Biosphere management invited all relevant local stakeholders, including the investing cable car owners, hoteliers, a local farmer engaged in agro-tourism, and representatives of the Tourism Board, to an open forum on the future objectives for tourism in the area. In this context, the attractive landscape was addressed as one asset of local tourism and how tourism shapes the landscape was discussed as well. Although the forum did not address the general public, it was open to other stakeholders. The workshops of the forum were facilitated by a member of the Biosphere management and aimed at group learning and a consensus-oriented communication (Healey, 1997). The outcome of the workshops, i.e., the future tourism strategy, was relevant insofar as it will provide guidelines for the allocation of new investments and infrastructure, but attendance was not obligatory.

However, a first workshop conducted in 2003 without any visualisation support, suffered from the lack of innovation and the facilitator suggested using landscape visualisations. The research team agreed to include the forum in its case study, because the issue was landscape related and the organisation of the forum was a good example of collaborative planning. The second workshop, held at the local agricultural school in May 2004, was supported by interactive landscape visualisations, attended by eleven tourism stakeholders (10 men, one woman) and three researchers, and facilitated by one of the Biosphere managers. In comparison to the rather common use of visualisations at the end of a planning process, the landscape visualisations were introduced at a very early stage to support the development of scenarios (cf. Lange and Hehl-Lange 2006).

4.2. Methods

A shared observation guideline assisted each of the three participating researchers in looking for triggers that would

indicate an impact of the visualisations. Triggers included gestures towards the display, verbal references to the image or an emotional response like laughter. The content of the overall discussion was documented in a protocol while screenshots and photos showed the setting and the visualisations. After the forum discussion, a 10-min group discussion was held in order to establish a group position on the visualisations. This group assessment was compared with the individual assessments of the impact of the visualisations. In addition, questionnaires were given out. As a third element of data triangulation, the facilitator was interviewed in depth.

In the May 2004 workshop with 11 stakeholders from the tourism sector, a discussion on the current condition outlining the strengths and weaknesses took place. The chances of the current tourism supply and the possibilities for new supplies were also analysed. The two topics of winter and summer tourism supplies in the Entlebuch region were evaluated consecutively. At the beginning of the workshop, the facilitator introduced the 3D visualisations to the participants as instruments that can deliver relevant data for the discussion. The VisuLands team was responsible for showing the visualisations on demand and explaining their content. In this workshop, two different kinds of integrated visualisation tools could be applied, i.e., thematic maps and linking diagrams to the 3D visualisation. Visualisations of indicator species were not used because the vegetation was of minor importance. In the following section, the course of the second workshop is presented with the focus on the use of indicator visualisations.

4.2.1. Thematic map on basis of an elevation analysis

Traditionally, winter skiing around the village of Soerenberg (1165–2350 m above sea level) has been the major tourist activity in the area. Therefore, most of the initial discussion in the first workshop focused on winter tourism and it was stated that safe snow conditions are of great importance, as is long-term quality, and an infrastructure that meets demand. One of the key results of the first workshop was the identification of climate change as a key driver of change because the skiing areas of Soerenberg are lower than those of the competitors and will be one of the first to suffer from global warming.

In preparing the second workshop, the facilitator asked for visualisations of scenarios from climate research that would show the average elevation at which snow will sufficiently be available for skiing over the winter season, i.e., this average “snow line” worked as aggregated indicator for the economic prospects of winter sports. On the basis of studies by Föhn (1990) and Elsasser and Bürki (2003), a snow line (coloured green) at an elevation of 1500 m was chosen through an elevation analysis of the terrain (Fig. 1). Personal communication with one of the researchers in climate change and tourism in Switzerland supported the assumption that Soerenberg will be among the first places to suffer from climate change, although no local climate model that incorporates the topography exists

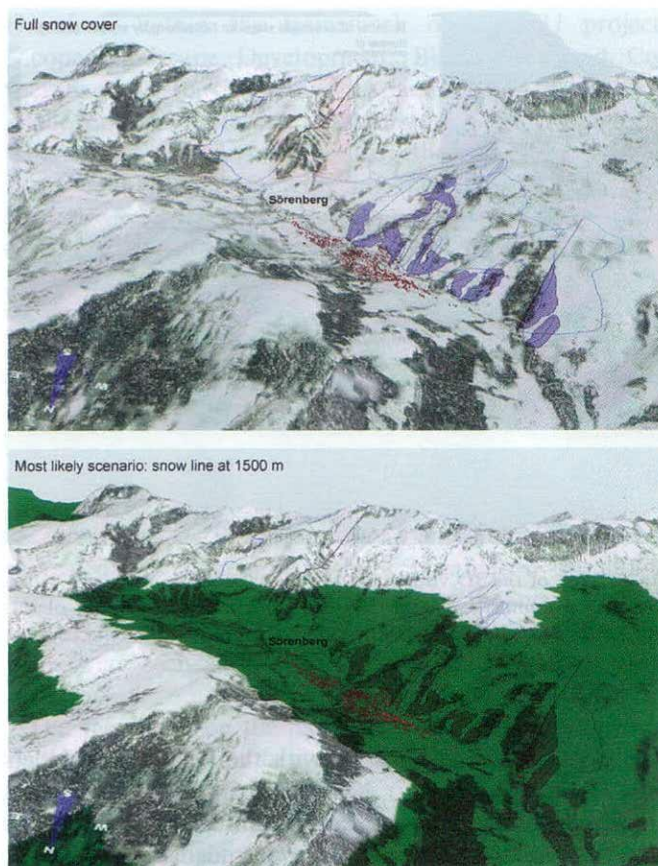


Fig. 1. Average level of sufficient snow conditions for skiing (snow line) in comparison to the existing infrastructure: The green areas are below the average level, black lines represent the ski lifts, the blue areas are covered with artificial snow and the village is shown in red. The second variant represents the most likely climate change scenario (3D visualisation: VisuLands 2005; geodata courtesy of GIS Canton Lucerne).

for the area. The use of the LandXplorer software (<http://www.3dgeo.de>) made it possible to change the elevation on demand and the intention was to use this feature to show different scenarios in a transparent way.

Combining the snow line with the realistic 3D terrain model and showing it from an overview perspective should draw the participants' attention towards the consequences of climate change. Highlighting the area of Soerenberg and the local skiing facilities should establish closeness and address the participants' everyday experience. In order to represent uncertainty visually, the areas without snow got an abstract, transparent green colour in contrast to the past situations with snow that were rendered rather realistically. The levels of realism and complexity should not only be suggestive of the situation but were also intended to assist the viewer in forming an evaluation and building a personal opinion of this rather abstract issue with regard to local conditions.

4.2.2. Linking the number of overnight stays to the location of hotels

After the discussion of global warming as a key driver of change, the discussion focused again on the decline of the

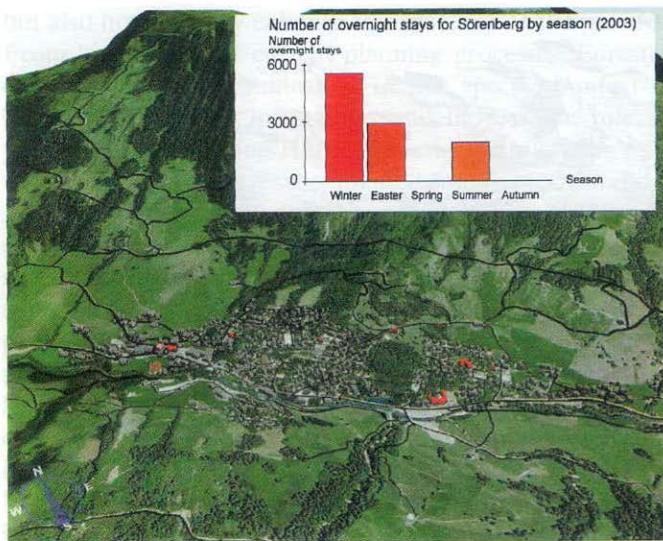


Fig. 2. Link of the 3D visualisation of the village of Soerenberg with a diagram on numbers of overnight stays over seasons. The red objects represent the hotels (3D visualisation: VisuLands 2004; geodata courtesy of GIS Canton Lucerne).

infrastructure. The GIS layer with the location of chalets (holiday houses, in grey), bed and breakfasts, hostels, and hotels (red) in Soerenberg was laid onto the terrain model with the buildings in the form of extruded boxes (Fig. 2). The red colour should direct the attention to the overall number and spatial distribution of accommodation for short-term tourists. The overview perspective of a rather realistic landscape and the abstract building models should help in contextualising the information without getting too complex.

As an economic indicator, the number of overnight stays in the region in 2003 was shown in a diagram in an extra window and linked to the short-term accommodation objects in the model. The diagram was designed with rather simple highlighting to indicate the main use of accommodations in winter, the smaller peaks at Easter and in summer, and the long vacancies during spring and autumn.

4.3. Results and discussion

Overall, data was collected from three different perspectives—the observers (protocols, observation guidelines), the forum participants (individual questionnaires, shared group discussion), and the facilitator (in-depth qualitative interview). For the analysis, these data sources were transcribed and related to the visualisations. Altogether, the data was processed in a content analysis, summarising the observed visualisation impacts and comparing the inside view of the participants with the observations by researchers and facilitator. In the following, the impacts on the planning process and outcomes are extracted. The results are assessed with regard to the visualisation functions from Table 1 and the need for transparency (see the requirements of collaborative planning).

4.3.1. Thematic maps

In the workshop, the facilitator chose a future level of probable safe snow conditions of 1500m in 50 years. Although the numbers had been known before, the visualisation caused some discomposure and astonishment, indicating the emotional effects of the 3D visualisations. This means that the design was rather useful for triggering the attention of the participants and addressing them emotionally as they revealed the effect of the change on the local situation. The relevance of the information was stressed by this approach and it raised the participants' awareness. One participant recapitulated that "the green will be without snow". The high degree of abstraction of the climate change scenario assisted in the extraction of the main message, although one participant assessed it as too simplified. Thereby, participants were motivated to contribute their own view of the issue and their local knowledge. This is an indication that the visualisation was compared with the individual's cognitive concept of the shown facts. With regard to information processing, the design turned out to be very suitable for transferring the message of the scenario. The topic was further elaborated in the discussion by exchanging knowledge on factors and their effects. Thus, the relevance of the indicator was assessed collaboratively.

As a direct impact of the visualisations, the focus of the discussion shifted from the enhancement of winter sports to the diversification of tourist opportunities towards hiking, educational trails and farm holidays, and, making better use of the landscape as an asset. In conclusion, it can be suggested from the meeting minutes that the elevation analysis was the turning point of the discussion and the facilitator confirmed that it had a very strong impact on participation. Nevertheless, it should be noted that one participant felt uncomfortable working with the 3D images and stated in later conversation that he felt slightly manipulated because the image had such a strong impact. Another participant expressed his doubts on the credibility of the visualisations, because local conditions like exposition were not considered specifically. These experiences are in accordance with findings by Dockerty et al. (2005) and Sheppard (2005), who identify the downscaling process for national data on climate change to locally engaging scenarios as one of the biggest challenges in visualising climate change.

However, such detailed forecasts based on local models are not necessarily required in "what-if" scenarios, which aim to facilitate the discussion of hypothetical futures: How do the stakeholders respond if climate change will have an impact? Nevertheless, it is suggested that clarifying the relevance of the "what-if" scenarios in comparisons to forecasts or other more precise methods is necessary to present the assumptions in a transparent way. The collaborative and interactive development of the visualisations seems to be the right approach to making the assumptions more transparent, but there was not enough time in this workshop to go through the alternative

scenarios in detail, and the interactive analysis could have been used more as well.

Did the visualisations have a long-term impact (Nicholson-Cole, 2005)? There are strong indications that the visualisations did have an impact on the planning outcomes. From follow-up meetings with local stakeholders, it appears that the owners of the local skiing infrastructure installed the new facilities at higher elevations with regard to the discussion and the visualisation. In addition to winter tourism, the diversification towards a stronger focus on summer tourism was not only a consensus but a variety of new offers for summer tourists have now been established.

4.3.2. Linking diagrams to the 3D visualisations

Overall, the representation of the indicators by hyper-linking was understood by all participants and eight of the eleven participants favoured linking the landscape visualisations to statistical indicator data. The facilitator mentioned that all participants were familiar with the data but showing them in combination with the 3D visualisations “put more stress on them and they might have got an official character.” This means that the indicators were noticed more consciously and in context because of the visualisations, thereby increasing transparency and credibility of the assumptions.

Looking at the uneven distribution of overnight stays for winter in contrast to other seasons, the participants recognised the open potential for summer tourism. With regard to the uneven distribution of holiday houses and hotels, the stakeholders identified a lack of hotel space. It became clear that this lack of hotel space makes it impossible to host large groups, e.g., conferences or bus tourists, who usually travel in groups of about 30 people. Cause-and-effect chains were elaborated in the discussion and taken into account in the tourism development concept by calling for additional hotel space.

The chosen design seemed to assist the stakeholders in the workshop very well in the comprehension and assessment of the factors shown. As this group was used to abstract designs, the results may not be transferable to other stakeholders who are not so familiar with abstract presentations.

5. Case study 2: agriculture

5.1. Concept

The characteristic landscape of the Entlebuch region has been shaped by agriculture, in particular, cattle breeding and dairy farming. However, the future development of this area depends on political and economic driving forces, such as the liberalisation of the agricultural market and declining subsidies that will increase the pressure on existing farm management practices. A decline in grazing will cause major changes in the landscape with negative impacts on local socio-economic and ecological conditions.

Therefore, within the framework of the EU project: Lacope–Landscape Development, Biodiversity and Co-operative Livestock System (www.lacope.net) local farmers of the Entlebuch Reserve, administrative representatives, experts, and scientists worked together on a concept for future management systems on the alpine farms. The outcome of the collaboration was thought to show measures that take into account very specific regional characteristics but their implementation was optional for the individual farmer and not tied to legal documents. The major aim was to elaborate sustainable land use practices on the alpine farms that would be suitable to keep the dynamic of forest and pastures in a balance and thus the landscape open. For this task, landscape functions, e.g., the production and habitat functions, should be integrated into the assessment of possible land use changes. Indicators to assess these landscape functions should match the interest of the stakeholders, be applicable on the alpine farms, and be calculable on the basis of the available GIS data set. In this case, the vegetation types on the alpine farms were seen as a valuable data set for deriving the indicators.

The vegetation on the pastures is an important resource for the productivity of an alpine farm. The productivity of a pasture can be determined by the specific fodder quality of the vegetation types. A declining fodder quality is mainly expressed by the percentage of weeds in the respective type (Landwirtschaftliche Lehrmittelzentrale, 2004). For the assessment of the biotope function, the intactness of the respective vegetation types can be used as an indicator expressed by plants and plant associations. Therefore, plant species were chosen as an indicator for both the economic and the ecological condition of the pastures at different time periods of the agricultural trend scenario.

5.2. Methods

The Lacope team organised the workshops and recruited the participants. In a strong collaboration with the Lacope team, the concepts for the integrated 3D visualisations for two of the workshops were developed. The first workshop, in November 2004, was attended by eighteen stakeholders (fourteen agricultural specialists (i.e., farmers) and four representatives from public offices) and three scientists (agricultural experts) working on the Lacope project, who discussed the concrete impact of possible future landscape developments and the consequences for alpine farms. The group met again in a second workshop in June 2005, but this time only eight stakeholders and two scientists were present. They dealt with the developing solutions to optimise the management of the alpine farms, taking economic and ecological aspects into account. Using the integrated 3D visualisations in a workshop series, it was possible to enhance their design by applying the research results of the earlier workshop.

The stakeholders described a restructuring of the alpine farms according to the agricultural trend scenario.

As a consequence thereof, the view of the landscape would change drastically as a lot of open areas would be subject to a succession to forest. This scenario was to be prepared with 3D visualisations of all three types in order to show the consequences of the changes on single areas for an in-depth assessment.

First, the qualitative scenario had to be translated into a GIS database. A basic problem was that such detailed statements on regional landscape change require a large number of parameters that could not be collected in the given time. Moreover, as the simulated landscape processes grow more realistic, the parameter's uncertainty also grows larger. In addition, the results become difficult to interpret (Fritsch, 2002). As a compromise, simplified estimates were used to identify landscape processes, keeping in mind that the model's limited spatial validity had to be communicated.

Quantifiable criteria for pastures with high potential for land use change to extensive grazing or abandonment were derived from literature, e.g., the distance between farm building and pasture, the height above sea level, the slope, the soil moisture expressed by the vegetation types, and the current type of management (Pezzatti, 2001; Gotsch et al., 2004). In the next step, these criteria were translated by a spatial analysis of the digital terrain model and a query of the thematic data using ArcView 3.3 (www.esri.com) into a spatially explicit GIS database for the farms under discussion in the planning workshop. As numerous ecological and economic variables cannot be anticipated with sufficient certainty beyond 30 years (Lederbogen et al., 2004) and as the perceived relevance of distant consequences of changes is rather low for most people (Nicholson-Cole, 2005), a time horizon of 30 years was defined. A time period of 5 years was chosen to demonstrate economically relevant changes due to management alternatives in the short run and two other time frames from today, each of 15 years, should reveal the impact of the development on the vegetation and thus the view of the landscape.

Causal chains were built, including knowledge on vegetation ecology, and were used to allocate the changes in the land cover in the selected time frames according to the agricultural trend scenario. An example for such a causal chain is: If grazing pressure declines, then extensive pastures on a rather wet fen will be avoided by cattle. This will cause the initiation of a succession process to forest that would start with dry grass and tall forbs in the first stages. On extensive pastures in dryer areas, grazing weeds and groves would come up in a time frame of 5 years, followed by an area-wide growth of spruces (*Picea abies*).

5.2.1. Visualising indicator species of fens

To enable an assessment of the view of the landscape, the intactness of the vegetation types, and their fodder quality, rather realistic representations of the landscape changes were prepared with the software Visual Nature Studio (VNS; www.3dnature.com). The programme allows GIS

shape files to be imported and can distribute different plant models in the polygons. The vegetation types were mapped following a simple mapping key useful for vegetation mapping in an agricultural management context. The size of the key plant species of each vegetation type, e.g., *Eriophorum latifolium*, *Ranunculus acris*, *Ranunculus acro-nitifolius*, and different clover species (*Trifolium*) indicating fens, was exaggerated. Additionally, indicators for the direction of long-term development, e.g., rush species (*Juncus* sp.) and *Veratrum album* as indicators for effects due to changes in the grazing intensity were shown. Thus, the viewer's attention should be drawn to these indicators without disturbing the represented view of the landscape (Fig. 3). For a better orientation, viewpoints were chosen that are easily recognisable due to landmarks, e.g., by showing the Schratzenfluh, a large karst mountain in the area, in the background. In the first workshop, the distribution pattern of the plants in the polygon and some of the plant species shown were criticised as incorrect by the stakeholders. These aspects were improved in the 3D visualisations used in the second workshop.

In both workshops, these visualisations were used to activate the subsequent discussion. In the first workshop, they were part of an impulse presentation whereas in the second one, they were presented in a loop of a sequence that presented each image for six seconds so that the participants were able to see them several times and then make their thoughts or comments known.

5.3. Results and discussion

The effects of the integrated 3D visualisations used in the two workshops are based altogether on four observation protocols, two group discussions, and four in-depth qualitative interviews, i.e., three with the facilitators (in the first workshop, the facilitator team, comprising the regional manager and a scientist of the Laco project, was interviewed together, in the second workshop, they were interviewed separately) and a telephone interview with one of the representatives of public office who focuses on nature protection. The data analysis followed the same methods as in the case study described in Section 4.2.

5.3.1. Visualising indicator species

In both workshops, the specific visualisations received rather intuitive responses from the stakeholders. These emotional reactions can be traced back to their identification with the area shown, also recognised by the facilitator. Overall, this can enhance the motivation to deal with the subjects shown.

The exaggeration of the indicator species in some of the visualisations was criticised. In one image, the pasture was said to look like a fairy tale due to the distribution of too many of the indicator species. One farmer said that pastures like those represented do exist but not in their area. In another visualisation, the transition between two vegetation types was very sharp because of the GIS

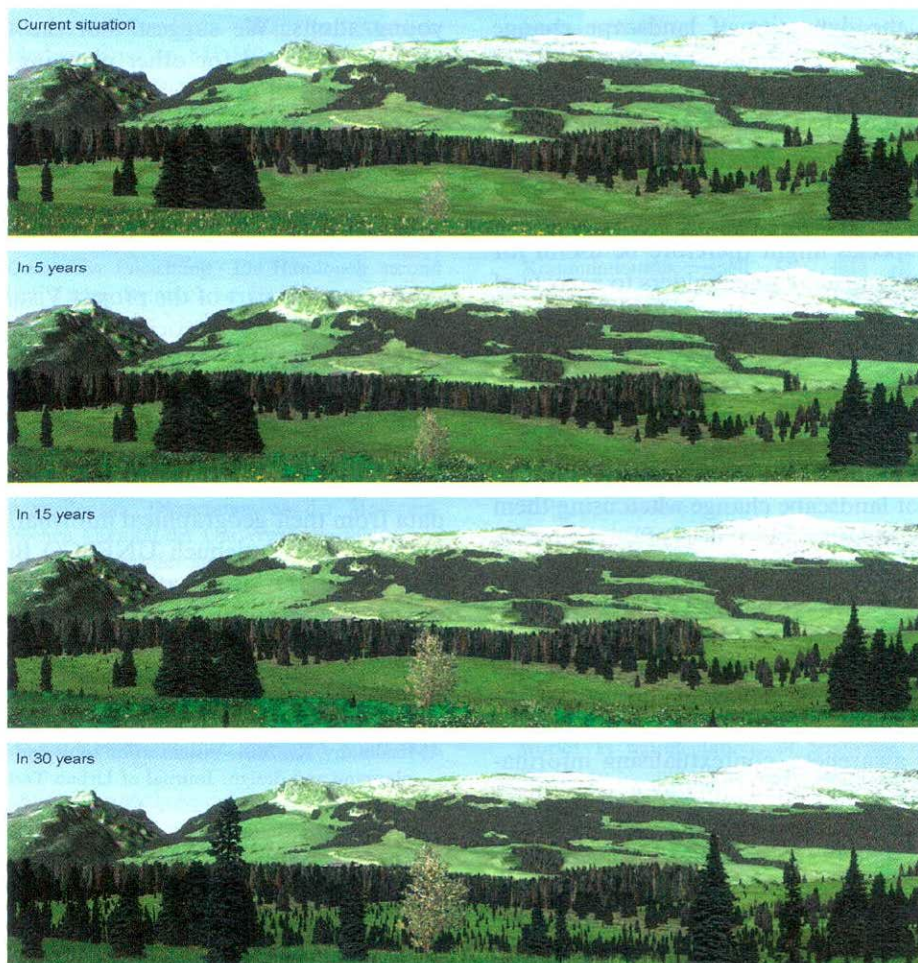


Fig. 3. Realistic renderings demonstrating the impact of a management change on the habitat quality through the use of indicator species on vegetation level (3D visualisation: VisuLands 2005; geodata courtesy of GIS Canton Lucerne).

polygons and from the chosen standpoint it looked awkward and rather unrealistic. Therefore, standpoints showing landscape elements in a perspective where they are not recognisable at first glance should be avoided and exaggerations carefully applied. On the other hand, the participants were of the opinion that exaggerations in these kinds of visualisations are good for raising the awareness of lay people who are not familiar with the area with regard to problematic issues. The actual effectiveness for lay people should be analysed in further studies.

Lively discussions on the accuracy of the content followed the presentations. The stakeholders responded according to their own experience and thus they revealed different opinions on the development of the vegetation. The farmers mentioned that deciduous trees would come up in the first succession stages, whereas the foresters were of the opinion that spruces would occur area-wide. Rush species were said to be indicators for an overuse of wet pastures. Indicator species occurring in cases of undergrazing were listed by a representative of the nature protection office. Although the represented vegetation change in the 3D visualisations was not correct in every detail, the feedback shows that the stakeholders recognised

the indicator species. The visualisations pointed out their use in promoting the exchange of experience between stakeholders with different perspectives. The method of showing new aspects in the form of indicator species in known development processes was said to be very useful for this task. With regard to the effectiveness, these 3D visualisations could be enhanced by integrating more local knowledge and specialists' experiences. Their use could lead to more meaningful discussions between stakeholders, e.g., on problematic developments with regard to the maintenance of biotope functions due to apparently small management failures, thus communicating certain measures and their intended aims more comprehensively. In addition, the farmers stressed that they got a stimulus for their thoughts on the future landscape and possible land use.

The stakeholders in the workshop knew the development used for the visualisations very well but seeing it as a time series brought a new aspect. Verbal references and gestures indicate that the interactive temporal presentation assisted them in recalling or even anticipating experiences, in turn motivating them towards active participation in the discussion on possible solutions. In other words, the time

series communicated the dynamics of landscape change and highlighted how the visual landscape will change in this scenario. Referring to some of the indicator species, discussions on cause-and-effect chains took place, e.g., mistakes made in management practice that led to the occurrence of the rush species, revealing interest for a deeper analysis to find solutions to solve the problem. Visualising indicator species might therefore be useful for simple initial assessments to alert stakeholders to aspects of change that should be subject to further investigation.

6. Conclusions

Overall, all three ways of integrating indicators into 3D landscape visualisations have shown to be effective in assisting the analysis of landscape change when using them as an introduction to the working phase of participative planning workshops. These results correspond to the conclusions by Lange and Hehl-Lange (2005) that landscape visualisation can facilitate the communication between professionals and the public and increase the scope of participatory workshops. The chosen designs fulfilled the functions required by assisting in information processing by raising awareness, contextualising information, and encouraging a critical comparison with one's personal perception as well as the further analysis of a topic. The interactive spatial analysis was flexible enough to respond to the fact introduced by the facilitator and to show the possible impact of a climate change scenario on local tourism. The visual analysis supported the facilitator's attempt to open the discussion on more balanced tourism strategies for winter and summer tourism and there are strong indications that it had an impact on the outcomes as well.

Interactively linking the spatial distribution of accommodation with diagrams on their average utilisation, animated the stakeholders to set up cause-and-effect chains that drew attention to problematic relationships that should be considered in a further analysis. Data known beforehand but not included in the considerations were thus used for the assessment.

Visualising indicator species seems to provide a common language for different stakeholders to discuss problematic developments from different perspectives and to alert stakeholders by offering a simple initial assessment. The dynamic presentation of indicator species in a time series especially proved to support the understanding of landscape change. By drawing attention to how slow processes evolve on the vegetation level, they helped stakeholders to recall experiences, which in turn brought up local information very useful for a more comprehensive assessment of the development shown in the visualisation.

Finally, the approaches to integrating indicators into 3D visualisations could only be tested with collaborative stakeholder groups. As public participation addresses the general public, their effectiveness should be tested with interested citizens, the passive public, and children or

young adults. We suggest that the three approaches be further developed for other planning settings and participant groups. For different participatory settings, other approaches with simpler representations and interactivity will have to be found.

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Linking GIS-based models to value ecosystem services in an Alpine region

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Abstract

Planning frequently fails to include the valuation of public goods and services. This can have long-term negative economic consequences for a region. This is especially the case in mountainous regions such as the Alps, which depend on tourism and where land-use changes can negatively impact key ecosystem services and hence the economy. In this study, we develop a semi-automatic procedure to value ecosystem goods and services. Several existing process-based models linked to economic valuation methods are integrated into a geographic information system (GIS) platform. The model requires the input of a digital elevation model, a land-cover map, and a spatially explicit temperature dataset. These datasets are available for most regions in Europe. We illustrate the approach by valuing four ecosystem services: avalanche protection, timber production, scenic beauty, and habitat, which are supplied by the “Landschaft Davos”, an administrative district in the Swiss Alps. We compare the impacts of a human development scenario and a climate scenario on the value of these ecosystem services. Urban expansion and tourist infrastructure developments have a negative impact on scenic beauty and habitats. These impacts outweigh the benefits of the developments in the long-term. Forest expansion, predictable under a climate change scenario, favours natural avalanche protection and habitats. In general, such non-marketed benefits provided by the case-study region more than compensate for the costs of forest maintenance. Finally, we discuss the advantages and disadvantages of the approach. Despite its limitations, we show how this approach could well help decision-makers balance the impacts of different planning options on the economic accounting of a region, and guide them in selecting sustainable and economically feasible development strategies.

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1. Introduction

Faced with tightening budgets, decision-makers are often asked to demonstrate the economic benefits of their investments. In their decisions, they may consider many objectives, including environmental quality and potential effects on people's quality of life. However, these impacts are difficult to evaluate economically. The need for public goods and services values was already noted by Westman

(1977). Since then, the valuation of ecosystem services has become one of the most significant and fastest evolving research areas in environmental and ecological economics. During that time, the number of publications on the benefits of natural ecosystems to human society has grown rapidly (e.g., Daily, 1997; Costanza et al., 1997; Heal, 2000).

Above all, the estimation of ecosystem service values on a global scale, has engaged both scientists and policy-makers. Costanza et al. (1997), e.g., valued the world's ecosystem services to be in the range of USD 16–54 trillion per year. This paper helped to draw attention to this topic (Costanza, 2002). Several authors have since transferred the unit ecosystem service values estimated by Costanza

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et al. (1997) to their study region (Sutton and Costanza, 2002; Williams et al., 2003). Nevertheless, regional studies that value multiple ecosystem functions simultaneously and that capture the “before and after” states during environmental changes are rare (Bockstael et al., 1995; Mallawaarachchi et al., 1996; Higgins et al., 1997). On a local scale, however, these “before and after” types of analysis are by far the most important aids for rational decision-making where the conservation of ecosystems may be pitted against development situations involving different stakeholders.

Alpine regions are often perceived as economically non-profitable regions. Mountain ecosystems, however, provide society with a wide range of goods and services, including protection against natural hazards (e.g., floods, avalanches, and landslides), carbon sequestration and storage in mountain forests (cf., the Kyoto protocol), natural resources (e.g., dairy products, timber as renewable raw material for energy production and for construction), tourism and recreation (e.g., skiing, hiking, biking, bird watching, and hunting), fresh water, and biodiversity.

In modeling ecosystem processes, geographic information systems (GIS) are useful as they have the capacity to incorporate the complexities of the spatial dimensions involved. They allow spatial and field survey data to be used in models within the same graphic environment. They are particularly useful in mountainous regions, where complex topography and distinct environmental gradients require a special consideration of spatial patterns (Heywood et al., 1994). A large number of sophisticated models have been produced. They differ in their research objectives and the scales associated with these objectives. Several authors have embedded such ecosystem process models into a GIS platform (e.g., Turner, 1990; Fischer et al., 1996; Arlinghaus, 1996; Mitasova, 1998; Boll et al., 2004). Others have gone one step further and linked the ecosystem service quantification processes to economic valuation methods in a GIS (e.g., Eade and Moran, 1996; Mallawaarachchi et al., 1996; Termansen et al., 2004). However, to our knowledge, no one has tried to integrate into a single GIS platform several ecosystem process models simulating the provision of ecosystem services simultaneously with economic valuation procedures.

This paper presents a modular framework for valuing semi-automatically various ecosystem services under different land-use change scenarios. We integrate process-based models using GIS to quantify ecosystem services together with economic valuation procedures. The modular framework allows the flexible use of state-of-the-art models. Where existing process simulation models are not appropriate, new models can be developed and easily added to the system. The model aims to provide orders of magnitude of the impacts of development scenarios on the values of ecosystem services, which can then be used to support decision-making. We illustrate the approach by valuing key ecosystem services in the Alpine region of the administrative district of Davos (Graubünden, Switzerland).

The ecosystem services to be studied were selected to correspond with the four main ecosystem functions described by de Groot (1992), namely regulation, habitat, production, and informational functions. Regulatory functions are those that maintain the ecosystems and life-support systems, for example, how the forest provides protection against avalanches. The habitat function refers to the availability of habitats for the various life cycles of plants and animals, which helps to maintain biological and genetic diversity and the evolutionary process. This function is illustrated by examining the distribution and extent of habitats for Capercaillie (*Tetrao urogallus*) in the study area. This large forest grouse prefers semi-open forests with intermediate canopy cover and extensive ground vegetation (Schroth, 1992; Sjöberg, 1996), and has been shown to act as an indicator for a rich mountain forest community especially for red-listed mountain forest bird species (Suter et al., 2002; Bollmann et al., 2004). The information functions involve those aspects of ecosystems that contribute to human mental and spiritual well-being. An assessment of scenic beauty preferences serves this function. Production functions consist of the processes that combine and change organic and inorganic substances, through primary or secondary production, into goods that can be directly used by humans. This last function is illustrated by timber production.

2. Method

The conceptual framework used in this study has three major components: scenario-building, process-modeling, and economic valuation (Fig. 1). These are integrated into a GIS platform. Central to the modeling framework is the use of a single programming language (Visual Basic.Net). This standard Windows programming interface allows easy retrieval of spatially explicit data, incorporate routines and display the results in ARC/INFO 8.3 (Environmental System Research Institute, 2000). The main datasets include a digital elevation model (DEM), a land-use cover map, and an average temperature grid of the case-study region. These three spatial data layers build the input into the process models, which are called within the main program. The graphical user interface automates the connection between the GIS data and the models, and guides the user through the process of selecting the GIS data, conducting the model simulations, and viewing the results.

The scenario-building component consists of the modification of the land-use maps according to scenarios developed for the case-study region. In this step, planners are required to adjust the land-use maps to reflect new development strategies. The modified land-use maps form the input for the process-models.

The process-modeling component is the core of the system. It includes the process-based models to quantify the ecosystem service changes. All the models are stand-alone routines written in ARC/INFO 8.3. Inputs to the process-based models are the modified land-use maps, the

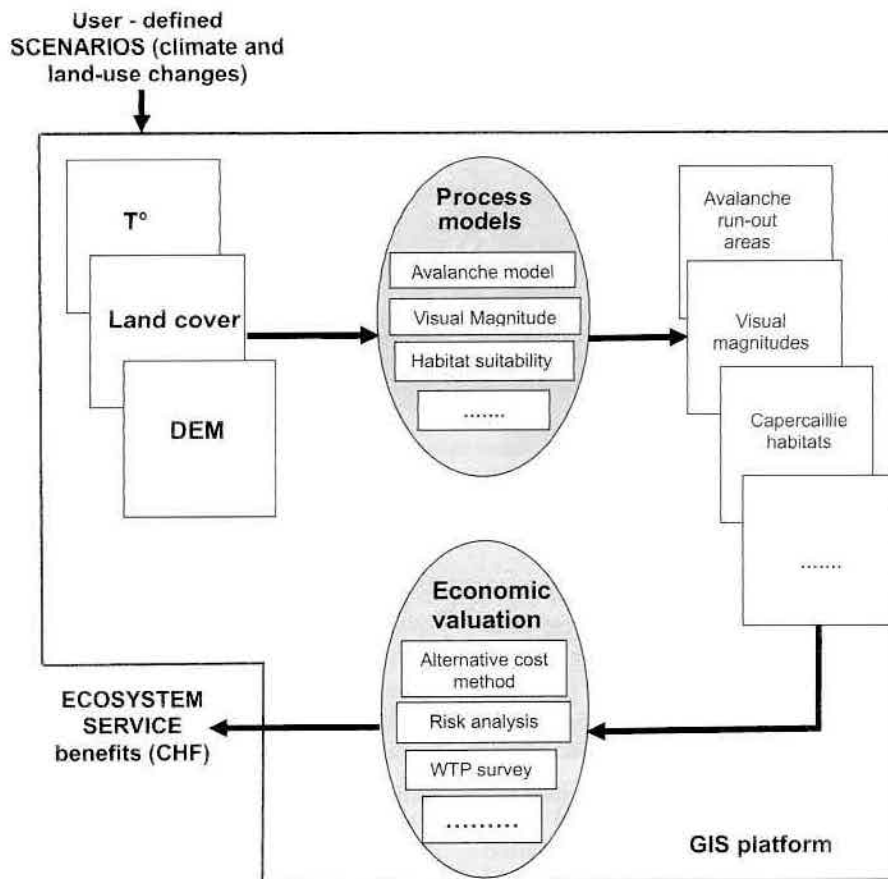


Fig. 1. Conceptual framework of the GIS modeling platform to semi-automatically value ecosystem services. A Graphical User Interface guides the user through the model. Modifications of the input data are reflected in the ecosystem service benefits.

DEM, and a spatially explicit temperature dataset. Models used to quantify avalanche protection, scenic beauty, and habitat suitability are summarized in Section 2.3 and described in detail in the Appendices A–D. The user can select to run the process models separately.

In the economic component, the changes to ecosystem service are valued. We calculate the impact of an incremental change in an ecosystem service (production of goods or services). Unit economic values calibrated in the case study or empirical models using local data are linked to the output of the ecosystem process models. The economic values represent what people would be willing to pay for an extra unit of that service under actual conditions in the current time period, given the existing allocation of other resources. The input for this component is socio-economic data, including controversial aspects such as the economic value of people. As the majority of these data are drawn from the literature rather than empirical findings, default values, which the user can modify, are provided in the program.

2.1. Case-study region and data sources

The study area encompasses a 100 km² section of the “Landschaft Davos”, an administrative district in the

eastern part of the Swiss Alps (Fig. 2). It has as its center the town of Davos, and includes most of the urban, forest, and agriculture areas of the administrative district. The “Landschaft Davos” consists of a NE–SW-oriented main valley (Landwassertal) and four SE–NW-oriented valleys. The altitude of the valley bottom varies from 1400 to 1600 m a.s.l., and the highest peaks are over 3000 m. Davos is a mountain resort with a population of around 11,000 permanent residents, although during the peak season in winter up to 28,000 tourists can be accommodated. The central part of the main valley hosts the core settlement with a well-established urban and tourist infrastructure. The rest of the main valley and the three side valleys have remained relatively rural with a few small, scattered settlements and a landscape still strongly dominated by mountain agriculture. The main source of income is tourism. Medical clinics and four scientific institutes also contribute to the economy of the region. Forestry (22% of the total area of 254 km²) and agriculture, including about 90 farms, provide further employment.

Land-use data on a hectare grid are available from two surveys of the Swiss Federal Office for Statistics for the entire country (Land Use Statistics 1979/1985 and the Land Use Statistics 1992/1997 data) (Bfs, 2006). The vector25 dataset, based on the National Map 1:25,000

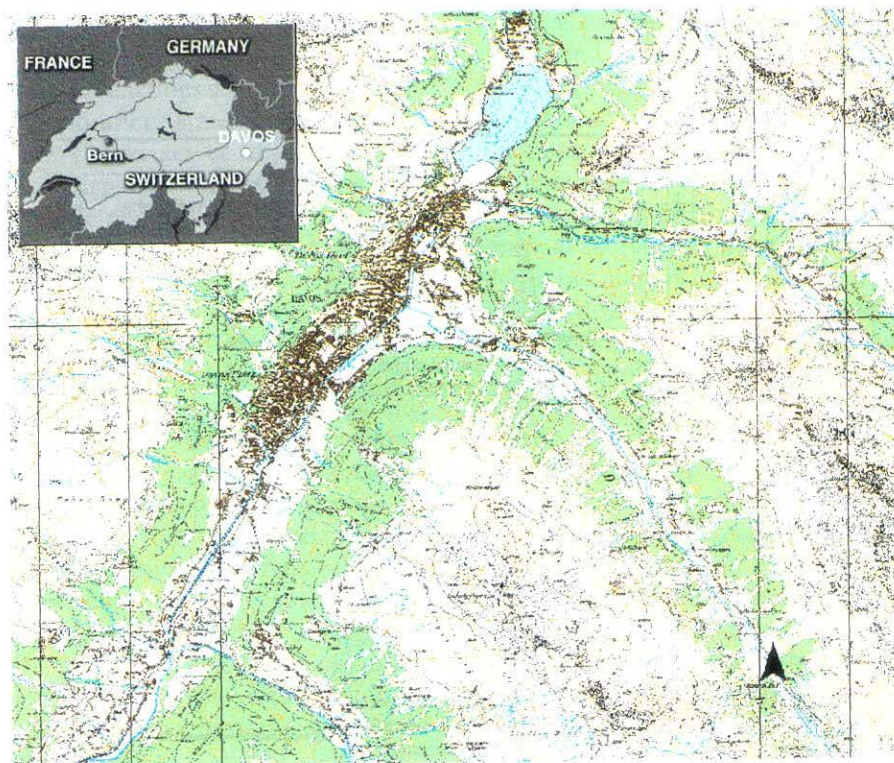


Fig. 2. The case-study area encompasses a 100 km² area of the administrative district of Davos located in the eastern part of Switzerland. The green area represents the forest; the grey area the town of Davos.

provides information on roads and the locations of buildings (Swisstopo, 2003). We also use a more detailed forest-cover map on a 5 × 5 m grid of the “Landschaft Davos”, based on aerial photographs from 1950 and 2000 (Lardelli, 2003). In this dataset, the forest structure is classified into four categories of crown projection (95%, 80%, 55%, and 30%). Topographical variables were obtained from the 25 m digital elevation model (DEM25; Swiss Federal Office of Topography), and temperatures from the national network of weather recording stations at different altitudes.

2.2. Scenarios

Scenarios were devised for the study area within the frame of the Swiss National Research Project 48 (Bebi et al., 2005a). Predictions about future developments until 2050 were formulated during workshops with the main stakeholders of the administrative district of Davos. This information provided the basis for the scenario stories. Three main types of land-use changes associated with these scenarios were determined, including a higher tree-line, new ski runs, and urban expansion (Fig. 3).

Scenario A is a climate- and landscape-change scenario characterized by an increase in average temperature of +2.4 °C (OcCC, 2003). It is associated with the abandonment of alpine pastures caused by a decrease in government subsidies (Anwander et al., 1990; Broggi, 1995; Bugmann et al., 2005). The land-use change associated with this

scenario is the densification and expansion of the forest-cover at higher altitudes (Fig. 3). We estimated the changes in forest-cover using transition probability matrices (Turner et al., 1996) based on transition rates from 1950 to 2000. Transition probabilities were estimated for 200 m vertical height strata. To simulate a raise in temperature, we applied the transition probabilities to the next strata located 100 m above. For example, we estimated probability matrices for the areas between 1700 and 1900 m and applied them to the areas between 1800 and 2000 m. This corresponds to a conservative scenario with a natural increase in temperature of 0.5 °C per 100 m, but it also matches results from recent models and modern hypotheses about the rising tree-line (Theurillat and Guisan, 2001; Schumacher, 2004). We manually digitized areas of avalanche activity, clearances, and the valley bottom and estimated transition probabilities for each these strata. The avalanche activity areas were delineated according to the avalanche observations from 1950 to 2003 (unpublished data, SLF, Switzerland). Clearances and the timberline were digitized from the 2000 forest-cover map. In addition to avalanches, wind storms are considered as the main disturbances in Swiss forests (Brassel and Brändli, 1999). We thus added windthrow areas, which cover 2% of the total forested area in the “Landschaft Davos”. This corresponds to the surface destroyed by the storm Lothar in Switzerland in 1999 (WSL and BUWAL, 2001). We distributed the disturbances areas randomly according to the fractal geometry described by Schmidtke (1993).

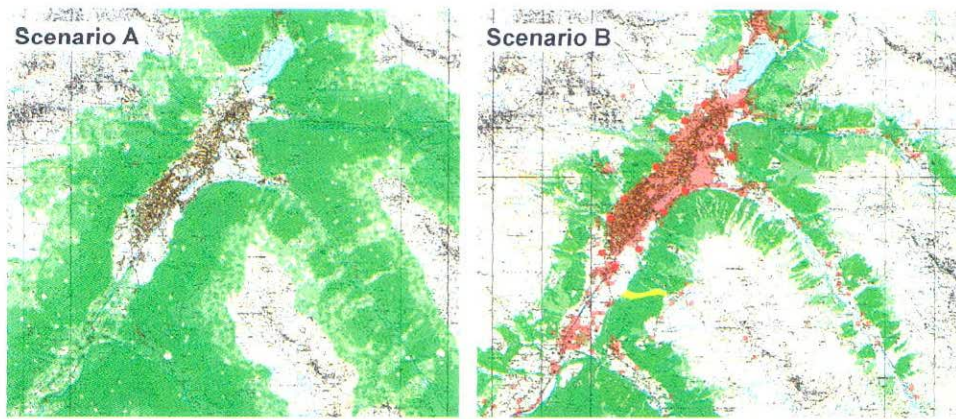


Fig. 3. Scenarios developed for the study area. Scenario A is a climate change scenario characterized by denser forest and higher timberlines (green area). Scenario B is a tourist development scenario characterized by urban expansion (brown area) and the addition of a ski slope (yellow area). The red points are view points representative of rental locations used for the visual magnitude calculations.

Scenario B is a tourist development scenario which would result if a large sport event, such as the Winter Olympic Games, took place. Land-use changes associated with this scenario are an increase in urban area of 40 ha (Fig. 3A) and the addition of a new ski slope of 11 ha above Davos (Fig. 3B) to accommodate the predicted 2.4% increase in people visiting Davos. Probable locations of urban development were assigned using logistic regressions based on an aggregated dataset from the Land Use Statistics 1979/1985 and the Land Use Statistics 1992/1997 data (Walz, 2005).

2.3. Process-based models

We quantified the changes in the selected ecosystem services under the different scenarios using four process-based models. Details about these GIS-based models are provided in the Appendices A–D. We calculated the avalanche run-out areas and associated forces under each scenario using AVAL-2D (Gruber, 1999; Maggioni and Gruber, 2003), a state-of-the-art two-dimensional dynamic avalanche simulation model which is used in Switzerland for avalanche prediction and hazard zoning (Appendix A). For the quantification of scenic beauty, we developed a 3-D GIS model of the landscape to calculate visual magnitudes (VM) defined as the portion of the field of view occupied by an object (Grêt-Regamey et al., 2007) (Appendix B). The quantification of suitable habitats for Capercaillie was based on a recently developed predictive Capercaillie habitat suitability model for Switzerland (Graf et al., 2005) (Appendix C). In order to estimate biomass production, we calculate the forested area under each scenario using GIS (Appendix D).

2.4. Economic valuation

We adopted several approaches to value the selected ecosystem services provided by the case-study area: a risk

analysis and an alternative cost method is applied to value the service of avalanche protection. The run-out areas were overlaid with buildings and road layers to estimate the damage potentials. To estimate people's preferences for views, we used the results of a willingness-to-pay (WTP) survey conducted with tourists in the "Landschaft Davos" (Grêt-Regamey et al., 2007). We priced the service of habitats for Capercaillie using habitat replacement costs. Finally, we used a market price approach to value timber production. Details about the economic valuation processes for each ecosystem service are given in the Appendices A–D.

3. Results

The results of the modeling framework are summarized in Table 1. Scenario B is characterized by urban expansion and the addition of a ski slope. This has a negative impact on the provision of the ecosystem services considered, namely scenic beauty, avalanche protection, and habitat. In contrast, the forest expansion under scenario A increases ecosystem service benefits, especially avalanche protection.

Scenic beauty is negatively impacted by urban expansion and the addition of ski slopes. The urban expansion we hypothesized, which has an estimated average VM of 49 from the 15 points of views shown in Fig. 3A, occupies a much larger proportion of the field of view than the ski area (average VM = 1.9). By implementing the VM results into the relationship between VM and WTP responses and multiplying the predicted WTP by the number of tourists accommodated in Davos in 2050, we obtained a negative average WTP of 1.9 million CHF for urban expansion and a negative average WTP of 33,600 CHF for the addition of the ski slope.

The impact of an increase in forested areas on people's perceptions of scenic beauty perception was not considered. This was because Grêt-Regamey et al. (2007) found

Table 1
Benefits from selected ecosystem services provided by the administrative district of Davos (Switzerland)

Scenario	Land-use changes	Scenic beauty benefits [CHF]	Habitat service benefits [CHF]	Avalanche protection benefits [CHF] using a risk analysis approach	Avalanche protection benefits [CHF] using an alternative cost method	Costs of forest maintenance [CHF]
A	Forest expansion	No preferences	45,300 to 111,700	8,034,700	16,159,000	143,300 ^a
B	Urban expansion	–1,900,000	0	0	0	2700
	Addition of ski slope	–33,600	–900 to –2200	–72,600	–2,251,300	1080

The numbers represent differences in the benefits arising from the land-use situation in 2000 and those arising from the land-use situation devised for the study area in 2050 (scenarios A and B).

^a Only 50% of the forest growth is removed for sustainable forest management.

that the view with a higher timberline and denser forest did not have a significant impact on scenic preferences in the case-study region. Other studies have, however, shown that people have preferences for different forest types (e.g., Patterson, 1989; Morton, 1999; Tahvanainen et al., 1996; Hunziker, 2000; Li et al., 2004). This difference might be due to the small size of forest modifications made in the original pictures or the already large forest areas present in the original photographs. The findings are discussed in detail in Grêt-Regamey et al. (2007).

The forest grouse benefits from an increase in forest area. Scenario A increases the surface of suitable habitats for Capercaillie by 151 ha (Fig. 4A). This improvement can be expressed in monetary terms as a rise from 45,300 CHF to 111,700 CHF, which is determined using the price per hectare for Capercaillie habitat restoration measures. The addition of ski slopes, however, destroys 3 ha of habitat suitable for the grouse (Fig. 4B), which corresponds to a negative impact of –900 CHF to –2200 CHF. Urban expansion has no impact on Capercaillie habitats as the development occurs in areas unsuitable for grouse (Fig. 4B).

Avalanche protection is considerably increased under scenario A. The protective effect of forests can be demonstrated by comparing the increase in potential release areas in a hypothetical situation where there is much less forest-cover than in 2000 (Fig. 5). Thus, there would be fewer potential release areas (Fig. 5) and run-out areas (Fig. 6) under scenario B, where the timberline is higher and the forest denser. The costs of fatalities prevented during this scenario amounts to approximately 8 million CHF while the addition of ski slopes leads to more risks for humans valued at 72,000 CHF. In contrast, the new urban areas do not increase the fatality rate as they are not planned in high avalanche risk zones.

Avalanche protection benefits estimated with the alternative cost method are larger than the benefit estimates using the risk analysis approach (Table 1). The smaller the land-use changes, the larger the differences between the estimates, as snow fences covering 1 ha have a minimum

price of 1 million CHF. Having a new ski area would create new snow release areas amounting to 2 ha, which would have to be eliminated by snow fences costing up to 2.3 millions CHF. In contrast, forest expansion could hinder avalanches originating from release areas of up to 16 ha, which corresponds to 16.2 million CHF worth of snow fences.

The cost of forest maintenance would increase under the climate- and landscape- change scenario. If 50% of the forest expansion were removed, it would cost up to 143,300 CHF. The development of the ski slope would require clearing 11 ha, which would cost 1080 CHF and the development of urban areas would be at the expense of 55 ha of trees valued at around 5400 CHF.

4. Discussion and conclusions

The modeling framework presented in this paper allows physical data to be translated into an economic value for ecosystem services. It does not aim to put an accurate absolute “\$ price tag” on the environment, or its component parts, but it is intended to enable the effects of a marginal change in ecosystem services to be expressed and compared in such a way that they can be included in decision-making. This allows the economic benefits of different development scenarios to be compared.

The model helps, for example, to weigh up the impacts of different development strategies on the economy of a region. Ski slopes are often planned in forest areas, which provide natural protection against avalanches. Under high development pressure, urban developments might be planned in avalanche-prone areas or fragile natural habitats. Such developments can have a significant negative impact on the value of the ecosystem services provided by a region. In this study, we show that new snow fences and restorations of habitats to compensate for the impacts caused by a large sport event (scenario B) can cost up to 2.3 million CHF, and scenic beauty can be negatively impacted by urban expansion to the order of 2 million

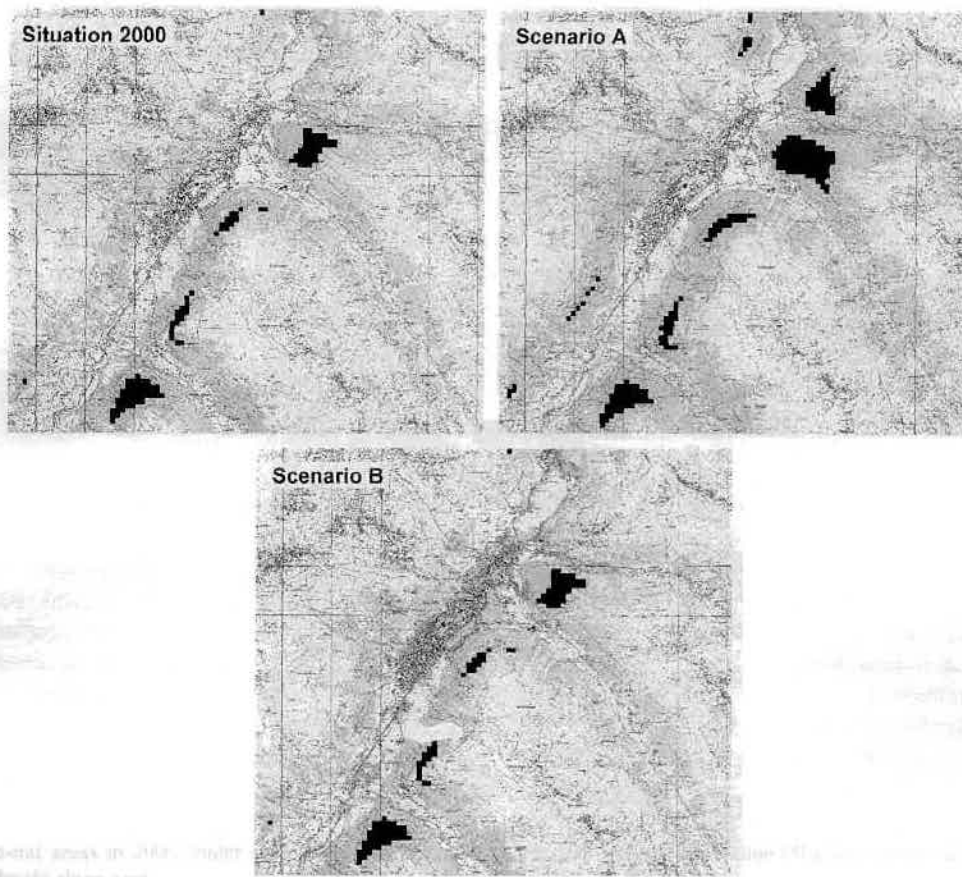


Fig. 4. Results of the Capercaillie-habitat-suitability model in 2000 for scenarios A and B. Suitable habitats for Capercaillie are shown in black.

CHF. The impact of snow fences on scenic beauty might even increase these costs as they have been shown to affect people's assessments of landscape attractiveness negatively (Messerli, 1989). Furthermore, the costs of restoring a special habitat might correspond to a small part of the expenses to protect grouse populations in the area, as even suitable areas might not be repopulated naturally. The long-term negative impact of such a large sport event on the costs of providing local ecosystem services can be compared to the economic benefits of 6 million CHF per year predicted for the "Landschaft Davos" (Kytzia, S., unpublished data, ETH Zürich).

The modeling framework can also support decision-making attempting to cope with the allocation of scarce resources among competing demands. The value of forests is evident in the climate- and landscape-change scenario (scenario A), especially their value for avalanche protection. Denser forests and higher timberlines can provide benefits of approximately 8 million CHF in the form of avalanche protection and 45,000 to 110,000 CHF as special habitats. This applies specially to situations during extreme weather events when ski slopes are not maintained and avalanches are released in these otherwise safe areas. The sum of these benefits outweighs by far the costs for forest maintenance (140,000 CHF). Today, as funding for forest

the model assumes no release. Since structure depends on both spatial and temporal analyses of minimum snow accumulation is diminishing, it is important to concentrate efforts on forest areas providing the highest benefits. For example, the cost of fatalities in the Dischmatal, a scarcely populated valley, is approximately 400 CHF/ha and in the area around Davos it is 7200 CHF/ha. Furthermore, under scenario A, the Dischmatal (especially to the east of the entrance to the valley) provides many more potentially suitable habitats (16,000–40,000 CHF) than do areas around Davos (4000–10,000 CHF). Thus, reducing maintenance in the Dischmatal in favor of maintenance of forest areas above Davos would increase the provision of avalanche protection and habitat services in the region (Bebi et al., 2005b).

The number of input datasets to the modeling framework is small, which makes it feasible to implement the model in other areas. DEM, land-use and temperature raster datasets are available for many regions in Europe. However, the transfer of the economic valuation is less straightforward. The problems associated with benefit transfer have been reviewed by several authors (Smith, 1992; Boyle, 1992; Bergland et al., 1995), who note that survey results are especially difficult to transfer to other areas. To overcome this problem, it helps if there are a range of estimates from different methods, for instance the service of providing avalanche protection can be valued by

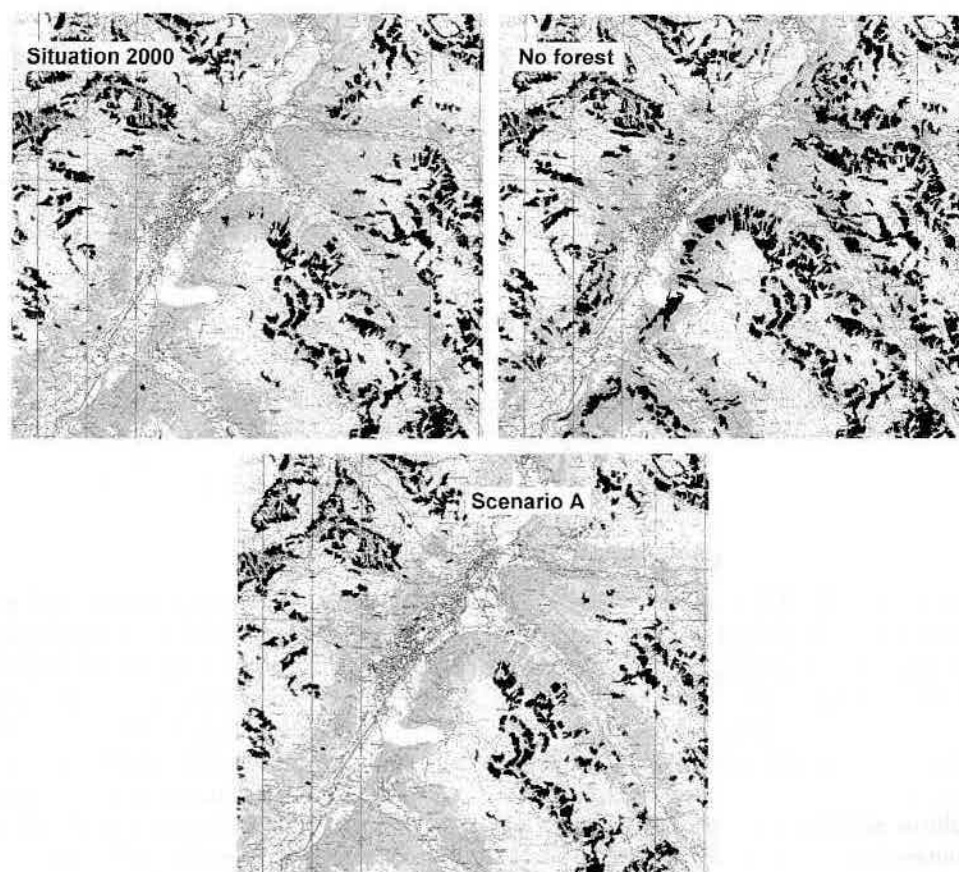


Fig. 5. Automatically determined avalanche release areas with the model AVAL-2D. The black areas represent the avalanche releases areas under the forest cover of 2000, a hypothetical scenario of missing forests and scenario A.

risk analysis or an alternative cost method. In this study, avalanche protection provides the greatest economic benefits under both of both economic valuation methods considered.

The proposed framework offers many possibilities for further development. In its present form, the model does not include the explicit quantification of the uncertainties related to the process-based and valuation models. Uncertainties can be related either to the input data, such as the GIS data layers or the unit economic values, or to the modeling processes. This might considerably influence the results. One approach to help quantify and visualize either of these uncertainties in a spatially explicit manner is based on Bayesian theory and was applied in the field of risk assessment (Aspinall, 1992; Stassopoulou et al., 1998) and recently in the field of natural hazards (Straub and Grêt-Regamey, 2006; Grêt-Regamey and Straub, 2007). Such an approach has the advantages that it helps to identify the variables causing large uncertainties in the results, that it can present the uncertainties on a map, which builds the basis for providing credible information to planners, and that the models can be updated if better information becomes available. This last point is especially important in the valuation process, as with time the accuracy of the monetary evaluation should improve

(Carson, 2000) and as better data and models become available. Currently, we are exploring applying a probabilistic framework to the approach described in this study (Grêt-Regamey and Straub, 2007).

Avalanche protection and habitat services are only a few of the benefits provided by forest resources. The model described here is only a first step towards the integration of process models in order to value ecosystem services. There are many other ecosystem services, such as carbon sequestration, gas regulation, and pollution control, which are provided by natural resources. Yet, the flexible modeling framework allows it to be integrated easily with other ecosystem process models. A comprehensive model that included the valuation of all the relevant ecosystem services provided by a region would add a new and important facet to the information available to decision-makers.

Acknowledgments

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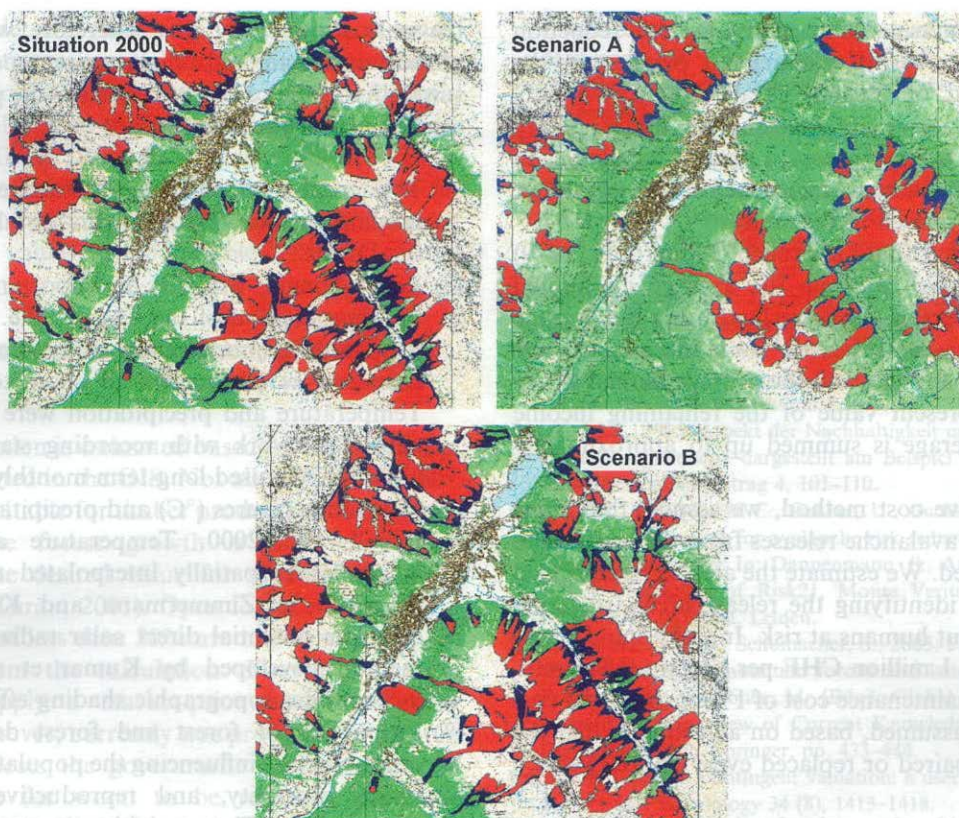


Fig. 6. Avalanche run-out areas in 2000, under scenario A with a denser forest and a higher timberline (5b), and under scenario B with the newly developed areas and the ski slope area.

Dr. Roland Graf from the Swiss Federal Institute for Forest, Snow and Landscape Research for his advice concerning the Capercaillie model and Dr. Urs Gruber from the Swiss Federal Institute for Snow and Avalanche Research for the AVAL-2D and his continuous support. Finally, we would like to thank Dr. Silvia Dingwall Stucki for the English corrections.

Appendix A. Quantification and valuation of avalanche protection

The methodological approach used to quantify and value avalanche protection is based on the concept of risk (see, e.g., Fuchs et al. (2005) or Bründl et al. (2006)). In the area of natural hazards, risk is defined as a function of the probability of occurrence of defined events and the corresponding extent of damage. In this study, we base our analysis on a 30- and 300-year recurrence scenario, and determine the damage potential by overlaying a map with the location of buildings and roads and the spatial extent of the avalanche run-out areas using GIS.

The run-out areas and the forces associated with the avalanche event are estimated using AVAL-2D (Gruber, 1999; Maggioni and Gruber, 2003), a two-dimensional avalanche dynamic program. In a first step, AVAL-2D identifies the sizes of avalanche release zones based on terrain characteristics and fracture depths. In forest areas,

the model assumes no releases. Snow fracture depths are built upon statistical analyses of maximum snow accumulation for 3-day periods in the historical record. In a second step, the model predicts run-out distances, flow velocities and the impact pressures of dense snow avalanches. The flow simulation model employs a “Voellmy-fluid” flow law, which assumes small shear strains in the flow body. Flow resistances, given by a dry-Coulomb type friction (μ) and a velocity squared friction (ξ), are assumed to be concentrated at the base of the avalanche. The presence or absence of forest in the avalanche path is modeled with an increase in the turbulent friction parameter ξ of 400 m/s² for the forested areas in the avalanche path.

Inputs to the dynamic avalanche model are a raster-based forest-cover map and the DEM. The output is the annual maximum pressures at each cell as a function of the friction parameters and the release scenario. The run-out areas are classified into red and blue zones. Red zones are defined as areas with pressures of more than 30 kN/m² and a recurrence period of up to 300 years, or with pressures less than 30 kN/m² and a recurrence period of up to 30 years. Blue zones are characterized by pressures less than 30 kN/m² and a recurrence period of between 30 and 300 years.

The location and number of potentially endangered persons located in domiciles and vehicles inside the red and blue zones are determined by overlaying the run-out zones

with the vector25 dataset. Vulnerability factors, reduction factors and the number of endangered persons in the buildings are based on Bründl et al. (2006). We only consider fatalities, as we are focusing on the monetary amount people are willing to pay to protect themselves in order to compare these economic benefits with the other economic values estimated in the study.

We select a human capital approach (Linnerooth, 1979) to value fatalities. We calculate the average discounted present value of a person in Switzerland using the average remaining working years, derived from the average age and average retirement age, and the average annual salary (BfS, 2002). The present value of the remaining income of a person on average is summed up to approximately 1.5 million CHF.

For the alternative cost method, we assume that snow fences eliminate all avalanche releases from the area where the fences are located. We estimate the area to be equipped with the fences by identifying the release areas triggering avalanches which put humans at risk. Initially snow fences cost approximately 1 million CHF per hectare (Margreth, 2000). An annual maintenance cost of 1% of the initial cost for snow fences is assumed, based on an estimate that the snow fences are repaired or replaced every 50–100 years.

Appendix B. Quantification and valuation of scenic beauty

The quantification and valuation of preferences for a view are based on Grêt-Regamey et al. (2007). A three-dimensional GIS model, including the effects of slope, aspect, and distance, as well as the height of landscape features, is used to calculate the proportion of land-cover areas that make up the view (visual magnitudes). Willingness-to-pay (WTP) responses for the considered landscape-changes are gathered using a web-based survey. A forced-choice questionnaire asks participants to compare pairs of landscape photographs. Two original pictures are digitally altered to visually represent landscape-change scenarios developed for the study area. The VMs of the different land-cover areas are found to be correlated with the WTP values expressed by the respondents. The relationship is used to predict changes in scenic values for other views in the region. VMs and the corresponding WTP values are estimated from 15 view points above Davos, which are representative of views from rental locations (see Fig. 3B). The predicted WTPs are multiplied by the number of tourists in rental apartments and hotels to obtain the total average WTP for a certain land-use change.

Appendix C. Quantification and valuation of habitat

The quantification of suitable habitats for Capercaillie is based on a recently developed Capercaillie-habitat-suitability model for Switzerland (Graf et al., 2005). The model of Graf et al. was developed for the whole Switzerland, it is not sensitive enough to the expected land-use changes on

the scale of our study area. Therefore, we used the results of their univariate logistic regression models to predict the suitability of the case-study area for the grouse. Dominant environmental variables include:

- (1) Topography, which includes altitude, slope and topographic position. Data for this variable were based on the DEM.
- (2) Local climate, which is an important factor affecting the reproduction of the Capercaillie. We used average temperature, precipitation and potential direct solar radiation as parameters to characterize the climate. Temperature and precipitation were derived from the natural network with recording stations at different altitudes. We used long-term monthly mean of average June temperatures (°C) and precipitation (mm) for the period 1971–2000. Temperature and precipitation means were spatially interpolated using a DEM as described in Zimmermann and Kienast, 1999. To calculate potential direct solar radiation, we used the method developed by Kumar et al. (1997), which incorporates topographic shading effects.
- (3) Proportion of forest and forest density, which are crucial factors influencing the population density, home range, mortality, and reproductive success of the Capercaillie. The variable “proportion of forest” describes the forest cover within a circle of 500 m and is estimated on the basis of the forest-cover dataset using GIS. The variable “forest density” is based on forest-stand-structure data provided by Lardelli (2003).
- (4) Disturbance by tourism and leisure activities. Disturbance by human activities is expressed by the presence of roads, alpine ski runs and settlements. Their locations were provided by the vector25 dataset.

For each environmental variable, we identified suitable cells in our case-study area, which were set to one. Based on the univariate logistic regression models, these include areas with more than 60% forest cover in a circle of 500 m, average June temperatures between 7 and 11 °C, convex landforms such as ridges, hilltops and exposed sites, more than 100 m from disturbed areas, and a canopy coverage between 30% and 80%. The overall suitability of a cell for Capercaillie is finally estimated by multiplying the *boolean* maps of all the predictor variables in the GIS environment. We validate the performance of the model by comparing our predicted results under the actual land-use cover with the results predicted by the habitat-suitability model of Graf et al. (2005), which was calibrated with presence and absence data for Capercaillie in the Swiss pre-Alps and Alps.

The habitats for Capercaillie are valued using habitat replacement costs. We collect information on the costs of projects in Switzerland, targeting the restoration of forest areas for Capercaillie habitats. Enhancement measures consist primarily of thinning out dense forest areas to promote ground vegetation and edge density. Other

procedures include soil scraping, placing root wads, fostering young trees, especially pines, and managing thickets. Costs vary between 300 CHF/ha for the delineation of a Capercaillie reserve (Schweizerischer Forstverein, 2004) and 740 CHF/ha (Bott, G., forestry officer Südbünden, personal communication, December 1st, 2004) for the improvement of a forest area for Capercaillie habitats. We applied these values to the suitable cells in the case-study area.

Appendix D. Quantification and valuation of timber production

Biomass production is estimated based on the number of forested cells counted in the GIS. Not all the forested cells, however, are exploitable for timber production. We assume that 50% of the forest growth is removed, which corresponds to the desired value for sustainable use of forest resources (Thrän, 2001). Open forest stands with a crown projection of less than 30% are not cleared and are thus excluded from the calculation. For the valuation procedure, we apply a market-price method. Timber production is, however, currently not profitable in Canton Graubünden. It costs the government approximately 98 CHF per hectare for wood to be removed from the forest (Costa, 2000). Each forested cell of 1 ha and a crown projection larger than 30% costs, thus, approximately 50 CHF.

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Integrated landscape planning and remuneration of agri-environmental services Results of a case study in the Fuhrberg region of Germany

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Abstract

Until now, existing remuneration of environmental services has not sufficiently supported the goals of spending money more effectively on the environment and of motivating farmers. Only a small share of the budgets for agriculture in the EU, as well as in US and other countries, is available for buying environmental goods and services beyond the level of good farming practice (GFP). This combined with the insufficient targeting of compensation payments to areas where special measures are needed leads to an unsatisfactorily low impact of agri-environment measures compared to other driving forces that stimulate the intensification of farming. The goal of this paper is to propose a management concept that enhances the ecological and cost efficiency of agri-environment measures. Components of the concept are a comprehensive environmental information base with prioritised goals and targets (available in Germany from landscape planning) and new remuneration models, which complement conventional compensation payments that are based upon predetermined measures and cost. Comprehensive landscape planning locates and prioritises areas which require environmental action. It contains the information that authorities need to prioritise funding for environmental services and direct measures to sites which need environmental services beyond the level of GFP.

Also appropriate remuneration models, which can enhance the cost efficiency of public spending and the motivation of the farmers, can be applied on the base of landscape planning.

Testing of the planning methodology and of one of the remuneration models (success-oriented remuneration) in a case study area ("Fuhrberger Feld" north of Hanover, Germany) demonstrated the usability of the concept and led to proposals for future development of the methodology and its application in combination with other approaches.

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1. Introduction: background and goals

Sustainable rural landscapes are not—and have never been—created solely as a by-product of agriculture and forestry. Although today's agriculture may have positive effects on landscape functions like soil fertility or ground water recharge, serious problems and risks for the environment can spring from either intensive farming, on one hand, or abandonment of extensively used land on the other (a significant share of valuable habitats depend on

extensive farming practices, see for example European Environmental Agency (EEA), 2006, p. 2). Nitrogen leaching and phosphorus output from agriculture are the dominant sources of nitrogen pollution in the rivers of the EU-15 and the nutrient charge of the North and Baltic seas (EEA, 2006; The German Advisory Council on the Environment (GACE), 2004b; INK, 2002; Lääne et al., 2002). Agriculture is also one of the main threats to biodiversity world wide (for Europe: Institute of European Environmental Policy (IEEP), 2004, p. 12). Simple compliance with "good farming practice" (GFP) is not sufficient to tackle these problems (see for example results of Simoncini, 2004). GFP is generally understood as the

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"type of farming that a reasonable farmer would follow in the region concerned, which entails as a minimum compliance with general statutory requirements concerning the environment, occupational safety, animal welfare, etc." (IEEP and DLG, 2004). Every farmer has to fulfil the standards of GFP without being compensated for possible cuts in income (Fig. 1). The EU has defined these duties in a rather general way as a basis for their Agenda 2000 CAP reform and more specifically in EU directives, which need to be implemented through national legislation. In national legislation, GFP is described in more detail and with national variations. In order to enable their farms to compete on the world market, most countries have chosen objectives for GFP which reflect environmental concerns but do not cause serious income reductions. If properly implemented, such objectives should suffice to achieve goals such as erosion prevention. However, without endangering the economic existence of farmers, these regulations do not have the power to implement the 'polluter pays' principle (for Germany, e.g. Di Fabio, 1995; Bielig, 2003), nor can they address more extensive site-specific problems, such as the special risk of ground water pollution or the existence of especially valuable habitats. Cross-compliance (CC) regulations do not significantly improve the degree of environmental consideration to a level which is needed for strong sustainability (definition according to Goodland and Daly, 1995; see also IEEP and

DLG, 2004, p. 1 IEEP, 2004). CC has been recently introduced by the EU CAP-reforms of 2003. The regulations tie direct payments from the EU to the compliance of farming practice with certain environmental requirements.

In addition to legal instruments, some countries try to implement the polluter pays principle in agriculture by levying taxes or placing additional charges on fertiliser or nutrient surpluses (e.g. Denmark, or MINAS—the Dutch Manure and Fertiliser Policy OECD, 2005). These additional instruments improve the implementation of GFP and reduce pressure on sites with average ecological sensitivity. However, they do not take into account the sensitivity and value of the ecological and the aesthetic functions of specific sites, which require improved or alternative land use adaptation measures.

Consequently, the publicly desired ecological goods and services must be purchased from farmers either with private or public funds. Public "green payments" are generally defined as payments made to agricultural producers as compensation for environmental benefits that accrue at levels beyond what producers might otherwise achieve under existing market and farm income objectives (Hanrahan and Zinn, 2005, p. 1). In the EU and in many other countries, such as US or Japan, agri-environment programs have been set up to offer incentives for farmers to deliver these services (OECD, 2005). Generally, such compensation payments to farmers are not considered to be trade effective, and therefore, comply with the "green box" requirements set up by the World Trade Organization (WTO, 2002).

However, these compensation approaches also suffer from severe shortcomings in terms of environmental and cost effectiveness:

- (1) Only a small share of the budgets for agriculture in the EU as well as in the US and other countries is available for buying these environmental goods and services.
- (2) Compensation payments are not sufficiently targeted on areas in need of special measures beyond GFP. In combination with the previous point, this means there is an unsatisfactorily low impact of agri-environment measures compared to other driving forces that stimulate intensification of farming.
- (3) Furthermore, there is a sceptical attitude towards more demanding environmental services and a lack of training and awareness of the farmers, which further hinders the successful implementation of such programs (for example for Germany by Gay et al., 2004; for Greece in OECD, 2005).

Considering the unsatisfactory present situation and future prospects, ways should be found to better target agri-environmental payments and to motivate farmers to promote sustainability. A prerequisite for better targeting of such measures is the definition of concrete environmental goals and targets which define the ecological

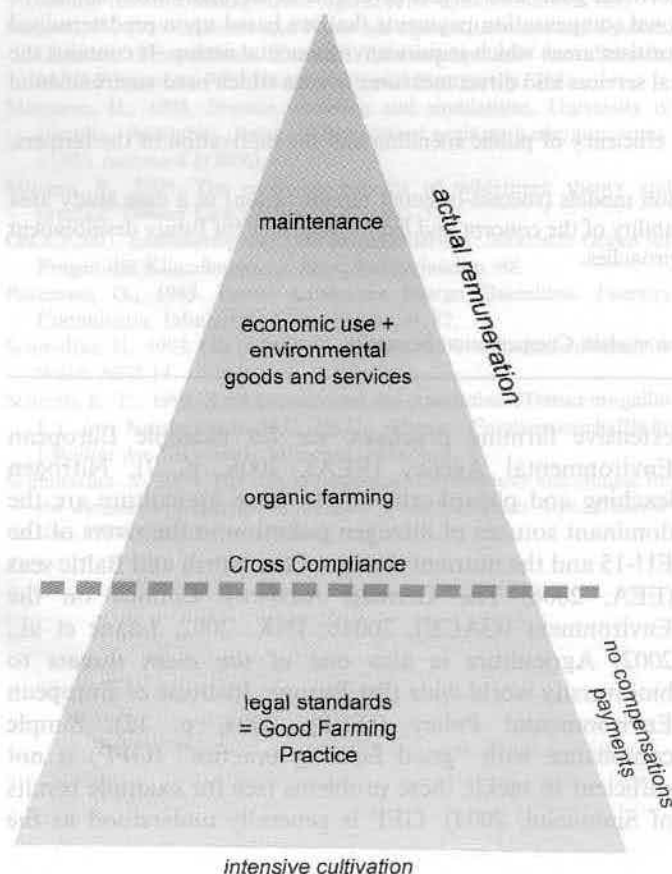


Fig. 1. Land use intensities and remuneration.

“shipping lane” for the “ship” of sustainable rural development.

In view of this situation, the objectives of this paper are:

- (1) To develop and demonstrate ways in which landscape planning (a comprehensive environmental planning) can support the allocation of agro-environmental measures (as proposed by IEEP et al., 2004) and of different remuneration models.
- (2) To share experience about the suitability of new models for efficient remuneration which promise better gains for nature, improved motivation and environmental education of farmers or increased value for the money.
- (3) To propose a concept for spatially targeting of the application of these models for agri-environmental services (in which type of area should which type of remuneration be preferred?).

In order to demonstrate possible solutions, this paper makes reference to the findings of a research project (Bathke et al., 2003) carried out in the “Fuhrberger Feld”, a region north of Hanover, Germany. The goal of the project was to develop a system for the future management of multifunctional sustainable landscapes. In view of the occurrence of similar problems in many other European countries (see Section 2), the findings of this project should be applicable to other situations. The project focussed on integrating comprehensive nature conservation and specific water protection objectives with agriculture and with the requirements of municipalities through multilateral co-operation.

2. Current problems of agri-environment programs

Both the EU and the US demonstrate relatively low and ineffective levels of expenditure on agri-environment measures: The EU budget for agriculture and rural development for the time period 2007–2013 amounts to €371 billion (Council of the European Union, 2005). About 80% of the entire budget is spent on market-related expenditure and direct payments. This praxis of primarily unconditional subsidies counteracts the establishment of efficient markets for environmental services (Bielig, 2003, p. 502). Only about 20% of the EU agricultural budget from 2007 until 2013 will be spent on rural development, including expenditure on agri-environment measures. Until now (2000–2006) agri-environment measures have made up about 40% of the EU-15 budget for rural development (less than 10% of the whole budget), although this differs greatly among the member states, ranging from about 5% (Greece) to almost 70% or 80% in Sweden (Gay et al., 2005, p. 12). In Germany, almost 50% of the available rural development funds have been spent on agri-environmental measures. The rest was allocated to rural development measures, such as farm tracks and land consolidation, which have often counteracted environmental goals throughout the last decades. Furthermore, the

spending on agri-environment programs is insufficiently targeted. The majority of the money and programs are available for measures which can be easily implemented by the farmer and do not require substantial changes in farming practices (European Commission DG Agriculture and Rural development, 2005, p. 16; Osterburg, 2002). These measures are funded on a first come, first serve basis. In Germany only about 20% of agri-environment measures have been tied to more demanding and site-specific requirements (Gay et al., 2004). As a consequence, agri-environment measures are not effectively targeted with respect to environmental needs. Such indiscriminate distribution (by what is called the “watering can principle” in Germany) has been documented for the majority of German agri-environment measures (GACE, 2002, 2004a; Osterburg, 2002). The situation in the EU as a whole seems to be similar (IEEP, 2004, p. 15): Statistical analysis shows, for example, that there is a poor geographical overlap of agri-environment schemes and Natura 2000 areas, which are of the highest importance for biodiversity in the EU-15 (EEA, 2006, p. 2; Gay et al., 2005). In practice, both insufficient funding and inadequate targeting of payments have resulted in the low impact of agri-environment measures in comparison to the other driving forces that stimulate farming intensification (Defra/Environment Agency, undated; GACE, 2004a). In contrast, many evaluations of the effectiveness of agri-environmental measures show the good results of regional and site-specific measures as well as measures linked to certain ecological conditions and problems. In terms of effectiveness, the policy measures have been producing positive results, particularly when clear targets or objectives have been set (OECD, 2005, p. 11). For example in Sweden, the most targeted form of support showed a substantially higher efficiency in terms of the positive effects obtained (OECD, 2005; similar: Niedersaechsisches Landesamt fuer Oekologie (NLO), 2003). However, environmental effectiveness studies also show that schemes are more successful at conserving the historical environment than at enhancing or developing biodiversity (e.g. results for England OECD, 2005, p. 20; Kleijn et al., 2001, 2006).

Compared to the EU, only a few compulsory environmental requirements apply to those farmers in the US who receive commodity payment. The goals of such CC are restricted to discouraging farmers from converting wetlands into farmland and from farming highly erodable land (Hanrahan and Zinn, 2005, pp. 3, 21). Only about 50% of the country's two million farmers are affected by this CC. Voluntary agri-environment programs (“farm bill programs”) appear to be well targeted to certain problems. However, the share of money spent in the US on agri-environment programs has been relatively even less than in the EU (Hanrahan and Zinn, 2005, pp. 8, 20).

In the future, European agriculture will have to address new framework conditions that presumably will lead to further liberalisation of agricultural policy. These conditions include future WTO obligations, the cost of eastern

expansion of the EU, and the growing public expectation that transparent agricultural subsidies are based to a greater extent on their societal benefits. Liberalised agricultural policy will have considerable impact on current agricultural and landscape structures and therefore should be accompanied by environmental and societal policy measures (GACE, 2004a).

The reorientation of subsidies is a possible response to the liberalisation of the CAP. Targeting environmental objectives would also mitigate the effects of structural changes on farmers who have unfavourable agricultural conditions and are willing to deliver environmental goods and services. The more subsidies are reoriented in future, the more essential it will be to have a firm basis for landscape management such as the one outlined in this paper (cf. Royal Commission on Environmental Pollution (RCEP), 2002, p. 6).

3. Data and methods

3.1. Planning methods

In order to efficiently target remuneration for farmers, a broad base of spatial information about ecological and social landscape functions, as well as prioritised landscape development goals—including local residents' preferences—are necessary. In Germany, landscape planning can provide such information and planning targets (see Kiemstedt et al., 1998; v. Haaren and Warren-Kretzschmar, 2006; Scholles and v. Haaren, 2004; v. Haaren, 2002). Landscape planning is a comprehensive environmental planning and can contribute to the assessment of the value and resilience of an area and to the evaluation of impacts and resulting measures. Landscape planning is carried out with blanket coverage and coincidence at all levels of spatial and zoning planning (for the state level in the scale 1:200 000–1:500 000, for the region usually 1:50 000 and for the municipality in 1:10 000 or 1:5000). It provides for the acquisition and integration of the interests of nature conservation and landscape management into spatial planning. Landscape analysis covers data for all environmental factors (soil, water, air, climate, flora, fauna, natural scenery and cultural assets at different spatial scales). In addition, it addresses the interrelationships between these factors by describing and assessing the ecosystems in terms of a wide variety of landscape functions. These range from the natural capacities of the landscape for supporting agriculture and forestry as well as for providing drinking water and flood protection, to the landscape's habitat and recreational functions. Suitable methods for inventory and appraisal of ecological and social landscape functions as well as for risk assessment are widely used. These have been developed by adapting methodologies from soil science (e.g. classification of soil erodability), hydrology (e.g. assessment of ground water recharge capacity and risk of input of nitrate), climatology (classification of terrain climate), vegetation science,

zoology and landscape aesthetics. The data needed for the application of these methodologies are either commonly available (e.g. soil maps) or can be acquired by field work (for methodology commonly used in Germany see Bastian and Schreiber, 1994; v. Haaren, 2004; Jessel and Tobias, 2002). In the Fuhrberg region, which comprises about 30,000 ha and eight local communities, landscape plans exist for the whole region at a scale which is suitable for local zoning and land use planning (1:10 000). The content of the plans varies slightly, and therefore, the data had to be standardised before it could be entered into a GIS database. All plans included an evaluation of the environmental situation, pressures and impacts. This information was then used to identify areas of priority for different landscape functions (see Table 1). In addition, site-related obligations of GFP could be deduced from this information. Special emphasis was placed on the protection of groundwater resources because the Fuhrberg region is a principal water supply area for the city of Hanover. Although abundant information was available about soils and geohydrology (e.g. Boettcher et al., 1992; Heumann et al., 2001), the vulnerability of the ground water was not spatially differentiated, as the sensitivity was very high all over the region. Therefore, positive synergies and potential conflicts in this field had to be identified by comparing priority measures of water protection and nature conservation.

Especially important in developing a procedural approach to landscape development which goes beyond protecting existing and historic landscape features, was the application of a methodology for *assessing the landscape potential for the development of new habitats* and restoration of former ones ("habitat development potential" (HDP)). In the Fuhrberg project this methodology for assessing the potential of the soils to support the development of (rare) target vegetation, which is worthy of protection (Brahms et al., 1989), was modified and applied to the data in Fuhrberg (Bathke et al., 2003). Soil maps at a scale 1:5000 and 1:25 000 provided the necessary soil data. The methodology results in an evaluation of the abiotic environmental site conditions that are relevant for habitat development and the recommendation of different development options. Using a geographical information system, the information was processed automatically and displayed in maps.

3.2. Methods for stakeholder-participation in data acquisition and planning

In the Fuhrberg project, the affected farmers, the farmers' union, and the local authorities of the villages and small cities in the area actively participated in the entire data acquisition and planning process. About 20 farmers, most of who had been working with the advisory service of the drinking-water supply company in the region before, took active part in regular meetings. The first contact and invitation was made via the farmers union.

Table 1
Sources and interpretation of landscape information used in the Fuhrberg project

Information available in existing landscape plans	Goals, targets, measures and priorities ^a	Additional data, data source	Improved methodology	Further interpretation and formulation of requirements for remuneration
Description of environmental factors and evaluation of their functions (including sensitiveness, existing and proposed pressures, evaluation and prediction of impacts) Assessment of natural potential for crop production (soil fertility, favourable mesoclimatic, water conditions, data from official soil maps, available data about climatic factors); Sensitivity of soil for erosion and compaction; Pressure: allocation of cropland and grassland (statistical data about crop rotation, additional information about land use taken from habitat mapping); Impact/risks: certain crops on sensitive sites, cropping on bog soil Groundwater recharge (deduced from soil, geology, precipitation); Sensitivity of groundwater to nitrogen input (soil and climate data from official sources); Pressure/impact: land use, land use intensity; Crops/crop rotation with high risk for nitrogen leaching	Yes The LPs indicate that the entire area had a high groundwater recharge priority and high vulnerability (no differentiation possible with simple methods) Yes	Irrigation data (from water supply company) More comprehensive data about water catchment areas, flow rate of groundwater, nitrate load of untreated water (from water supply company, research data)	More comprehensive methodology and scenarios by hydrologists	For overlapping areas with priority goals for soil, habitat, climate protection and recreation, the proposed measures were compared and synergies were identified. Because of the special importance of the area as an aquifer protection zone, measures which promoted both water quality/quantity management and other landscape functions (synergies) were given special priority for the cost effective remuneration Additional maps which show opportunities for farmers to offer habitat management In order to define priority or target sites for remuneration, the slightly different terms and categories of objectives in the different LPs had to be adjusted
Water retention on floodplains and storage capacity in the whole area (deduced from soil, geology, vegetation and land use parameters) Pressure: classification of housing and infrastructure based on degree of surface sealing Biod climatic functions: no comprehensive analysis in the landscape plans, because settlements are small and have no considerable air pollution or climatic impairments. Therefore the agricultural area has no important microclimatic function Assessment of: • Habitat development potential (in 1 LP); • Quality and density of existing habitats (data: aerial photographs, habitat mapping); • Mapping of selected species Pressure: land use intensity (usually taken from habitat mapping) Recreation: • Evaluation of landscape aesthetics (landscape attribute mapping); • Need for recreational qualities of the landscape in areas close to settlements; Pressure: visual disturbance, noise emission	All LPs of the Fuhrberg region have a comprehensive information base and evaluation of the habitat functions Yes	Use of the existing, very detailed soil data of the water supply company (LPs had used standard soil data)	Adaptation of methodology for assessment of habitat development potential to detailed soil data	

^aGoals, targets, measures and priorities for conservation, rehabilitation or development (based on information about landscape value, sensitivity, vulnerability)

This co-operation lead to substantial integration of the participants in the research work. Farmers took part in the development of some of the methodologies. They also took part in defining the preconditions for different scenarios, in which the rate of diffuse nitrate pollution was predicted by varying the amount of grassland that was ploughed or managed.

In fact, the participation of the farmers resulted in an additional analysis which was not originally planned. The convincing presentation of environmental issues motivated the farmers to represent their own interests more clearly. The identification of particularly important agricultural areas should help farmers and local authorities to decide where either agriculture or environmental goals should be given priority. In addition to the existing information about soil fertility in the landscape plans, current indicators for the description and evaluation of agrarian structure (commonly used in plans set up by the agricultural authorities in Lower Saxony) were then compiled and discussed with the farmers. A group of farmer's representatives agreed on a set of indicators, which comprised factors such as size of farms, annual revenue, sites of irrigation farming, agriculturally used lanes. In order to produce a spatial evaluation of agricultural interests in the region, the indicators were applied to the information provided by the farmers: 22 representatives of the farmers union (1 for each village) collected the data for the existing 121 fulltime an 41 part time farmers mostly by questioning the local farmers in meetings. Some of them provided their own local knowledge. The application and interpretation of the data was the responsibility of the scientists from the University of Hanover.

3.3. Methods for efficient remuneration

In the Fuhrberg project, the farmer is viewed as an active producer of environmental goods who is interested in selling his goods in the market. The market is created primarily by the public's demand for environmental services, which is represented by the goals and targets of landscape planning. This approach is a reversal of the traditional concept, which addresses the farmer, in principle, as an injured contracting party who must be compensated for financial losses. In order to test new remuneration models that were based on this concept in the Fuhrberg project, funds were required from sources other than the official agri-environment programs, which would not allow new approaches. The finances were supplied by the county of Hanover, the German environmental foundation (DBU) and in subsequent years by the State of Lower Saxony.

Both current and new remuneration types have been analysed, assessed (based on existing evaluations) and tested in Fuhrberg in order to evaluate their "environmental success" and effects on the motivation of the farmers (Table 2).

Conventional remuneration is based on predetermined measures and costs, and therefore is considered by many to be deficient in terms of the cost effectiveness of public expenditure, and in motivating the farmers (e.g. Knauer, 1992). A considerable portion of the farmers in the Fuhrberger Feld expressed a lack of motivation in several farmers' assemblies and in interviews (with 25 farmers) in a preliminary investigation before the start of the research project (Richter gen Kemmermann, 2001, p. 99). The majority of the farmers who were questioned

Table 2

Attributes of different approaches to remuneration for environmental services provided (substantiated by existing evaluations, and assumed for tendering procedure and success-oriented remuneration on the base of analysing the approach)

Remuneration model	Conventional remuneration, based upon predetermined measures and costs (measure-oriented) ^a		Tendering procedure	Success-oriented (incentive) remuneration
Assessment criteria	Environmental service required in and restricted to priority areas	Service not bound to special locations (possibly area-wide)		
Effectiveness for nature and landscape	+	–	?	++
Cost optimisation for public budget	+	–	++?	+
Acceptability, motivation of farmers	–	++	–	++
Implementation by farmers	+	–	?	++
Monitoring effort and options	+	–	++?	+
Administrative effort	–	+	++?	?
Comprehensive information prerequisites	Yes	No	Yes	YES

++ Very good; + good; – not good; – – bad; ? = not evaluated in this study.

^aResults of studies from Bielg (2003), GACE (2002), Grajewski et al. (2003), NLO (2003), OECD (2005), Osterburg (2002) and Pierr and Matzdorf (2004).

expressed willingness to participate in agri-environment measures in principle, but requested desirable rewards and measures, which were easy to integrate into farming practice. Seven of the 25 farmers were not interested in any participation at all. In addition to economic reasons, this negative attitude was motivated by the fact that farmers did not like the idea of being subject to directives ("being no entrepreneur").

In order to overcome these shortcomings, new models such as tendering or success-oriented remuneration have been suggested by several authors (e.g. Glebe, 2005, pp. 14, 15). In Germany, a ground-breaking approach to remuneration is the invitation to *tender a public bid to provide certain environmental services*. When the price for the service is tendered, it is determined by market mechanisms. In the US "Conservation Reserve Program" a bidding procedure, in which bids are ranked on the basis of an environmental benefits index, is used to enhance environmental gains (Plankl, 1999; United States Department of Agriculture (USDA), 1997). This method was chosen to be applied in Fuhrberg, complemented by a regionally adapted benefits index for several environmental goods (water, soil, biodiversity, scenery, climate) and a spatial differentiation of possible remuneration according to the special needs of individual sites (Bathke et al., 2003, pp. 128, 129). Farmer's assemblies were used to encourage farmers to participate and to identify possible objections. Another innovative type of remuneration is incentive based, or *success-oriented remuneration* developed on the basis of the MEKA (programme for the reduction of overproduction and cultural landscapes compensation) methodology from the German state of Baden-Wuerttemberg and the Swiss ecological quality guideline (Bronner et al., 1997; Ministerium für Ernährung und Ländlichen Raum Baden-Württemberg, 1999; Öko-Qualitätsverordnung-Schweizerischer Bundesrat, 2001). The approach calculates the appropriate fee which the farmer should receive, based on the degree of success in achieving the desired benefits. In the Fuhrberg project, this approach was developed and tested for the remuneration of biodiversity benefits. The success was assessed according to the number and abundance of indicator and target plant species that farmers can prove are present on their grassland. The hypothesis is, that the indicator species represent the desired ecological good "species-rich grassland" in a more realistic and direct way than the indirect way based on predefined measures. The measures for achieving such success were left up to the farmer. He was only given information about the potential of his land to successfully "produce" target species or habitats (supplied by the assessment of HDP from landscape planning). The farmers had to survey the abundance of selected indicator and target species themselves by using a simple transect method (developed for application by farmers in MEKA II, 1999). The number of indicator species were counted along a transect across a grassland site. Each transect was divided into three segments in which

all indicator species growing within 1 m distance from the transect line were recorded. In the area of Fuhrberg, a list of 24 easily recognisable indicator species seemed to be sufficient to identify valuable grassland types. The species were selected by analysing regional data about the vegetation, with special consideration to species characteristic for grassland among the regional and endangered species. Continuing a success-oriented approach, an improved list was developed after 2004. Now target species were selected by analysing the plant communities of Lower Saxony searching for character species and rare differentiating species (according to the definition of Braun-Blanquet, 1964) of endangered grassland plant associations and alliances. In the beginning, 10 farmers participated in the success-oriented remuneration, in the following years the number rose to 17. The farmers were selected because of their willingness to participate and because they owned grassland with a good HDP. Every year a group of 6–12 farmers took part in a training course to better identify the species. The training courses were a good opportunity to discuss and exchange experiences and seemed to be important for the acceptance of the programme. On about 50% of the parcels the farmers' results were checked using the same method and on 21 parcels by using vegetation records (according to Braun-Blanquet, 1964). In addition, the participating farmers were asked in one-to-one interviews and in plenaries about their appraisal of the method.

The approach was not carried forward and applied to ground water or soil protection services because principal methodological difficulties arose. Either the control and documentation of success turned out to be very difficult or the success could not be proven by the individual farmer but only by a large group of farmers in the catchment area, which would have required collective participation.

In order to enhance the ecological effectiveness of the remuneration for soil and water in the other remuneration schemes, a ranking of the ecological effects of protection measures was carried out. The information basis for the ranking consisted of empirical data from the control programme of the water company about nitrogen leaching and from previous research in the Fuhrberger Feld (e.g. Boettcher et al., 1992; Heumann et al., 2001) as well as from other areas with comparable geohydrological conditions.

4. Results of the case study

4.1. Use of landscape planning for targeting of compensation payments

The information, which the landscape plan provided on a GIS basis, proved to be useful for the following applications:

- Suitable prioritising of sites with need for environmental action

The environmental information basis which landscape planning provides made it possible to prioritise goals and targets, in order to direct funds from agri-environmental measures into those areas where urgent environmental action was most needed. The output of the assessment of the HDP offers environmental authorities information that can be used to decide where limited funds should be concentrated for the development of new habitats. As a basis of the success-oriented remuneration, farmers could choose the site with the best prospects for success.

The information is applicable as a basis for all possible remuneration models, which aim at targeting agri-environment measures in areas with environmental priority. Exceptions are a few measures, which were assumed to have general beneficial effects beyond the level of GFP for all locations—such as organic agriculture. These measures may be offered on an area wide basis.

- Identification of synergies between different landscape functions provides a basis for co-operation

The information from the landscape plan was also used to identify positive synergies and potential conflicts by determining areas where different priorities overlapped. The analysis thus offered the option of creating measures which promised the best synergetic results without interfering with other landscape functions. For example, measures taken to enhance habitat qualities had the potential to affect water supply functions favourably or adversely. With this in mind, funds from different sources (like water protection and nature conservation) could be consolidated to create co-ordinated projects.

- Spatial concretion of GFP

Using information from the landscape plan, it was also possible to transform many general legal obligations of the GFP (as defined in the German legislation) into spatially concrete information. For example, it was possible to identify grassland in flood plains or on sites with a high ground water table. The conservation of such grassland is demanded by the federal nature conservation law as part of GFP. Such spatially concrete information which is relevant to mandatory standards was important to farmers as well as to authorities because compensation payments to the farmers are not meant to cover the implementation of mandatory obligations.

4.2. Results of the contribution of farmers to the information base

The participatory approach that was used to add local knowledge to the information base revealed several aspects of the approach. On one hand, the farmers contributed valuable information and corrections about the actual land use or soil specifics to the environmental information base. Also, in the field of the assessment of the agricultural conditions of the area, which was not covered by the landscape planning, they personally involved in developing a set of indicators and collecting farm data.

On the other hand, their biased interests in the results of the assessment of the agrarian structure were not favourable to a transparent information base. Once the farmers saw the results of the application of the indicators, they became very sensitive about making this information public or available to the authorities. The reason for this was that the spatial distribution of agricultural priority areas was not in the interest of individual farmers whose land was indirectly disqualified as being non-priority. The farmers, therefore, decided to exclude such “incriminating” information and to significantly limit the area-specific information which was presented publicly.

4.3. Validity and acceptability of new remuneration models

The approach involving *tendering a public bid to provide certain environmental services* could not be tested in Fuhrberg because the farmers were not willing to participate in it. When questioned about the reason for this, the farmers did not deny the economic logic of the approach. However, they feared that this would put the social balance in the farming community at risk and make the provision of environmental services even less attractive.

Success-oriented remuneration turned out to be much more acceptable. Most farmers saw that it led to an improvement in their image and were in favour of the concept of being treated as entrepreneurs instead of as the subjects of directives. Willingness to participate in the scheme rose significantly in the second year (Table 3) from 10 to 17. During the following years more farmers wanted to participate. However, expenditure on the scheme was capped and the number of farmers who could participate was limited.

In general, farmers participated because of a general interest in the scheme and because they hoped for a positive reaction of the public. All questioned 17 farmers said that

Table 3
Participation of farmers, and parcels included in the success-oriented remuneration scheme (Fuhrberg, Germany)

	2001	2002	2004	2005
Number of farmers	10	17	17	17
Number of fields being surveyed	33	79	73	92
Number of fields with more than three indicator species in each segment	19	32	50	64
Area being surveyed (ha)	70	249	210	269

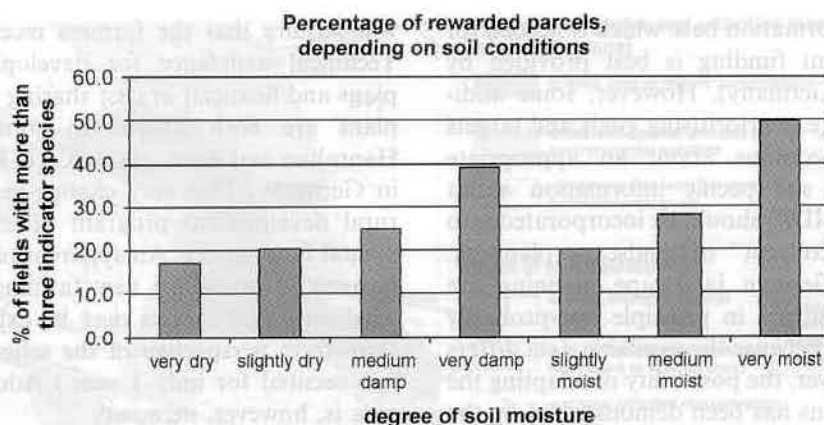


Fig. 2. Presence of indicator/target species in relation to degree of soil moisture (Fuhrberg, Germany).

they made positive experiences with the programme and none of them dropped out during the following years. An open question about what they especially liked about the programme was answered by seven farmers: Besides the positive reaction of the public, their own raised attention to plants and nature conservation and the flexible uncomplicated approach seemed to be most attractive. Two farmers pointed out how important it was that the list of target species should only contain species that may occur in the Fuhrberg region.

The transect survey method that the farmers used proved to be sound. For the most part, the control checks led to the same results with only few discrepancies (for field margins see Braband et al., 2003). In some cases, the farmers had difficulty differentiating *Cirsium palustre* and *Cirsium vulgare*. *Senecio*-species were also taken out of the list because they were often identified incorrectly. In 2004 two members of the Country Women's Association voluntarily supported the surveying of the target species as well. In general, the acceptance of the scheme was very good.

The results of the vegetation mapping and the monitoring of the farmers survey show the method to be successful in delivering the environmental service of "species-rich grassland. The number of indicator and target species was positively correlated with the total number of species. Endangered species (target species) were found exclusively on parcels with the highest number of indicator species. On mowed parcels as well as on pastures, high numbers of indicator species were clearly correlated to a low input of fertiliser.

However, the farmers stated that they only changed their land use practice slightly or not at all (on 70% of 66 parcels) during the first 2 years. They hoped for target species without further activities. The most frequent changes on the other parcels were to mow later in the year and apply no pesticides. In order to produce more target species most farmers considered late mowing and the reduction of fertiliser input as the best measures. Only one farmer mentioned wetting of grassland.

For moist grassland (very wet grassland was not included in the scheme), the use of the "HDP" approach proved to be useful as a basis for selecting suitable sites (Fig. 2).

The soil moisture which had been used in the HDP as criteria for selecting the valuable sites was positively correlated to the number of target and indicator species. For dry grassland habitats, no such correlation could be proven. This may be explained by the predominant influence of fertilisation, the generally intensive cultivation of these grasslands in the Fuhrberg region and the short examination period, which did not allow enough time to observe substantial changes in the presence of target species.

5. Discussion

The key findings of the study are:

- that comprehensive information about landscape functions and goals provides a suitable base for
 - o targeting agri-environmental services,
 - o identifying opportunities for co-operation and consolidation of funding from different sources and
 - o showing site-specific implications of the GFP,
- that farmers voluntarily contribute valuable data if given the opportunity to hold back data which they do not want to be published,
- that farmers had reservations about tendering but showed high acceptance of success-oriented remuneration,
- that nature conservation authorities accepted success-oriented remuneration except for its application in very valuable habitats,
- that the methods seem to be suitable but need improvements in detail.

These findings can be interpreted in the view of the further development of the methodology and their transformation to other cases.

The comprehensive information base which is needed for targeting agri-environment funding is best provided by landscape planning (in Germany). However, some additional data and methods (e.g. prioritising goals and targets in order to support decisions about an appropriate remuneration approach, site-specific information about GFP, and assessment of HDP) should be incorporated into the “standard German concept” of landscape planning. The methods used in German landscape planning are transferable to other countries in principle but probably not always in every detail because the available data differs between countries. However, the possibility of adapting the concept to other conditions has been demonstrated by the development of landscape planning in Russia (Antipov, 2006). Approaches similar to those in Germany are used in other countries (overview for Europe: v. Haaren et al., 2000; examples for UK e.g. RCEP, 2002; for US, e.g. Steinitz, 1990). To date in few countries, comprehensive spatial data from landscape planning is available with blanket coverage. This may change rapidly in the future for the 26 European countries that have already ratified the European Landscape Convention, which contains the obligation to establish landscape planning (Council of Europe, 2000). The water framework directive also contains planning obligations that can be used to establish a sound environmental information base (for UK: Cullingworth and Nadin, 2006, p. 270).

The involvement of land users into the compilation of the information base of the landscape planning has proved a useful approach for incorporating local knowledge and enhancing credibility and acceptability of the information provided. However, if the interests of the farm enterprises are involved—as was the case in the assessment of the agrarian structure—this approach shows ambivalent implications. On one hand the results for the whole process were very favourable, because the approach greatly increased the farmers’ willingness to co-operate in the project. On the other hand scientific completeness and integrity of the results were partly sacrificed.

The testing of the success-oriented remuneration scheme showed generally satisfactory results but also potential for improvement. For example, the list of indicator and target species based only on the analysis of the regional vegetation did not produce results which could be compared to those of other regions. This in turn will require including character species of plant communities, which are valuable or endangered on different spatial scales (European, national, state or regional level). For Lower Saxony this work has been completed in the meantime. This approach generates a much larger number of target species. However, a shorter regional list can be extracted from the long overall (state) lists. The list of target species should also not be restricted to flowering plants which are easy to recognise (like in the MEKA concept) but should be expanded by including grass- and sedge-species to enhance the representation of species-rich habitats like wet, extensively farmed grassland. This in turn

will require that the farmers receive additional training. Technical assistance for developing farm conservation plans and financial or cost sharing assistance to implement plans are both offered in some countries (e.g. US: Hanrahan and Zinn, 2005, p. 21; Kloepper, 2006) but not in Germany. This may change in future as the new EU rural development program offers funding for environmental farm advice. An apparent reluctance by some of the farmers to introduce new farming practices in order to produce target species may be explained, in part, by the short-term perspective of the scheme. (Initially, financing was secured for only 1 year.) Additional research in this area is, however, necessary.

Although success-oriented remuneration seems to be a successful approach, experience in the Fuhrberg project showed that it cannot be promoted as the only compensation model. The methodology is generally not suitable for achieving goals that require development over a long time period or for goals which cannot be monitored by simple indicators of the type discussed here. Furthermore, the nature conservation authorities considered it too perilous to leave the choice of the measures for priority habitat protection areas to the discretion of the farmers. Therefore, *remuneration, based upon predetermined measures and associated costs*, may maintain its place in nature reserves, especially vulnerable zones, and other priority nature conservation areas. However, this recommendation should be further verified in the future.

As a consequence, the range of approaches should be applied differentially in appropriate situations and according to the priority attached to different environmental goals presented in landscape planning (Fig. 3).

In areas with less priority but special demand for environmental services because of special value, vulnerability, development potential or impairment of the environment the success-oriented remuneration has obvious advantages. It improves the motivation and environmental education of farmers and increases the value for the money. The course of environmental development can be more flexible here than in high priority areas. Larger areas with general environmental goals and a larger number of farmers potentially able to supply the demanded service are necessary for successful introduction of the tendering process. In this case, predetermined agri-environment measures whose ecological effectiveness does not depend on an area-specific demand can be offered in a tendering process. In the future, additional incentives for co-ordinated and collective action that have larger cumulative benefits, e.g. for ground water quality or habitat networks than actions on individual farms should also be considered (Hanrahan and Zinn, 2005, p. 20).

6. Conclusion

In conclusion, a comprehensive and adapted landscape plan provides a suitable information basis for targeting remuneration for agri-environmental services to sites with

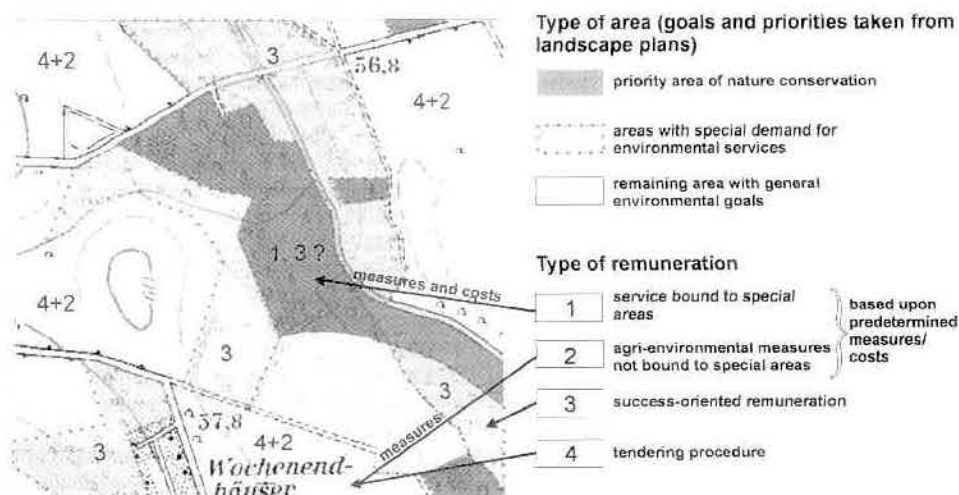


Fig. 3. Where to use which type of remuneration?

an explicit demand for such services. The output can be used by environmental authorities to decide where the limited funds available should be concentrated. Agri-environmental programs should demand such information as a precondition for targeted remuneration. Farmers who have access to this information can also actively offer environmental services on agricultural land which offers the best prospects for success. Giving farmers the choice between several different development opportunities may help to motivate them to actively participate in a success-oriented remuneration programme. The very high level of participation of farmers even in methodological questions and data acquisitions resulted in some advantages, such as increased co-operation and high acceptance of the project, but it also had disadvantages. The approach may not be recommended if complete and publicly transparent information is crucial.

For the new remuneration models it can be concluded that success-oriented remuneration seems to be a valid and sound approach to measuring the present biodiversity services delivered by the farmers. However, long-term research is necessary to show whether positive changes occur on sites funded under this scheme and to better prove the value of the "HDP" assessment technique to select the best sites. Further research is also necessary to explore the potential of the success-oriented approach for soil and groundwater protection services, considering the identified methodological difficulties.

Tendering or bidding appears, in principle, also to be a very useful approach that could improve the efficient spending of public money. The negative reaction of the Fuhrberg farmers to this approach is not necessarily representative of German or European farmers in general. It should be kept in mind that it is common procedure in the US to let farmers bid competitively in soil conservation programmes.

A final question which remains unanswered is how much the transaction cost for the implementation of such funding

schemes will be. This too needs to be addressed in future research (OECD, 2005, p. 13).

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Incentives for low-input land-use types and their influence on the attractiveness of landscapes

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Abstract

Changes in agricultural policy have traceable effects on landscape aesthetics. For the catchment area of Lake Greifensee, an economic land-use model predicted land-use changes caused by agricultural policy. Three scenarios implementing different direct payment schemes show that land-use intensity will decrease by 2011 compared with the 'reference status' 2000.

The output of the economic land-use model is explicit in space. It was assessed by the 'naturalness' perception factor of the method proposed by Hoisl et al. [1989. *Landschaftsästhetik in der Flurbereinigung. Materialien zur Flurbereinigung—Heft 17. Bayerisches Staatsministerium für Ernährung, Landwirtschaft und Forsten, München*] with regard to landscape aesthetics. Even though lower land-use intensity is generally predicted by 2011, the values of the 'naturalness' perception factor do not significantly improve if the payment scheme remains unchanged, or if the payment scheme is amended by incentives for specific location of the ecological compensation areas (ECAs). A significant reduction in the values of the 'naturalness' perception factor was found when subsidies for ECA's were cancelled. This leads us to the conclusion that in order to keep Swiss landscapes as attractive as they are at present, policy must sustain incentives for low-intensity land-use types.

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1. Introduction

Besides producing healthy and reliably available food, Swiss agriculture must protect biodiversity and care for landscape amenity.

Due to the WTO agreements, direct payments will be of increasing importance in Switzerland, while production-oriented payments will decrease in future. At the same time, a shortage of financial resources requires the payment scheme to be more effective. Efficiency and effectiveness of the measures cannot be the only benchmarks for evaluating a direct-payment scheme for agriculture. This is especially

true if direct payments are supposed to sustain multifunctional agriculture.

In order to protect biodiversity, direct payments for ecological compensation areas (ECAs) were introduced in 1993 (Swiss Federal Legislation on Agriculture). Since 1998, Swiss farmers have been required *inter alia* to convert 7% of their farmland to ECAs to qualify for direct payments. The principal types of ECAs are low-input grassland, hedgerows, standard orchards, and—mainly in arable landscapes—wildflower strips.

A further aspect of multifunctional agriculture is to provide an attractive landscape, as prescribed in the Swiss Federal Legislation on Agriculture. According to Potter and Burney (2002), one of the key questions of the failed WTO negotiations was to prove to what extent domestic subsidies and direct payments really enhance multifunctional agriculture, rather than primarily distorting trade. Hence, it is desirable to assess landscape aesthetics for the different scenarios of direct payments for ECAs.

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'Naturalness' plays an important role in landscape aesthetics. 'Naturalness' is part of landscape theory, e.g. according to Kaplan and Kaplan (1989). Furthermore, it is a criterion for different subjectivist or objectivist approaches to assessing landscape aesthetics, e.g. van den Born et al. (2001), De Groot and van den Born (2003), Lee et al. (1999).

Land-use intensity is one aspect of 'naturalness'. High-intensity land-use types such as crop production are attributed a lower 'naturalness' value than low-intensity land-use types such as ECAs. Liberalisation of the agricultural market aims to reduce costs and prices; therefore, if the agricultural market is liberalised, it can be assumed that product prices will be lower than factor prices in Switzerland. This will reduce land-use intensity owing to the change in relative prices. ECAs, however, could gain in attractiveness if they are still subsidised.

The aim of this paper is therefore to answer the following questions:

- How do land use and landscape aesthetics differ among the various scenarios for ecological direct payments?
- How do a supposed reduction in land-use intensity and a changing proportion of ECAs influence landscape aesthetics?
- Which payment scheme for ECAs is the most efficient from an economic point of view?

Scenarios are often used to evaluate policy alternatives (Penker and Wyrzens, 2005; Nassauer and Corry, 2004; Tress and Tress, 2003; Palang et al., 2000). Economic land-use modelling is a feasible tool for anticipating general trends in prices and comparing different agricultural-policy scenarios (Webster, 1997).

The economic land-use model developed and applied within the 'Greifensee' interdisciplinary research project (Zraggen, 2005; Zraggen et al., 2004) is spatially explicit. This enables assessment of the externalities of agricultural policy with regard to landscape aesthetics or biodiversity (Flury et al., 2004).

In our study, a geographical information system (GIS) is used to assess the outcome of a spatially explicit economic model in terms of landscape aesthetics. This paper describes the application of a linear sector model simultaneously optimising the income of eight different farm types in the catchment area of Lake Greifensee. Scenarios are modelled in order to simulate liberalisation of trade in combination with different direct-payment schemes for ECAs. The outcomes are evaluated by a method combining GIS techniques with a theoretical background in order to assess landscape aesthetics.

2. Economic land-use modelling

Mathematical modelling differentiates between simulation modelling and optimising modelling (Hazell and Norton, 1986; Barlas et al., 1996). Optimising models are

especially suited as a decision-support tool for policy-makers elaborating national policy concepts and optimal sectoral policy measures for given aims (Kopainsky et al., 2003). A key criterion for economic modelling is the time span. The time horizon of our model is derived from the aim of evaluating policy measures in the medium-term. This requires a sector model taking account of prevailing agricultural structures (Hazell and Norton, 1986). A sector model helps to explain the producers' reactions to external changes such as prices or policy measures. Solving the model under different assumptions as to policy parameters or policy measures can provide important information (Norton and Schiefer, 1980).

Land use offers numerous examples of spatial environmental externalities (Bouman et al., 1999): loss of habitats, soil erosion, increased vulnerability of soils and loss of natural amenities are manifestations of the negative effects of land exploitation. In order to evaluate the externalities of land use, a spatially explicit model is required (Flury et al., 2005; Zander and Kächele, 1999). There are two ways to create a spatially explicit model: either build it in a GIS, or combine a GIS with other models (Lausch, 2003). We combined GIS with a mathematical optimising model because the solvers in GIS do not support a sector model (Zraggen, 2005).

3. Assessment of landscape aesthetics

3.1. General overview

Lothian (1999) describes two paradigms for landscape quality assessment. On the one hand, we have an 'objectivist or physical paradigm' assuming landscape quality to be an intrinsic physical attribute that can be assessed by applying objective criteria. On the other hand, there is a 'subjectivist or psychological paradigm' which assumes that landscape quality results from the perception and cognition of the beholder, and that it can be assessed using psychological methods (Lothian, 1999).

Lothian acknowledges that 'objectivist' methods are less expensive and easier to handle, which is an important advantage if analysis covers a large area (165 km²) and different scenarios. Nevertheless, he criticises their lack of both theory and reflection of public preference. In fact, he supposes that the output of the assessment is very much influenced by the knowledge and experience of the individual who developed and applied the method (Lothian, 1999).

Against this, the method proposed by Hoisl et al. (1989) relies on Nohl's 'epistemological model' (in a revised version Nohl, 2001, 1988, 1980). The 'epistemological model' assumes that the amenity function of a landscape is best achieved when it provides an optimal mixture of stimulation, orientation in space and the feeling of both 'freedom' and 'identity'. These feelings, or combinations thereof, are implemented with three perception factors: 'variety', 'naturalness' and 'character'. Furthermore, the

project for developing the method included a photo survey for landscape preference with 120 participants to calibrate the model. The results of the survey were used in a multiple regression analysis in order to model the perception factors 'variety', 'naturalness' and 'character' (Hoisl et al., 1987).

Many 'objectivist' methods applying GIS are described, e.g. Brabyn (2005), Lee et al. (1999), and Bishop and Hulse (1994), whereas Brabyn takes the view that GIS is for classification of landscapes, not for quality judgement. The sound background of the method and the possibility of applying GIS were good reasons to use the method proposed by Hoisl et al. (1989) for assessing the landscape of the Lake Greifensee catchment area, as well as the outputs of economic modelling, in order to answer the questions concerning the influence of ECAs on landscape aesthetics.

3.2. Application of the method according to Hoisl et al. (1989)

In order to assess landscape aesthetics according to the method proposed by Hoisl et al. (1989), in a first step the landscape in question is partitioned into visibility units of about 1 km² each by a visibility analysis. Hence, the values of the three perception factors are calculated individually based on different maps containing the relevant landscape elements.

The 'variety' perception factor measures the extent to which a landscape provides stimulation and orientation in space. The values cover a range between 1 and 50. In order to calculate the 'variety' of a landscape, all the elements contributing to landscape 'variety' are reclassified into point elements (e.g. trees), linear elements (e.g. hedgerows) and patch elements (e.g. standard orchards). Point and linear elements are buffered by a distance depending on their effect on landscape scenery. All the resulting areas are divided by a constant value (2500 m² or 1000 m², depending on the height of the landscape elements). The results are summarised for each visibility unit, divided by the area of the visibility unit and standardised by multiplying by a factor of 2.5 (Hoisl et al., 1989; Schüpbach, 2003).

The perception factor 'naturalness' is highly correlated with land-use intensity. A landscape with low land-use intensity is high in 'naturalness', and can therefore provide a feeling of 'freedom'. To calculate 'naturalness', a score related to the intensity of human influence is assigned to each land-use type (see Table 3). The scored areas for each visibility unit are divided by the area of the visibility unit and standardised (Hoisl et al., 1989; Schüpbach, 2003; Schüpbach et al., 2004a). The values of the 'naturalness' perception factor cover a range between 1 and 50, and are standardised by the following formula:

$$\text{Value of 'naturalness'} = 10((\Sigma(\text{area of land use type} \times \text{scoring value})/\text{area of visibility unit}) - 1).$$

The 'character' perception factor measures the intensity of landscape change owing to the recent introduction of

landscape elements—most of them technical—or the loss of traditional landscape elements. The more a landscape changes, the less able it is to provide the feeling of 'identity'. The 'character' perception factor is calculated by assigning an area of impact to each 'disturbing element' (i.e. silos, overhead power lines, highways, etc.) based on its size or height. The area affected is scored, summarised for each visibility unit and divided by the area of the visibility unit (Hoisl et al., 1989; Schüpbach et al., 2004a). The values of the 'character' perception factor cover a range between 1 and 25 and are standardised by the following formula:

$$25(1 - (\Sigma(\text{impacted area} \times \text{scoring value})/\text{area of visibility unit})/8).$$

Finally, to calculate the total value for landscape aesthetics, for each visibility unit the values of the three perception factors are summed and standardised by a factor of 2.5 (Hoisl et al., 1989; Schüpbach, 2003; Schüpbach et al., 2004b).

4. Description of study area, data and methods

4.1. Description of study area

The catchment area of Lake Greifensee (about 165 km²) is situated to the southeast of Zurich (see Fig. 1). Consequently, it is both a settlement and recreation area for the city of Zurich and, traditionally, an agricultural area with wetlands. This diversity of functions and land-use types was the reason for selecting the region as a study area for an interdisciplinary research project.

4.2. Description of data

For the economic land-use model and the assessment of the outcomes with regard to landscape aesthetics, several data sets were used:

- *Soil map*: The 1:5000 digital soil map of the Canton of Zurich provides information about soil types and soil fertility.
- *Landscape types* (Szerencsits et al., 2004): Within the Lake Greifensee catchment area, 23 landscapes were delineated and classified into 12 landscape types with reference to relief, soil types and land use (see Fig. 3). Landscape types are a suitable unit for balancing the output of the economic land-use model and comparing the results of the landscape assessment (Banko et al., 2003).
- *Digital landscape model*: Based on the 1:25 000 Swiss map, the vector data set provides forests, buildings and streets. Vector25[©] 2005 swisstopo (DV002208.2). The data set was used as ancillary data for the land-use data set and the assessment of landscape aesthetics (see data sets described below).

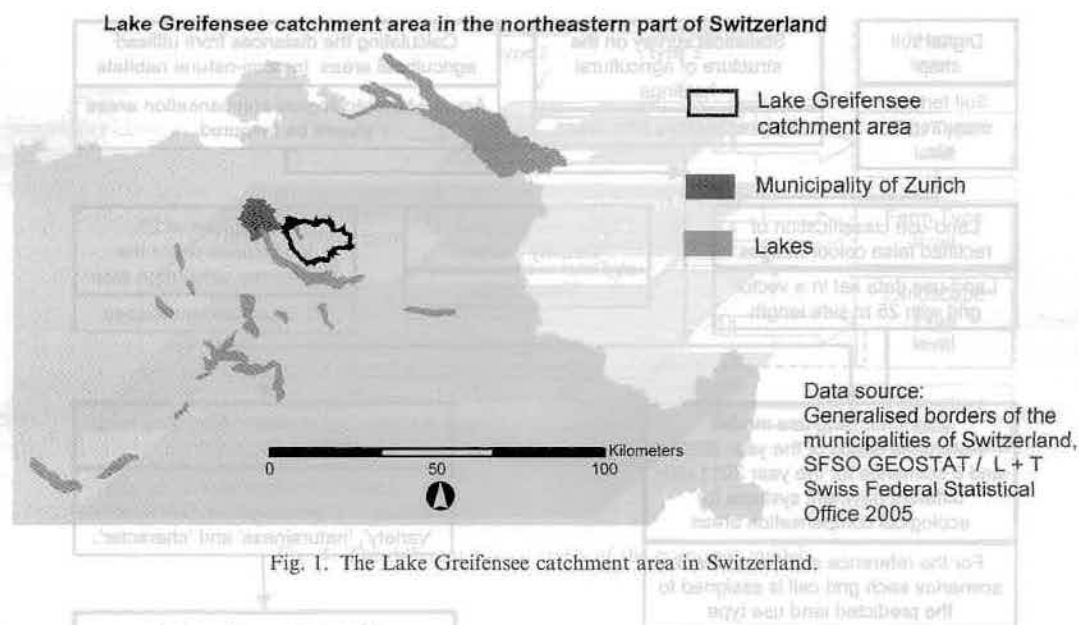


Fig. 1. The Lake Greifensee catchment area in Switzerland.

- **Digital elevation model:** A raster data set with a cell size of 25×25 m, DHM25[©] 2001 swisstopo (DV002207). The digital elevation model was used to establish visual units for the assessment of landscape aesthetics (see data set described below).
- **Land-use data set** (Schüpbach et al., 2003): The land-use data set was derived from rectified false-colour images by a supervised classification, ancillary data and visual control. The data set consists of a vector grid with 25 m side length. Each grid cell was assigned to the dominant land-use type. The data set differentiates 20 land-use types reflecting land use in the year 2000 in the Lake Greifensee catchment area. This was the basic data set for the 'Greifensee' interdisciplinary research project (Flury et al., 2004).
- **Census of agricultural holdings:** Within the scope of the survey of the structure of agricultural holdings, the Swiss Federal Office of Statistics collected production data at farm level (Swiss Federal Office of Statistics, 2000). These were used to build up eight representative farm types in the economic land-use model.
- **Distances from semi-natural habitats** (Szerencsits et al., 2004): This data set contained the Euclidian distance from each grid cell (25×25 m) of the land-use model to the nearest semi-natural habitat. The distances were calculated separately for wetlands, dry meadows, habitats with woody plants, and running water not significantly influenced by flood control. The distances were calculated by means of subsequent versions of the ESRI GRID. This data set enables the definition of areas where ECAs should be favoured.
- **Landscape aesthetics** (Schüpbach et al., 2004b): using the land-use data set described above and additional data (rectified false-colour images, the digital landscape model based on the 1:25000 Swiss map and the digital elevation model), the landscape of the whole Lake Greifensee catchment area was assessed by the method

proposed by Hoisl et al. (1989) for the year 2000. For each visual unit, this data set contained the value of the whole landscape and the values of the perception factors 'naturalness', 'variety', and 'character'. The calculations were made by means of subsequent versions of ESRI ArcGIS. The data set was used for a main component analysis in order to find out how much of the variance was explained by each perception factor.

Fig. 2 shows how the above-mentioned data sets and the foregoing work were used to enable assessment of the impact of the externalities of agricultural policy on landscape aesthetics.

4.3. Methods

4.3.1. Economic land-use model

The smallest unit of the linear sector model is a grid cell of 25 m side length. Each cell is unique and attributed to both vertical and horizontal site characteristics. Vertical site characteristics are e.g. soil type and erosion risk. Horizontal site characteristics are e.g. distances to wetlands or hedgerows (Fig. 4).

The larger model units are eight different farm types, which are modelled for each landscape type (see Fig. 4). The land-use model optimises the farmers' income by choosing and allocating land-use types on the available sites over a whole crop rotation. The farmers' land-use activities are meat and milk production, food crops, crops for animal feed, different grassland types and different ECA types. The ECA types modelled are 'low-input grassland', 'low-input grassland with hedgerows' and 'wildflower strips'. 'Wildflower strips' cover a whole grid cell in a whole crop rotation for 1 year. As only 1 year can be considered for the assessment of landscape aesthetics, the whole grid cell is modelled as 'rotational set-aside land', a quarter of the grid cell being assumed to be covered

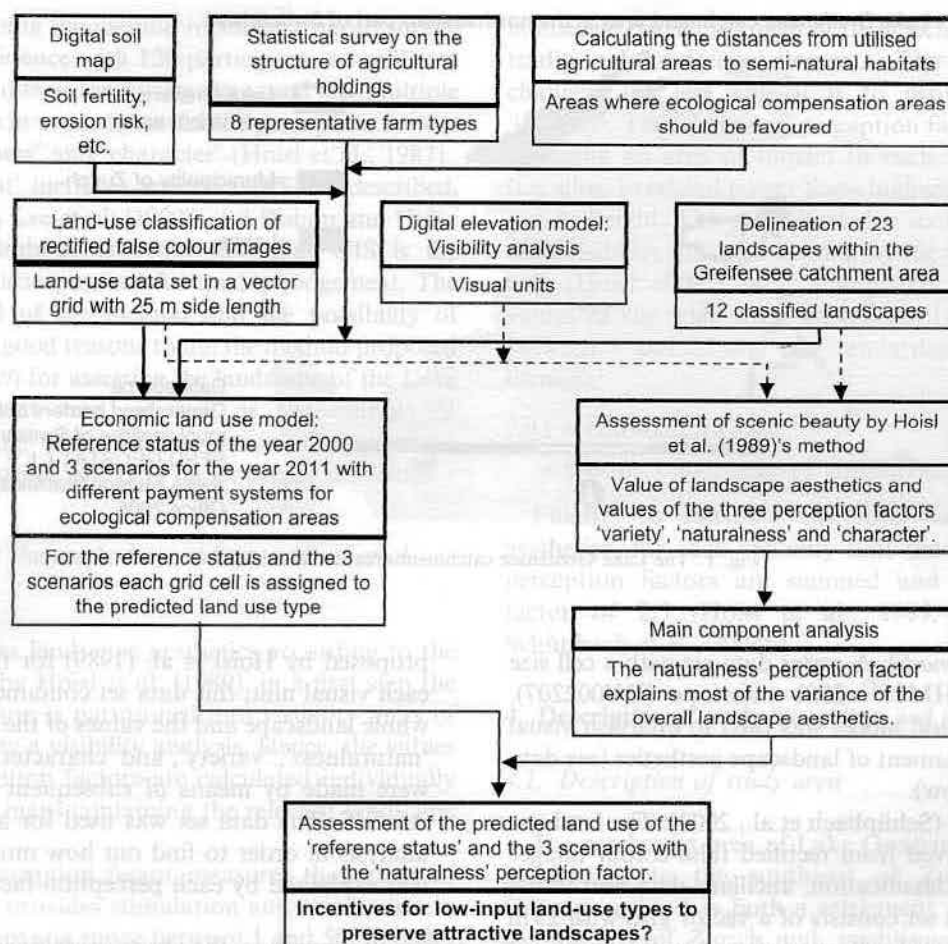


Fig. 2. Data sets and workflow for the assessment of land-use changes owing to changes in agricultural policy with regard to landscape aesthetics.

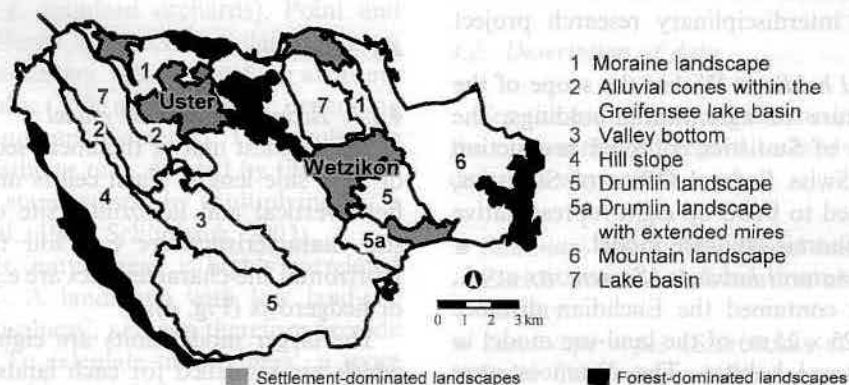


Fig. 3. Landscape types in the Greifensee catchment area.

by a 'wildflower strip' and the remaining area by a crop (Table 3). Only the utilised agricultural area was modelled; settlement areas, forests and nature-protection areas were excluded.

As is usual in a sector model, it is assumed that the farmer aims to maximise his income. In order to enhance biodiversity, different restrictions are modelled for the different scenarios.

4.3.2. Modelled scenarios

Economic land-use modelling was carried out for the year 2000 as a reference status (called 'reference status') and for the year 2011 within three different scenarios. Generally, all the scenarios for the year 2011 assume that Switzerland is not a member of the European Union. However, implementation of the 2007 Agricultural Policy will lead to moderate liberalisation. Milk production will

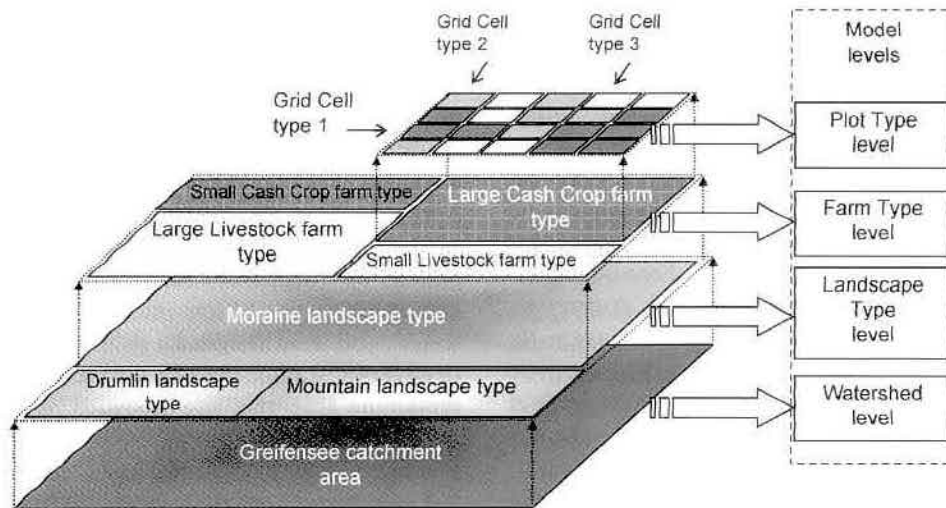


Fig. 4. The different spatial levels of the economic model.

Table 1
General description of the scenarios

	Reference	No changes	No direct payment	Incentives for location
Plot reallocation	Not allowed		Allowed	
Farm reallocation				
Mechanisation level	2000		2011 (> 2000 level)	
Labour costs	2000		Increasing (> 2000)	
Other factor costs	2000		EU Trend for 2011, decreasing	
Product price	2000		EU Trend for 2011 (< 2000 level)	
Ecological direct payment system		2000	No payments	Only ECA payments in grassland on sites with potential
ECA payment level		2000	No payments	66% of 2000 level

no longer be restricted, the cheese market will be liberalised and the level of product prices and factor costs will decrease (Table 1). The three scenarios differ in terms of the rules governing the direct payment for ECAs:

- (1) No changes in the direct payment system for ECAs compared with the 'reference status'. This scenario is called 'no changes'.
- (2) No direct payments are provided for ECAs. This scenario is called 'no direct payment'.
- (3) Incentives for specific location of the ECAs amend the 2000 direct payment system. This scenario is called 'incentives for location'.

The 'incentives for location' scenario tends to favour the location of ECAs at a maximum distance of 200 m from wetlands, dry meadows, habitats with woody plants, or running water not significantly influenced by flood control or buildings, in order to protect such semi-natural habitats and to improve habitat connectedness.

4.3.3. Assessment of agricultural policy with the 'naturalness' perception factor

Our aim was to assess the output of economic modelling via the method proposed by Hoisl et al. (1989) using GIS. As described in Section 3.2, the method measures stimulation and orientation in space by the 'variety' perception factor, land-use intensity by the 'naturalness' perception factor, and landscape change by the 'character' perception factor.

The output of the economic modelling is a unique land-use type for each individual 25 × 25 m grid cell; however, it lacks the correct spatial arrangement of hedgerows, wild-flower strips, single trees and standard orchards. Moreover, information on infrastructure development is missing; as is usual for a sector model, the actual agricultural infrastructures—buildings, silos and roads—remain unchanged (Hazell and Norton, 1986). Also missing from the model are other landscape changes such as new residential buildings or the removal of hedgerows and standard orchards.

The output of the economic modelling provides data on land-use intensity which enables assessment of the 'naturalness'

perception factor but is not suitable for assessing the 'variety' and 'character' perception factors.

However, the main component analysis of the reference status shows that the first factor explains over 50% of the variance, and that the 'naturalness' perception factor has the highest factor loading (see bold numbers in Table 2). Consequently, in the case of the Lake Greifensee catchment area, the 'naturalness' perception factor can serve as a substitute for landscape aesthetics.

Within the method proposed by Hoisl et al. (1989), the scale of the 'naturalness' perception factor reflects land-use intensity (Table 3). Both arable land and settlement areas score the lowest values, while surfaces with no or only slight human impact, such as wetlands, semi-dry meadows with low nutrient supply or shrub are scored highest. Grassland areas are in between these two extremes. The value for grassland is higher as it shows more colours and structure. In most cases, colourful and structured grassland is used at low intensity.

In the original German scoring system, standard orchards are assumed to be on low-input grassland, and therefore score 5 points. In Switzerland, however, the grassland below high stem-orchards is intensively used. To the high-input grassland, therefore, which scores 2 points, we add 0.5 points for the trees. The same holds true for low-intensity meadows with hedgerows. As they are 'areas of low-intensity agricultural use' (score 3), 0.5 points are added to them for the trees. Wildflower strips are considered 'areas of low-intensity agricultural use with no scrub', and were assigned a value of 4. As they are assumed to cover only a quarter of a grid cell while a crop covers the remaining area, they are modelled as a combination, 'crop production with rotational set-aside land', and are assigned a value of 1.5.

The scale of the 'naturalness' perception factor according to Hoisl et al. (1989) is similar to the scale applied by Lee et al. (1999), but differentiates between arable land and improved grassland.

Table 2
Output of the main component analysis of the reference-status assessment

Factor	Percentage of total variance (%)	Factor loadings		
		'Naturalness' perception factor	'Variety' perception factor	'Character' perception factor
Factor 1	52.4	0.81	0.72	0.64
Factor 2	27.8	−0.09	−0.54	0.73
Factor 3	19.8	−0.59	0.44	0.25

Table 3
Definition of land-use categories and the value of the 'naturalness' perception factor

Land-use types per grid cell in the economic land-use model	Value	Definitions of land-use types by Hoisl et al. (1989)
Settlement area, ^a road, ^a crop production	1	Areas used very intensively by man, such as intensive crop production and settlement areas
Crop production with rotational set-aside land	1.5	
High-input grassland	2	Areas with intensive agricultural land use, such as grassland with no trees
High-input grassland with hedgerows	2.5	
Low-input grassland, forest with timber yield ^a	3	Low-intensity-use agricultural land with groves such as extensively used wetlands with scrub, or low-intensity-use grassland, forests with timber yield
Low-input grassland with hedgerows	3.5	
Wildflower strip, ^b wetland meadows, ^a water surfaces ^a	4	Low-intensity-use agricultural land with no scrub, such as extensively used wetlands or dry grassland, water surfaces
Reeds ^a	5	Land with little or no agricultural use and scattered scrub such as wetlands or extensively used standard orchards
Wetlands, ^a mires ^a	6	Land with little or no agricultural use and scrub

^aHedgerows, 'rotational set-aside land' and 'low-input grassland' are ECAs with varying proportions in the different scenarios.

^aThese land-use types are not represented in the economic model, but are used from the land-use data set (Schüpbach et al., 2003).

^bWildflower strips are modelled as a part of crop production. In the economic model, they are represented as 'crop production with rotational set-aside land'.

4.3.4. Statistical analysis

In order to ascertain the extent to which changes in agricultural policy influence land use, we analysed the land use of the 'reference status' and the three scenarios statistically. On the one hand, the data were analysed by a one-way analysis of variance. On the other hand, since the data set is not normally distributed, a Kruskal–Wallis analysis of variance by ranks was carried out.

The output of the assessment of the four land-use data sets according to Hoisl et al. (1989) was statistically analysed by a pairwise *t*-test, in order to establish the extent to which the various payment systems differed both from one another and from the 'reference status'. The level of significance was corrected according to Bonferroni (Rice, 1989).

All statistical analyses were carried out using the 'Statistica' software bundle.

5. Results

5.1. Predicted land-use changes

A one-way analysis of variance shows a significant difference ($p < 0.01$) overall between the 'reference status' and the three scenarios owing to changes in agricultural policy. The Kruskal–Wallis analysis of variance by ranks gives a more detailed view: the only significant differences

($p < 0.01$) between the 'reference status' and the three scenarios were found in the proportion of 'crop production with rotational set-aside land' and the proportion of 'low-input grassland'.

Fig. 5 shows the percentage cover of the different land-use types in the landscape types according to the scenarios. Forest-dominated landscapes, settlement landscapes and the lake basins encompassing nature conservation areas were excluded because agriculture only covers a small proportion of the landscapes. In all landscape types and for all scenarios, 'crop production'—especially labour-intensive crop production (e.g. potatoes)—is decreasing. It is highest in the 'reference status' and lowest in the 'incentives for location' scenario. 'Crop production with rotational set-aside land' reaches a considerable proportion (nearly 10% and more, depending on the landscape type) in the 'no changes' scenario, while it is absent from the 'no direct payment' and 'incentives for location' scenarios since it is no longer subsidised. The proportion of 'high-input grassland' is lowest in the 'reference status', and highest in the 'incentives for location' scenario. For all landscape types except the Drumlin landscape, the proportion of 'high-input grassland' is greater in the 'no direct payment' scenario than in the 'no changes' scenario. 'High-input grassland with hedgerows' generally has the highest proportion in the 'reference status' or in the 'no direct payment' scenario, and the lowest proportion in the

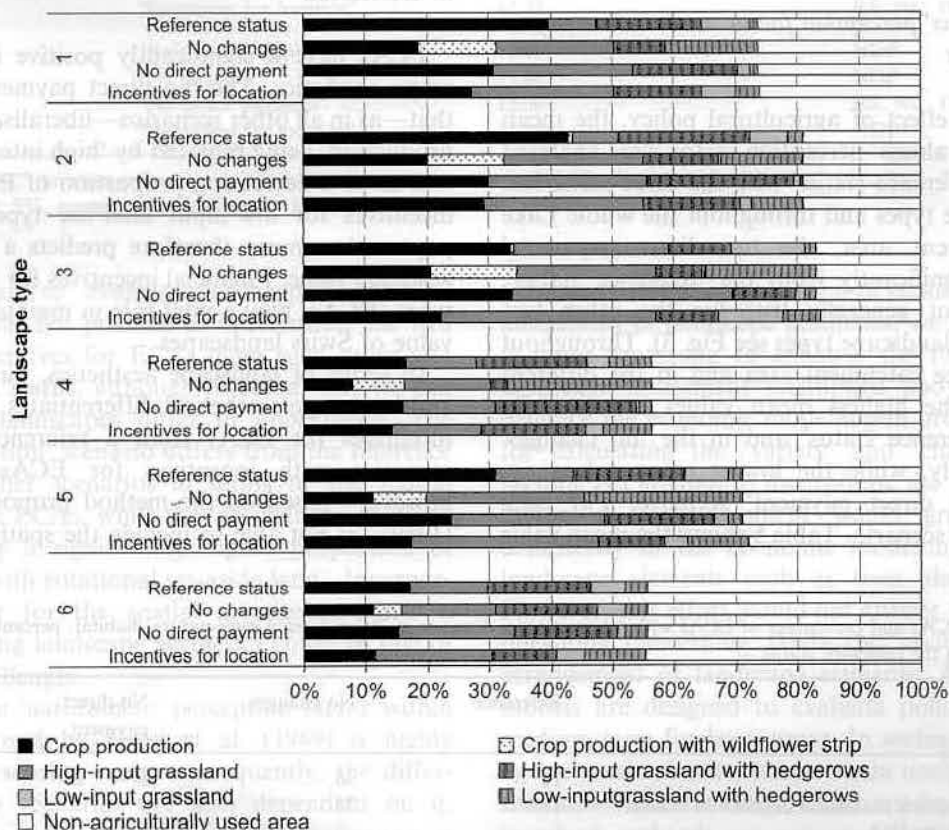


Fig. 5. Proportions of the different land-use types in the different scenarios and landscape types. Landscape types: 1: Moraine landscape; 2: Alluvial cones within the Greifensee lake basin; 3: Valley bottom; 4: Hill slope; 5: Drumlin landscape; 6: Mountain landscape.

'incentives for location' scenario. 'Low-input grassland' (ECA) is highest in 'reference status' and lowest in the 'no direct payment' scenario. Compared with the reference status, the proportion of 'low-input grassland with hedgerows' is increasing. This is especially true for the 'no changes' scenario, but not for the 'no direct payments' scenario. There is, however, considerable variation among the landscape types in terms of the proportion of 'high-input grassland with hedgerows'. In some landscape types, moreover, there is a decrease in the shared proportion of 'high-input meadows with hedgerows', 'low-input meadows' and 'low-input meadows with hedgerows' compared with the reference status.

Taking 'crop production' as the highest intensity land-use type, land-use intensity is generally decreasing compared with the 'reference status'.

Table 4 shows the proportion of ECAs for each scenario. The 'no changes' scenario indicates the highest proportion of ECAs. Furthermore, Table 4 shows that in the 'incentives for location' scenario, the highest proportion of ECAs are located a maximum distance of 200 m from an existing semi-natural habitat, while the amount for ecological direct payment is only 90% of the year 2000s. In the 'no changes' scenario, 38% of ECAs are located a maximum distance of 200 m from an existing semi-natural habitat, while the amount for ecological direct payment is 115% of the year 2000s.

5.2. The 'naturalness' perception factor as an indicator for landscape aesthetics

To evaluate the effect of agricultural policy, the mean values of the 'naturalness' perception factor were analysed to compare the 'reference status' with the three scenarios. For most landscape types and throughout the whole Lake Greifensee catchment area, the 'no direct payments' scenario differs significantly from the 'reference status', whereas this is not generally true for the other two scenarios (Table 5, landscape types see Fig. 3). Throughout the Lake Greifensee catchment area and in the different landscape types, the highest mean values are typically scored in the 'reference status' and in the 'no changes' scenario respectively, while the lowest mean values are scored in the 'no direct payment' scenario. For each landscape type and scenario, Table 5 shows the mean value

of the 'naturalness' perception factor and whether there is a significant difference between the scenario in question and the other scenarios. The mean values of the 'naturalness' perception factor of the three scenarios are compared below with the 'reference status':

- *'No changes' scenario:* throughout the whole Greifensee catchment area and in all the landscape types, the mean values do not differ significantly from those of the 'reference status'.
- *'No direct payment' scenario:* Except for the 'alluvial cones within the Greifensee Lake basin' and 'valley bottom' landscape types, the mean values are significantly lower than that of the 'reference status'. Furthermore, the mean values are significantly lower than those of the other two scenarios, except for the 'alluvial cones within the Greifensee Lake basin' and 'valley bottom' landscape types (Table 5).
- *'Incentives for location' scenario:* throughout the entire Lake Greifensee catchment area and in the 'Drumlin landscape', the mean values are significantly lower than the 'reference status'. In all the other landscape types, the mean values are approximately equal to the 'reference status' (Table 5).

6. Discussion

ECAs have a significantly positive influence on landscape aesthetics. The 'no direct payment' scenario shows that—as in all other scenarios—liberalisation leads to 'crop production' being replaced by 'high intensity grassland', as well as to a decreasing proportion of ECAs, since it lacks incentives for low-input land-use types. The 'no direct payment' scenario therefore predicts a significant loss of aesthetic value. Financial incentives for low-input land-use types (ECAs) play a vital role in maintaining the aesthetic value of Swiss landscapes.

In terms of landscape aesthetics, our model (economy and landscape aesthetics) differentiates a scenario with no incentives for ECAs from a reference status and two scenarios with incentives for ECAs. This approach, however—based on the method proposed by Hoisl et al. (1989)—is not able to include the spatial configuration of

Table 4
Overall percentage of ECAs and percentage of ECAs within a maximum distance of 200 m from a semi-natural habitat; percentage of ecological direct payment compared with the reference status

	Reference	No changes	No direct payment	Incentives for location
ECAs of total area (%)	16	38	8	21
Proportion of ECAs within a maximum distance of 200 m from a semi-natural habitat (%)	13	38	5	41
Percentage of ecological direct payments compared with the 'reference status' (%)	100	115	0	90

Table 5

Mean values of the 'naturalness' perception factor for each landscape type and scenario, and statistically significant differences between the scenario in question and the other scenarios according to pairwise *t*-test

Landscape type	Scenario	Mean value of 'naturalness' perception factor	Significant ^a difference from the following scenarios:
Greifensee catchment area	'Reference status'	15.15	NDP, IFL
	'No changes'	15.05	NDP
	'No direct payment'	14.42	RS, NC, FFL
	'Incentives for location'	14.97	RS, NDP
Moraine landscape	'Reference status'	12.54	NC, NDP
	'No changes'	12.13	RS, NDP
	'No direct payment'	11.67	RS, NC, IFL
	'Incentives for location'	12.21	NDP
'Alluvial cones within the Greifensee Lake basin'	'Reference status'	11.00	–
	'No changes'	11.00	–
	'No direct payment'	10.67	–
	'Incentives for location'	10.92	–
'Valley bottom'	'Reference status'	10.06	–
	'No changes'	10.47	NDP
	'No direct payment'	8.59	NC
	'Incentives for location'	10.53	–
'Hill slope'	'Reference status'	14.46	NDP
	'No changes'	14.37	NDP
	'No direct payment'	13.90	RS, NC, FFL
	'Incentives for location'	14.41	NDP
'Drumlin landscape'	'Reference status'	12.80	NDP, IFL
	'No changes'	12.64	NDP, IFL
	'No direct payment'	12.04	RS, NC, FFL
	'Incentives for location'	12.37	RS, NC, NDP
Mountain landscape	'Reference status'	15.85	NDP
	'No changes'	15.80	NDP
	'No direct payment'	15.06	RS, NC, FFL
	'Incentives for location'	15.80	NDP

RS: 'reference status'; NC: 'no changes' scenario; NDP: 'no direct payment' scenario; IFL: 'incentives for location' scenario.

^aLevel of significance: 5%, corrected by Bonferroni (Rice, 1989).

the land-use types to evaluate landscape aesthetics. Consequently, it was not possible to differentiate the two scenarios with incentives for ECAs from each other and from the reference status, although in actual fact we can assume that the landscapes differ in appearance. The 'incentives for location' scenario differs from the reference status and the other scenarios in terms of the spatial arrangement of the ECAs, while the 'no changes' scenario is characterised by a significantly higher proportion of 'crop production with rotational set-aside land'. Incorporating an indicator for the spatial arrangement into a method for assessing landscape aesthetics could be one of the next major challenges.

The value of the 'naturalness' perception factor within the method proposed by Hoisl et al. (1989) is highly dependent on the scoring scale; consequently, the differences between the scenarios are also dependent on it. A broad survey to assess peoples' current preferences is needed to validate the scoring scale of the 'naturalness' perception factor.

In terms of the combination of economic modelling and assessment of landscape aesthetics, we may assume that it is more promising to enhance the two weak points in landscape assessment mentioned above, rather than to enhance the economic modelling in order to provide data for calculating the 'variety' and 'character' perception factors. An attempt to incorporate the 'variety' perception factor in the assessment would greatly increase the complexity of the economic modelling, since individual landscape elements such as trees should be modelled. However, this effort would not answer the aforementioned questions concerning landscape preference and spatial arrangement of landscape elements. Additionally, sector models are designed to evaluate policy measures in the medium-term for large areas. In sector models, the actual agricultural infrastructures remain unchanged. This means that new farm buildings, silos, roads, or the removal of standard orchards are not modelled. Landscape change resulting from residential buildings, traffic or leisure facilities is obviously not modelled either, although this

type of landscape change can in point of fact be considerable over a 10-year time span.

A rough estimate of the changes in the 'variety' and 'character' perception factors is difficult to perform, nor can it be regarded as reliable. We may assume that within the 'no changes' scenario, the value of the 'variety' perception factor could increase owing to the higher proportion of 'low-input grassland with hedgerows' and 'wildflower strips'. This could have the effect of differentiating the 'no changes' scenario from the 'reference status'. In order to obtain the cumulative effect of both perception factors, however, it would be necessary to calculate the total value of landscape aesthetics, which would in turn also require us to calculate the values of the 'variety' and 'character' perception factors (see Section 3.2). As mentioned above, this is not possible.

From an economic point of view, the 'incentives for location' scenario represents the most efficient payment scheme. With 90% of the subsidies spent on ecological direct payments in the year 2000, the highest proportion of 'low-input meadows' is located at a maximum distance of 200 m from an existing semi-natural habitat, compared with all the other scenarios and the 'reference status'. This can be considered a substantial contribution to improving habitat connectivity and biodiversity conservation. Those two advantages could be a good reason to favour this scenario. Penker and Wytrzens (2005) support this decision. They conclude that for sustainable agriculture, liberalisation should be accompanied by enhanced spatial planning of the utilised agricultural area, and by enhanced nature conservation.

The focus of the 'incentives for location' scenario is primarily to enhance the connectedness of habitats and possibly biodiversity. A landscape, however, not only provides habitats for plants and animals, but also serves as a living- and recreation space for people. In order to meet these varying demands, an overall concept for the development of the different landscape types is required. Nohl (2001) describes a promising way to establish realistic and meaningful targets for developing a landscape. He proposes classifying the landscapes into four different aesthetic categories according to their history and current land use. The individual category represents different types of landscapes, e.g. the 'traditional cultural landscape' or the 'succession landscape', which helps to set priorities for enhancing landscape quality.

7. Conclusion

Our study shows that in order to keep Swiss landscapes as attractive as they are at present, financial incentives for low-intensity land-use types are required. In terms of an efficient payment scheme, the measures require incentives for detailed landscape planning for the utilised agricultural area, as proposed by the 'incentives for location' scenario and by Penker and Wytrzens. (2005).

Enhanced landscape planning for the agricultural area utilised cannot answer the question of what an attractive landscape should look like. Land-use modelling and assessment of landscape aesthetics by means of GIS can help to compare different scenarios. Nevertheless, this technique is restricted to methods based on an 'objectivist or physical paradigm', with all their inherent advantages and disadvantages. In order to help define the desired landscape and enhance the methods on the basis of an 'objectivist or physical paradigm', additional surveys based on a 'subjectivist or psychological paradigm' (Lothian, 1999) are required.

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Towards a planning support system for environmental management and agri-environmental measures—The Colorfields study

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Abstract

The authors present the beginnings of a planning support system (PSS) for agri-environmental measures exemplified by a virtual implementation of Colorfields and blooming strips on model farms, based on real-world data. This paper starts with an introduction to the Colorfields, a concept for transdisciplinary and sustainable landscape design of set-aside land. Colorfields comprise of blooming strips of flowering annual or biennial plants, which are designed and drilled in pattern on fallow land creating Land Art. The temporary scenic arrangements of the Colorfields combine the advantages of ecological strips, e.g. providing habitats for insects (especially bees), improving soil fertility through the cultivation of intercrops, with improvements of the social recognition of farmers as producers of pleasant landscapes instead of monoculture fields.

The prototype of the PSS uses two software tools of different scientific origin, the bio-economic modeling system MODAM and the landscape visualization system Lenné3D, which are linked based on geo-data. The resulting system helps to assess the economic effects and visualizes the effects of the specific landuse patterns under different scenarios.

The economic assessment of blooming strips on arable land and of one Colorfield on fallow land shows that these measures prove to be profitable from an economic viewpoint assuming the current area payments for the obligatory European Union set-aside program. Furthermore, the visualizations enable the design to be tested virtually by exploring the resultant scenery. They provide artists, planners and stakeholders including farmers with a tool to virtually wander through landscape scenarios supporting a collaborative design and a shared vision for the community.

The results of the two model farms and previous case studies for Colorfields demonstrate how current policy conditions could be used for the improvement of environmental and scenic qualities. Furthermore, the ability of the tools, MODAM and Lenné3D, suggests to support and promote these activities.

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1. Introduction

This paper presents the beginnings of a planning support system (PSS) with integrated three-dimensional (3D) visualization for environmental management and agri-environmental measures exemplified by a virtual imple-

mentation of Colorfields and blooming strips on model farms. Colorfields comprise of blooming strips of flowering annual or biennial plants that are either drilled in pattern on fallow land or drilled as integrated or marginal ecological strips on arable land. The authors focus on the economic assessment of projected Colorfields, i.e. assess their profitability, and evaluation of the 3D visualization of the PSS. An ecological assessment has not been yet integrated.

In the first section, the authors describe the context and background of the Colorfields to an international audience.

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Previous results from case studies in Germany are summarized and benefits for flower-visiting insects are discussed based on a literature survey.

1.1. Problem description

Agricultural policies, trade liberalization, and world markets are the primary driving forces of rural landscape development (Mentink, 1990). Rural areas in Central and Eastern Europe are facing dramatic landscape changes and—caused by this—a loss of biodiversity and cultural diversity (Antrop, 2005; Palang et al., 2005).

The social recognition of farmers is often suffering from a poor public image, e.g. caused by large scale “industrial” farming, the use of pesticides or genetically modified crops (MacFarlane, 2000). Farmers (co-) produce scenery, both pleasant, diversified landscapes and monoculture fields.

Besides other causes, economical forces have apparently led to a substantial decline of flowering plants, bees, and scenic diversity of cultural landscapes in Germany. Due to socioeconomic, public conception, and sanitary problems, the number of bee colonies in Germany had decreased about 25% from 1991 to 2001, with organized beekeepers down to 86%. In 1955, the number of bee colonies was five times higher in the eastern part and 2.5 times higher in the western part of Germany than in 2001 (Bienefeld and Künemund, 2001). These trends are causing serious pollination deficits, e.g. in pomiculture (Radtke, 2005, personal communication).

In the past, subsidies for seed mixes for blooming strips were available sporadically to farmers and beekeepers. In the German federal state of Brandenburg there are currently no such measures, even though the European Union (EU) and the Federal government would finance the biggest part.

The OECD differentiates agricultural products into commodity (CO) and non-commodity outputs (NCO). Multifunctionality of agriculture has become a crucial issue in WTO negotiations on agriculture trade. In the Common Agricultural Policy (CAP) of the EU, ecological and socioeconomic sustainability play more and more a larger role (Berger et al., 2006). In practice of agricultural policy, this is not yet the case with scenic quality. Nevertheless, in the European Landscape Convention (Council of Europe, 2000), which has come into force in 2002 in several member states but not yet in Germany, landscape scenery is considered one essential basis for cultural and social identity.

1.2. The multifunctional concept of the Colorfields

Artists, landscape architects and others promoting the idea of “ecological aesthetics” (Strelow, 2004) believe that many current problems facing us have to be seen as creative issues of artistic environmental design. Prominent representatives like Herman Prigann are aiming to find productive viewpoints that go beyond beautification or

formalistic design. Environmentally aware landscape design should produce viable concepts for agriculture and forestry at a time of radical change in these fields. Current design efforts reach beyond the surface to recreate our cultural landscape fully and effectively.

In 1999, the artists Bernd Schindler and Frank Schumann developed a first concept of the Colorfields, and implemented three designs in a collaborative process with farmers and horticulturists. From 1999 to 2001, a second series of case studies adopted the concept within a joint research project (Müller et al., 2002) in the Elbe-Elster district in the south of the state of Brandenburg (Boeckmann et al., 2003).

The concept of the Colorfields was originally based on payments for the obligatory EU set-aside program that farmers have to implement for receiving their area payments. At first glance, Colorfields are a form of Land Art.

A central idea is that ecological, economic, and aesthetic considerations do not have to be mutually exclusive objectives in agriculture, as farmers are often active but unconscious designers of multifunctional landscapes.

Colorfields are conceived and implemented in a coalition of stakeholders, e.g. farmers, artists, landscape planners, beekeepers, companies, schools and rural tourism, in a kind of public private partnership using multiple funding sources, e.g. volunteer labor, funds of the tourist office, and sponsoring from seeds producers.

The advantages of these temporary scenic arrangements and novel landscape designs are the provision of habitats, improved soil fertility through the cultivation of intercrops, and an improved social recognition of farmers who generate pleasant landscapes instead of monoculture fields. The “weedy, messy” appearance of set-aside land (Nassauer, 1989) are an “aesthetic thorn” in farmer’s side. Leopold (1939) stated that the landscape of any farm is the owner’s portrait of himself. Farmers see beauty in the straightness of the rows, and prefer neatly mown field sides (Nassauer, 1988a). Nassauer found out that people perceive clearly visible patterns of soil conservation practices like strip cropping (Nassauer, 1995), and proper horticulture fields (Nassauer, 1988b) as vivid cues to care. Colorfields incorporate cues to care, e.g. the appearance of better stewardship than of fallow land, communicating human intention. The designed forms of Colorfields are unusual relative to the common cropping practices, but involved farmers that liked the sporty challenge (Schindler, personal communication, April 2000). Figs. 1 and 2 show some real-world examples of the case studies in Elbe-Elster district. During these case studies, it became apparent that planners and stakeholders would feel more comfortable if a decision-support tool could assist them in their envisioning of proposed Colorfields.

In Germany and Switzerland, marginal blooming or ecological strips are common measures of agri-environmental programs to enhance biodiversity and nectar flows (Berger et al., 2006; Friebe, 1992; Schaffner and Keller,



Fig. 1. Implementation of the 60 ha Colorfield near the village of Gröden (Photo: Dieter Rosenhahn, May 2000).



Fig. 2. On the Colorfield of Gröden. Local apiculturists put there bee yards on the site (Photo: FINIS e.V., July 2000).

1998; Schuhmacher, 1984). Colorfields are reinterpreting these linear structures in terms of multifunctionality and ecological aesthetics.

1.3. Benefits of blooming strips and Colorfields for flower-visiting insects

In principal, installation of more or less long-lasting biotope structures in agricultural landscapes seems to be ecologically advantageous. General remarks on benefits for flower-visiting insects can be found in the literature. From the sources, blooming strips within the landscape affect biodiversity positively, and therefore Colorfields, too. However, this statement is primarily affirmed by reports on benefits of those arrangements (with their summer flowering plant composition; see Table 1) for apiculture when nectar flows become scarce. As additional edge biotopes, blooming structures establish discrete habitats for some species (Müller, 1995; Wetzel et al., 2004).

Benefits of these blooming strips for honey bee (*Apis mellifera*) and wild bees (Hymenoptera: Apoidea), flower flies (Syrphidae), butterflies (Lepidoptera) and other insect

Table 1
Plant lists of “used” blooming strip seed mixes

(a)	Case 1: Blooming strips (Königslutter) Buckwheat (<i>Fagopyrum esculentum</i>) Calendula (<i>Calendula officinalis</i>) Sunflower (<i>Helianthus annuus</i>) White Mustard (<i>Sinapis alba</i>) Purple Tansy, Fiddleneck (<i>Phacelia tanacetifolia</i>) Garden Lupine (<i>Lupinus polyphyllus</i>) Cornflower (<i>Centaurea cyanus</i>)
(b)	Case 2: Colorfield (Uckermark district) White Mustard (<i>Sinapis alba</i>) Purple Tansy, Fiddleneck (<i>Phacelia tanacetifolia</i>) Garden Lupine (<i>Lupinus polyphyllus</i>) Cornflower (<i>Centaurea cyanus</i>)

groups were reported on various occasions; Boeckmann et al. (2003), Paar and Boeckmann (2001), and Radtke (2004) popularly report about observations from installed Colorfields, Hedtke (1996, 1997, 2000), Hedtke and Pritsch (1993), Kratochwil (1984), Ruppert (1993), Ssymank (2001) and others provide empirical data on the behavior of particular flower visitors. Also, observations of the flower-visiting fauna of particular plant species (Saure, 2002a and others) forebode expected advantages of blooming structures for insects.

We know scarcely anything about the flower-visitor fauna from the sample areas Königslutter and Uckermark: Richert (1999 ff.) provides some data on Lepidoptera and their host plants from the region around the town Eberswalde (to the south of the Uckermark sample area). Saure (2002b) is another source for flower-visitor data from sample areas within the Uckermark region, which could be use for a comparative study.

Positive effects on flower-visiting insects within specific, e.g. the sample areas would have to be examined, in particular, on a case-by-case basis. The occurrence of the anticipated insects has to be analyzed, and also parameters such as larval habitats, retreats and other essential structures (Richert, 2005, personal communication).

2. Methods

2.1. Sample areas

The first model farm is based on a planning scenario within the framework of the project “Interactive Landscape Plan” in Königslutter (Warren-Kretzschmer and Tiedke, 2005), sponsored by the German Federal Office for Nature Conservation (BfN). The aim of the collaboration was to test the Lenné3D system in practice under the conditions of a participatory landscape planning process, and to evaluate its acceptance and results in an accompanying survey. In collaboration with our partner project, a hilly side was selected for highly detailed landscape visualizations.

In early 2003, these visualizations supported the participation process with local stakeholders. The area is situated at the edge of the Elm Natural Park, Germany, is predominantly used for agriculture, and is affected by erosion. Soil erosion is a problem in this area due to the highly erodible soils combined with long slopes along the hills and the usual crop rotations with a high percentage of sugar beets, that leave the soil surface without cover for a long period during the year. The landscape inventory of the landscape plan highlights more deficits of the area, e.g. a lack of scenic landscape elements and a low biodiversity (enterra, 2004; Landschaftsplan Königslutter, Hannover, unpublished report). Positive aspects of the area are the high soil fertility as well as the proximity to the nature conservation areas (Natural Park Elm), which provides high scenic values.

The town of Königslutter wishes to enhance soil protection, promote landscape related recreation and protect the natural species and habitats that it houses (Haaren et al., 2005). One option to fulfill this postulation is to establish blooming strips within the agricultural fields. For an implementation of this measure, farmers can apply for an environmental conservation program of the federal state of Lower Saxony (Ministerium für Ernährung, Landwirtschaft und Forsten Niedersachsen, 2004). In our first model farm, a scenario of blooming strips is compared with the status quo situation.

The second model farm, uses a data set of a 1.4 ha site that is located in the Uckermark district: the main research area of the Leibniz-Centre for Agricultural Landscape Research (ZALF). With respect to soils, topography, hydrology and landuse systems, this region is typical for North-Eastern Germany as well as Central-Eastern Europe. The landscape is relatively unstructured with large fields with an extensive landuse and large set-aside fields. This area was selected because a basic dataset has been used for several tests of the Lenné3D system.

2.2. Framework of the planning support system

Our proposed system can be considered a planning support system (PSS), ought to assess and visualize the socioeconomic, ecological and scenic effects of the specific landuse patterns under different agricultural scenarios (Tress and Tress, 2003). PSS are a subset of geo-information based decision support systems (DSS) and used to support the planning process by communicating information as well as by generating solutions (Geertman and Stillwell, 2004; Klosterman, 1997).

The PSS used for a virtual implementation and assessment of Colorfields and blooming strips is based on four components: a geographical information system (GIS), a bio-economic modeling system, a vegetation modeling system, and a real-time landscape visualization system.

The prototype links MODAM (multi-objective decision support tool for agro-ecosystem management), a bio-economic modeling system, and Lenné3D, a vegetation

modeling and landscape visualization system. A GIS is still needed to design alternative land cover configurations, i.e. polygon clipping operations to integrate Colorfields and blooming strips.

2.3. MODAM: bio-economic modeling

In order to outline the on-farm costs of any agri-environmental measures such as blooming strips, a model must describe the effects of agricultural practices at field level in a very detailed way. The bio-economic modeling system MODAM (Zander and Kächele, 1999) gives such possibilities. It is based on a database system describing the work steps of cropping practices (Meyer-Aurich et al., 1998) and livestock activities. This allows the development of information about any specific pesticide application, fertilizer usage or the periods, when each work step is done on a field. This information may be used for the ecological evaluation of environmental objectives, which is one of the main differences from other models and databases used for the assessment of agri-environmental issues (see other applications of the model: Zander, 2003). Based on these data, economic and ecological analysis can be performed for the agricultural activities. In a further step, MODAM uses a linear programming (LP) approach that simulates farmers' profit maximizing behavior under the conditions of agricultural policies and environmental constraints, and assesses socioeconomic (e.g. profit, labor) and ecological effects (e.g. erosion) of resulting agricultural landuse (Sattler et al., 2006; Schuler and Kächele, 2003; Zander and Kächele, 1999). It is assumed that the main objective of farmers is to maximize the profit of their farms under given restrictions such as labor time, field sizes, limitations through crop rotations and policies. Although farmers obviously have objectives other than profit maximization, these are neglected for reason of simplicity. It is assumed that most farmers' decisions are based on economic rationality (Kächele, 1999, p. 4). The model provides data on the resulting landuse and its corresponding gross margin (a measurement of the economic success of a farm).

In this study, MODAM is used as a tool for two purposes: (i) to simulate farmers' behavior given specific scenarios in the first model farm (Königslutter, blooming strip example) where the study area is seen as a whole farm and (ii) as a database for an economic gross margin analysis of certain agricultural measures (Colorfields) where the economic decision is taken on field level (second model farm, Uckermark).

2.4. Lenné3D: vegetation modeling and landscape visualization

The interactive Lenné3D software system visualizes landscape three dimensionally and in real time—photo-realistically, graphically reduced and cartographically, both from map view and from first person view (Paar, 2003; Rekittke and Paar, 2006; Werner et al., 2005). The

system is a prototype for a GIS-data based vegetation modeling and visualization tool for interactive exploration of 3D landscapes. In this study, Lenné3D is used for the modeling of vegetation, calculation of plant distributions, and visualization of landscape scenes. The 3D scenes are generated using standard GIS data, e.g. landuse and biotope maps and a digital terrain model, an integrated vegetation model, and 3D objects, especially detailed plant models (Deussen, 2003; Reikittke and Paar, 2006). Lenné3D was primarily intended for use in landscape planning in order to enable scenarios and planned landscapes to be anticipated and explored by stakeholders and the general public.

In the Lenné3D system, the vegetation modeling component, called “oik” (Röhrich, 2005), calculates plant positions by means of heuristic-algorithmic models, and on the basis of habitat, e.g. biotope types (ESRI Shapefile) and landuse maps (ESRI Shapefile), cropping practices, vegetation reference mappings (i.e. phytosociological mappings, cf. Braun-Blanquet, 1964) and topographical site data.

For every scenario, specified in a landuse map, and every field the crops, the blooming strips seeds (Table 1) are virtually “drilled” by the “oik” system (Table 2). Data about the cropping practices, sowing amount and the used sowing machines is provided by the MODAM database system. “oik” computes row distance and plant distances within the row from this data. The direction of rows follows the longest field border. The occurring weeds and other plant species are spread on the basis of either regional, local or on-site vegetation reference mapping, depending on the data available. Local data are available for the two model farms.

The Lenné3D-Player is a program that interprets the scenic description and geo-data specified in a Lenné3D

project. 3D plant models are assigned to the plant distribution calculated by the “oik” component and positioned within the landscape model. The output is real-time visualization, video animation and static images. Hardware-based rendering techniques and effective storage mechanisms are utilized on personal computers (PCs) to render a landscape scene with millions of plants in real time.

3. Results

3.1. Socioeconomic effects

3.1.1. Model farm 1, Königslutter: a virtual farm with blooming strips modeled with MODAM

For the modeling of the economic effects of blooming strips on farm level, the fields in the sample area are aggregated as if they belong to one single virtual farm.

The total agricultural area comprises 115 ha, divided into 20 fields of differing sizes. The soil quality of the fields is assumed to be homogeneous over the whole virtual farm. Empirical data about the landuse of the sample area of Königslutter show that farmers mostly grow sugar beets and winter wheat in a ratio of 20–80%. Aiming at the reduction of erosion, the Landscape Plan of Königslutter pointed out areas with an increased erosion potential (Fig. 3). Blooming strips are a measure that also reduces erosion, besides providing other benefits to the landscape. Therefore, the implementation of such blooming strips was tested in a scenario calculation. The strips cut the length of the longest, highly erodible field into three parts while additional blooming strips in the lower, less erodible parts of the area fulfill other functions such as providing areas for bee harvesting and increased biodiversity.

Both in reality and in the model, set-aside obligations are switched to less fertile fields outside of the sample area. Furthermore, usual crop rotation rules are neglected by the farmers given the high productivity and profitability of sugar beets and winter wheat. Therefore, the status quo was modeled without model's crop rotation restrictions that force the virtual farm to follow the guidelines of good management farming practice.

The virtual farm within the model can choose among the most common crops grown in the region (sugar beets, winter wheat, winter barley, rapeseed, rye, triticale). The yields of these crops were adapted to the 6-year average yields of the region for the years 1998–2003 (Niedersächsisches Landesamt für Statistik, 2005). The usual EU-area based payments are introduced into the model, as well as a subsidy for blooming strips, which is provided as an agri-environmental measure by the federal state of Lower Saxony (600 €/ha; Ministerium für Ernährung, Landwirtschaft und Forsten Niedersachsen, 2004). The algorithm of the economic optimization model searches for a combination of crops providing the highest profits given the set of land and labor restrictions.

Table 2
Parameters for the virtual Colorfield (Uckermark district)

```
<item id = "3"
model = "Sinapis_alba_v1,Sinapis_alba_v2,Sinapis_alba_v3"
symbol = "13" quantity = "2" sociability = "8" stratum = "9"
size = "0.04 0.04 0.1">
<name>Sinapis_alba</name>
<path d = "m5 85 c0 50, 80 50, 25 0" style = "4"/>
</item>
<item id = "10"
model = "_Phacelia_tanacetifolia_v4,_Phacelia_tanacetifolia_v5,
_Phacelia_tanacetifolia_v3" symbol = "7" quantity = "2"
sociability = "8" stratum = "9" size = "0.04 0.04 0.1">
<name>Phacelia_tanacetifolia</name>
<path d = "m25 0 c0 50, 80 50, 10 85" style = "4"/>
</item>
<item id = "12"
model = "Lupinus_polyphyllus_v5,Lupinus_polyphyllus_v6,
Lupinus_polyphyllus_v7" symbol = "7" quantity = "1" sociability = "8"
stratum = "9" size = "0.04 0.04 0.1">
<name>Lupinus_polyphyllus</name>
<path d = "m0 45 q30 20, 60 40" style = "4"/>
</item>
```

Bezier curves for plant distribution of blooming strips (XML code).

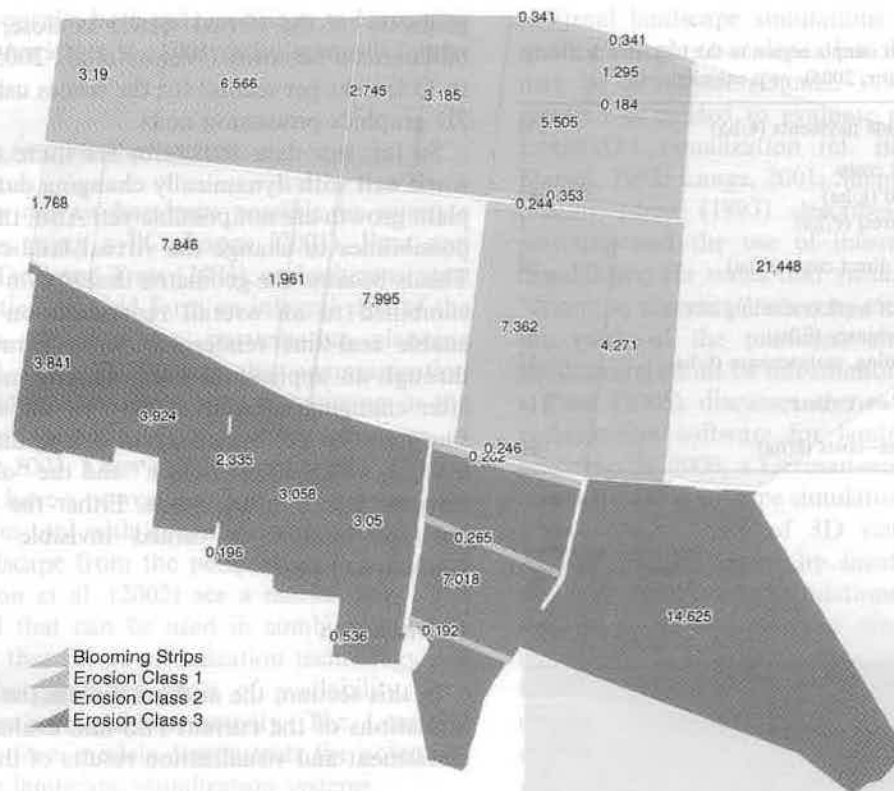


Fig. 3. Map of the fields of the sample area in Königslutter showing erosion classes and proposed blooming strips.

Table 3
Economic results of two scenarios of the virtual farm working in the sample area of Königslutter

Scenario	Total gross margin (€)
Status quo	65 113
Blooming strips	65 662
Difference	549

The introduction of blooming strips increased the gross margin of the area.

The validation result of the status quo scenario without blooming strips simulated exactly the crop share grown in the region (20% sugar beets, 80% winter wheat), which proves a correct adaptation of the model.

In the second scenario (with blooming strips), blooming strips were introduced as described before into the fields, covering more than 2 ha of the sample area with selected flowering plants. These strips are given a subsidy of 600 €/ha. For the modeling, it is assumed the strips are not increasing the work effort on the remaining fields, because of the shape and placement of the strips and the fact that farmers are allowed to cross these strips with their tractors.

The overall result shows that the blooming strips prove to be profitable, since the prime for blooming strips covers the loss of surface used for the production of sugar beets and winter wheat (Table 3). The subsidy provided by the

federal state was chosen high enough to cover the possible loss. However, this result is only valid for the case of pure cash crop farms with low interrelations between farm branches. On livestock farms, the opportunity costs for land that can no longer be used for fodder production can be surpass the amount of the subsidy.

3.1.2. Model farm 2: Colorfield: a gross margin-based assessment

In the second case study, an economic gross margin analysis was conducted on the efforts and gains that are related to this measure. A Colorfield can be financed by the payments from the EU set-aside program. The costs for preparing the seed bed and sowing per 1 ha of a Colorfield can be compared to the costs of a standard field fallowing combined with seeding of intercrops. Extra working time has to be considered for the small field units and different fillings of the sowing equipment. Therefore, the work time can rise substantially. However, these higher costs can be covered partly by the EU set-aside payment. Additionally, some of the costs (e.g. for seeding) can be borne by sponsors.

On this basis, total costs excluding costs for labor and tenure payments sum up to 178 €/ha. However, given a set-aside payment of 274 €/ha for Brandenburg, another 96 €/ha remains to pay labor and tenancy (Table 4), which can be sufficient given the low tenure payments in the region.

Table 4
Calculation for a Colorfield for a sample region in the Uckermark district
(Landesamt für Verbraucherschutz, 2005; own calculations)

Income	Set-aside payments (€/ha)	274
Costs	Direct costs	
	Seed (€/ha)	63
	Interest (€/ha)	1
	Total direct costs (€/ha)	64
	Cost of work (excluding labor)	
	Machinery (€/ha)	57
	Seeding, maintenance (€/ha)	57
	Total work costs	114
Gross margin	Income–costs (€/ha)	96



Fig. 4. Virtual implementation of blooming strips in Königsutter (screenshot Lenné3D-Player, computer generated image).



Fig. 5. Virtual implementation of a Colorfield in the Uckermark district (screenshot Lenné3D-Player, computer generated image).

3.2. Landscape visualization

Figs. 4 and 5 show visualizations of both sample areas. The renderings are screen captures of the interactive Lenné3D-Player. Several million virtual plants are distributed in the scenes. Each plant is represented by

geometry, if the virtual viewer is close, and by a set of billboards if far away (Werner et al., 2005). We achieve up to 15 frames per second for the scenes using current (2005) 3D graphics processing units.

So far, our data structures are quite static and do not work well with dynamically changing data. Animations of plant growth are not possible yet. Also, the user has limited possibilities to change the virtual landscape interactively. This is because the geometric description of many plants is combined to an overall representation of the scene to enable real-time rendering. Single plants can be added through an application programming interface (API) but after changing substantial parts of the scene, pre-processing must be performed again before display. As a work around, we load the “before” and the “after” situation on separate layers in one scene. Either the Colorfield or the previous landuse is turned invisible to visualize the landscape change.

4. Discussion

In this section, the authors discuss the effectiveness and limitations of the current PSS and evaluate the economic assessment and visualization results of the model farms.

4.1. Economic assessment

The implementation of measures such as blooming strips and Colorfields is strongly driven by economic consideration. Therefore, the provision of economic data on the financial feasibility supports farmers' decisions on implementation.

Both results of the model farms show how an economic assessment can be applied to the concepts of blooming strips and Colorfields. Depending on the level of analysis, either a whole farm approach with an optimization model in case of more than one field or a gross margin calculation for a one-field level is appropriate.

From an economic viewpoint, both measures, Colorfields and blooming strips, can be profitable under the current framework of agricultural policies. The concept of Colorfields is only profitable with either low labor costs, low tenure prices or additional voluntary support by sponsors. However, on better soils this measure faces high competition by energy crops, which can also be grown on set-aside fields, with a much higher revenue for the energy crop option. Nevertheless, Colorfields provide an opportunity especially for regions with poorer soils that can hardly be grown with cash crops economically. The socioeconomic benefits of Colorfields are not limited to a EU set-aside payment: other benefits should stem from other sources such as increased rural tourism. Therefore, a basic coverage of the costs is a promising starting point for such projects.

For a more precise assessment of the soil erosion risk, the underlying data can be improved by the use of erosion models such as an USLE risk assessment (Schwertmann

et al., 1987) that consider both soil conditions and cropping practices (Meyer-Aurich et al., 2001; Schuler and Kächele, 2001).

4.2. Visualization for planning support

For some time now it has been possible to generate virtual landscapes using a PC. Lange (2001), Paar and Reikittke (2005), Tress and Tress (2003), and others suggest that 3D visualizations should form an integral part of the planning process. Modern, i.e. participative planning approaches need tools facilitating the communication between stakeholders and planners, and assisting in the understanding and assessment of the consequences of future changes. In 2003, Tress and Tress pointed out that it would be ideal to have a powerful and photo-realistic GIS-based visualization tool with dynamic characteristics that would show landscape from the perspective of a moving observer. Appleton et al. (2002) see a market gap for a visualization tool that can be used in combination with GIS, and predict that future visualization technology will move towards the combined goals of availability, geographic detail, realism and interactivity. The Lenné3D results of the two farm models demonstrate the potentials of these emerging landscape visualization systems.

In Königslutter, interactive and GIS-data based landscape visualizations have successfully been used as a tool to support the dialogue on community landscape planning and decision-making (Haaren et al., 2005; Warren-Kretschmer and Tiedke, 2005). In the discussion process, stakeholders actively used the interactive capability of the Lenné3D system to locate comments, draw polygons and place objects in the 3D map. The visualizations provided by the PSS enable the design to be tested virtually by exploring the resultant scenery. They provide artists, planners and stakeholders including farmers with a tool to virtually wander through landscape scenarios supporting a collaborative design and a shared vision for the community. Well-known PSS that build on GIS are “What if?” (Klosterman, 2001), and CommunityViz (Kwartler and Bernard, 2001), the latter has an integrated 3D visualization module. The 3D visualization of the PSS used for the two model farms is currently less of an analytical but more of exploring character. It mainly differs from other PSS and real-time visualization tools in its capacity to render 3D plants in their millions. At present, due to the simply system linkage of MODAM and Lenné3D, the end-user is confronted with two separate graphical user interfaces: tables, diagrams or maps (MODAM), and interactive landscape visualization (Lenné3D). It seems rather helpful, if stakeholders could navigate in real time through realistic landscape scenes, while being able to review economic outcome of the proposed landuse change. However, at this stage both approaches were linked on a rather simple file system level. Further research is required for a testing and evaluation of MODAM and Lenné3D in practice.

Visual landscape simulations might be of high image quality, i.e. photo-realistic, but their accuracy and validity may be a suspect (Daniel, 1992; Perkins, 1991). More research is needed to evaluate reliability and validity of Lenné3D's visualization (cf. Bishop and Leahy, 1989; Daniel, 1992; Lange, 2001; Sheppard, 1982).

Klosterman (1997) describes the evolving view of planning and the use of information and visualization capabilities. He states that visualization has emerged as a “common currency” whereby citizens can readily evaluate the work of the planners, and the opportunities for misinterpretations of information are reduced.

Paar (2006) discusses the role and use of landscape visualization software for landscape and environmental planning. In 2000, a German-wide survey of user requirements for 3D landscape simulation software was conducted (Paar, 2003). Users of 3D visualization software were particularly concerned by insufficient representation of plants and habitats in simulations. Nevertheless, the survey showed that 3D landscape visualization has a positive image in landscape and environmental planning in Germany. A vast majority of landscape professionals was convinced of the advantages of the technology, and was eager to integrate 3D landscape visualizations into their working practices.

Geertman and Stillwell (2004) make some recommendations regarding the future of PSS development and application: PSS should be integral to the planning process; PSS should fulfill the key requirements of interactivity, flexibility, adaptability and maintainability demanded by modern participatory planning processes, as opposed to traditional planning practices; PSS should be appealing and tailored to user capability; the user-interface should be tailored to the needs of participants. Currently, our PSS is more an expert system than an end-user tool.

Stock and Bishop (2005) propose an Envisioning System based on massive multiplayer computer games technology and designed to help rural communities contemplate landscape level changes, negotiate desired future conditions and implement policies.

The emerging possibilities of an interactive design of land cover configurations, e.g. Colorfields by stakeholders, deserve further investigation from social scientists. It would also be interesting to examine the chances of successful marketing of Colorfields, e.g. by fundraising activities, using MODAM and Lenné3D.

5. Conclusions and outlook

The economic assessment of blooming strips on arable land and of one Colorfield on fallow land shows that these measures prove to be profitable from an economic viewpoint. Furthermore, the visualizations enable the design to be tested virtually by exploring the resultant scenery. They provide artists, planners and stakeholders including farmers with a tool to virtually wander through landscape

scenarios supporting a collaborative design and a shared vision for the community.

Furthermore, the case study and the results of the two model farms suggest how current policy conditions can be used for the improvement of environmental and scenic qualities. The potential of the tools, MODAM and Lenné3D, is shown in supporting and promoting these activities. For a widespread implementation of such on-farm measures, both visualization and economic assessment would most likely improve the chances of adoption.

In future applications, the PSS should make further use of MODAM's more advanced tools for assessments of commodity and non-commodity outputs (Sattler et al., 2006). A fuzzy-logic tool processing expert knowledge assesses the environmental effects of agricultural production activities, while an economic evaluation provides information on their profitability. A farm level optimization module allows for simulation of the production activities both at field, farm and regional level. Trade-off functions demonstrate the interdependencies of the analyzed outputs.

To comment on further development of the Lenné3D system, the software is actually prepared for a more interoperable application, i.e. ability to work with or use the parts of another system, by defining web services as interface. A closer linkage of both tools with such well-defined APIs could provide faster results, including a faster calculation of scenarios in stakeholder meetings.

In a sense, real-time virtual landscapes translate Repton's idea (1803) with his Red Books to draw before and after situations from the viewer's perspective into a new, digital media-based dimension. A user interface to design alternative land cover configurations is still subject to further research to enable designers an interactive drawing onto the terrain and visualize the consequent landscape in real time. Furthermore, precision farming already offers technology for an implementation of digital designs of Colorfields in the landscape.

High-quality prints of landscape visualizations could offer a potential to re-finance some of the costs of "real-world" Colorfields, similar to the approach of Christo and Jeanne-Claude that sell paintings and illustrations of their projects.

In EU, with changing consumer demands, the Common Agricultural Policy is changing. The concept of multifunctionality of agriculture provides further possibilities to create new markets for new products (Wiggering et al., 2003). This is also a chance for Colorfields that exemplify and vividly demonstrate the characteristics of multifunctionality.

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Scenario-visualization for the assessment of perceived green space qualities at the urban–rural fringe

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Abstract

The provision of green space is increasingly being perceived as an important factor for quality of life. However, green spaces often face high developmental pressure. The main objective of this study is to investigate a prospective approach to green space planning by combining three-dimensional (3D) visualization of green space scenarios and survey techniques to facilitate improved participation of the public. Aside from the 'Status quo', scenarios 'Agriculture', 'Recreation', 'Nature conservation' and 'Wind turbines' are visualized in three dimensions. In order to test responses, a survey was conducted both in print format and on the Internet. Overall, 49 different visualizations that belong to one of the scenarios were available in the survey and were rated according to the perceived esthetic, recreational and ecological values.

The highest rated scenes include vegetation elements such as meadows with orchards, single trees, shrubs or forest. The least attractive scenes are those where buildings are highly dominant or where there are no vegetation elements.

Based on the ratings for the individual images and on the corresponding scenarios, our study shows that there is high potential for improving the existing landscape. All suggested changes are either rated about equal to or considerably higher than the status quo, with the scenario 'Nature conservation' receiving the highest scores.

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Keywords: 3D visualization; Scenarios; Survey; Green space; Landscape perception; Esthetic, recreational and ecological values

1. Introduction

It is estimated that approximately half of the world's population is currently living in urban areas (Hall and Pfeiffer, 2000). In view of this situation, green spaces and the countryside in and around towns are increasingly gaining importance. They fulfill a whole range of functions such as health functions (de Hollander and Staatsen, 2003), amenity and social functions (e.g., Gälzer, 2001; Gehl,

1987) as well as ecological functions (e.g., Sukopp, 1982). In addition, they have a considerable economic importance (Tyrvainen, 1997; Bishop et al., 2004). As an illustration, Lange and Schaeffer (2001) showed that the economic value of views from hotels in Zürich, i.e., the prize for renting a room, is directly related to the quality of the view over the surrounding area. Green spaces and the countryside in and around towns often face high developmental pressure, such as being developed for infrastructure, housing or commercial use (e.g., Amati and Yokohari, 2006; Gallent et al., 2006).

2. Case study site Käferberg, Zürich, Switzerland

The main parts of the city of Zürich are situated on the shores of Lake Zürich, nestling between two ranges of hills: Zürichberg (676 m), Käferberg (571 m) and Höngerberg

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(541 m) to the north and the Uetliberg range (870 m) to the south of the city center.

In a recent worldwide survey (Mercer, 2007), the city of Zürich was rated as providing the best quality of life among 215 cities studied worldwide. According to a representative survey held in Zürich (Fachstelle für Stadtentwicklung, 2003), the provision of green space represents a key contribution to the quality of life of the citizens of Zürich. On the other hand, large areas at the urban–rural fringe are currently in the process of being developed.

The Käferberg case study site is situated within the large greenbelt directly adjacent to the north of the city center at the urban–rural fringe. It is located between the Käferberg forest and the campus of the Swiss Federal Institute of Technology (ETH Zürich–Hönggerberg). The first phase of this campus was built between 1961 and 1973, followed by the completion of a new chemistry complex in 2003. Because of the sloping terrain the site provides long-distance views towards the city and the Alps in the background. In the open space scheme of the City of Zürich about half of the site is classified as green space with recreation function while the other half is classified as 'residual' green space, indicating potential for improvement.

The case study site fulfills ecological functions as well as agricultural production functions. The farmland at the Käferberg with pasture and meadow includes remnants of valuable habitats such as: hedgerows, dry, nutrient-poor meadows and small streams. These landscape elements are protected as well as the neighboring woodlands. To preserve the open space, the site is zoned as 'Freihaltezone' (open space protection zone). It is mainly used agriculturally by a farmer who lives on-site, farming the majority of the area, and by a neighboring farmer.

The site is also very popular for urban recreational purposes such as walking, jogging, cycling, etc. Although many of the visitors to the site originate from nearby residential zones, the green space is easily accessible by public transport and also offers car parking nearby.

3. Objectives

The main objective of our research is to investigate a prospective approach to green space planning by combining three-dimensional (3D) visualizations of green space scenarios and survey techniques to facilitate improved public participation.

By using the 3D visualizations as a basis for evaluation in a survey, we are assessing the perceived esthetic, recreational and ecological values of different scenarios of green space ('Status quo', scenarios 'Agriculture', 'Recreation', 'Nature conservation' and 'Wind turbines'). In order to reach different groups of users of green space, the survey was conducted both in traditional paper format and over the Internet (Fig. 1).

To get an overview of the reaction to change, lay persons as well as expert planners, locals as well as non-locals are asked to rate 3D visualizations of the existing Käferberg open space as well as the potential impact of scenarios of alternative future landscapes. In particular, our research concentrates on how vegetation elements and the presence or absence of built structures in a scene, namely roads and buildings, influence the ratings. In addition to the actual content depicted in the visualizations, other factors that likely influence the ratings include familiarity with the given location (local vs. non-local) and professional background of the test persons; it is important to include these factors in the analysis so as to account for any effects they may have on the results.

4. Research design and methods

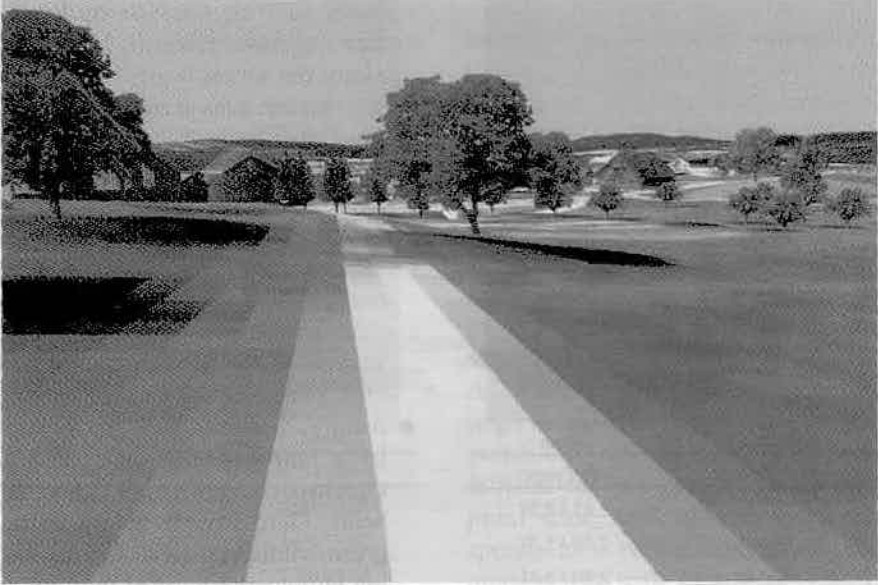
4.1. 3D visualization

The purpose of the visualization was to provide the foundation from which to analyze how people (stakeholders and interested citizens or citizen groups) interpret and react to the visual experience of the landscape and to the characteristics of green space. The visualizations were prepared with Polytrm software (Danahy and Hoinkes, 1995; Hoinkes and Lange, 1995) using 3D data from GIS and CAD, as well as interpreted 2D-data, site survey data and site photographs.

In order to provide optimal resolution while allowing the digital model to be computationally efficient, the landscape was represented in various resolutions. For the city of Zürich, a digital Terrain Model (DHM 25) with a resolution of 25 m and an orthophoto at a resolution of 2.5 m were available. The actual virtual model of the Käferberg case study site consisted of an orthophoto with a resolution of 0.5 m, 3D objects such as buildings and trees and a digital terrain model that was built as a TIN (Triangulated Irregular Network). In order to get a precise terrain representation, embankments, bridges and some trails were edited by hand. The modeling of the 3D elements was based on planning data, zoning data, and on-site visual surveying. The campus of ETH Hönggerberg and the neighboring farmhouses were modeled and visualized in detail with geospecific textured facades. Buildings further away were visualized by extruding the footprint in the digital topographic map 1:25,000 by using the approximate height allowed according to the zoning plan.

For a precise representation of the existing vegetation, tree and shrub species were surveyed, mapped and photographed in the field. Based on these photographs, a texture library consisting of local woody vegetation such as *Acer campestre*, *Acer pseudoplatanus*, *Aesculus hippocastanum*, *Alnus glutinosa*, etc. was established.

Once the base model was produced in the described manner, small changes or whole scenarios of landscape



How do you like the above landscape?

Would you enjoy walking in the above landscape?

What value do you think the above landscape has in terms of nature conservation?

11 of 20

Continue

not at all not much somewhat a little very much

not at all not much perhaps a little very much

no value barely valuable average value valuable very valuable

Fig. 1. Example of the online-survey, screen snap shot.

change could be performed with relatively low modeling input.

4.2. Alternative future scenarios

Scenario techniques are being used increasingly in the environmental sciences to support strategic planning (see Lange and Schmid, 2000; Alcamo, 2001; Mörtberg et al., 2007). Steinitz et al. (2003) define a scenario as ‘an outline or plot for a future of a landscape’. They also use the term ‘alternative futures studies’, with scenarios enabling planners and stakeholders to address a variety of issues across different geographies and at different scales.

Ringland (1998, p. 111) stresses the importance of communicating the contents of scenarios: ‘Scenarios are about ideas, and ideas are notoriously difficult to communicate’. The translation of scenarios into visual representations, often as an aerial perspective, has become increasingly popular in recent years. Examples include the hand-drawn sketches used by Heißenhuber et al. (2000) and static digital photomontages as used by Nassauer and Corry (2004) and Sullivan et al. (2004).

In our study, a freely navigable virtual environment was modeled to provide synthetic three-dimensional representations of alternative futures for the Käferberg area. Based on the assumption that the current zoning (open space) will



	Ranking	Mean
	web / paper	web / paper
Landscape preference	47 / 49	2.39 / 1.91
Recreation preference	47 / 49	2.44 / 1.99
Nature conservation	47 / 49	2.34 / 2.19

Fig. 2. Overview: Status quo.

be adhered to, various plans and ideas for change scenarios ‘Status quo’, ‘Agriculture’, ‘Recreation’, ‘Nature conservation’ and ‘Wind turbines’ were developed (Figs. 2–7). In our approach to green space planning, the development of scenarios involved the participation of experts and



	Ranking	Mean
	web / paper	web / paper
Landscape preference	45 / 46	2.45 / 2.21
Recreation preference	46 / 46	2.50 / 2.37
Nature conservation	46 / 46	2.40 / 2.41

Fig. 3. Ground-level view: Status quo.



	Ranking	Mean
	web / paper	web / paper
Landscape preference	42 / 39	2.64 / 2.63
Recreation preference	44 / 39	2.65 / 2.68
Nature conservation	44 / 36.5	2.46 / 2.85

Fig. 4. Scenario agriculture.

land-users. Godet (2000) and Roubelat (2000) stress the importance of a participatory process in scenario development.

Details of the five scenarios:

- **Status quo:** The existing virtual model of the Käferberg site. Currently, Käferberg is a large farmed open space with only a few vegetation elements.
- **Agriculture:** This scenario was developed by the farmer living on the Käferberg site. The farmer's idea was to change the existing landscape in order to reduce the number of obstacles within the fields and meadows

(such as fruit trees or bushes). Instead, to make the farming more efficient, he preferred to have fruit trees along the access roads.

- **Recreation:** This scenario was developed by a recreation researcher from ETH Zürich to create a landscape that would encourage recreation activities such as walking. More single trees and new hedge structures of varying height and length are introduced, mainly along the ditches, along the embankments and along the main road, visually separating motorized traffic from pedestrian circulation paths. With respect to tradition, and because of the flowering and fruit aspect, new fruit trees were planted close to the farmhouse.
- **Nature conservation:** This scenario was developed by a landscape ecologist of a project partner in the Greenspace consortium from the University of Hohenheim, Germany. It incorporates ideas of a proposed green/wildlife corridor linking Käferberg and neighboring Höggerberg forest that was originally developed by the forestry department of the city of Zürich (Stadtforstamt Zürich) in the early 1990s. Also, a new wetland was established between the two ditches draining the site. As a buffer for the nutrient-poor and rather dry embankments north of the farmhouse towards the forest, new hedgerows were planted. North of the wetland towards the forest a new orchard was established.
- **Wind turbines:** This scenario is based on a project proposal of ETH Zürich. As a symbolic gesture towards renewable energies and sustainable development three light wind turbines of 25 m in height were proposed paralleling the main road. They were located on either side of the central axis of the campus.

The five scenarios were visually represented in one overview scene and via eight ground-level views. The ground-level views provide the impression gained from walking on the trails. The viewpoints were selected with the aim of showing a representative cross-section of the landscape of Käferberg.

4.3. Survey methodology

In order to test responses to the different scenarios a survey was conducted both via a paper-based format and via the Internet. A print version of the survey with all viewpoints and a complete set of 49 images were provided in a face-to-face situation where a representative from the research team was present or as a mail survey (see e.g., Stermerding et al., 1999). The order of the images used in the paper-based survey was randomized for each test person.

The Internet part of the survey was implemented via the php scripting language. This is a widely used general-purpose language that is especially suited for Web development. The scripts generate the HTML pages that were viewed by the subjects. Also, php receives the subjects'



	Ranking	Mean
	web / paper	web / paper

Landscape preference	34 / 25	2.97 / 3.05
Recreation preference	35 / 29	2.95 / 3.02
Nature conservation	31 / 26	2.79 / 3.08

Fig. 5. Scenario recreation.



	Ranking	Mean
	web / paper	web / paper

Landscape preference	11 / 11	3.55 / 3.59
Recreation preference	13 / 17	3.52 / 3.50
Nature conservation	11 / 12.5	3.26 / 3.50

Fig. 6. Scenario nature conservation.

responses and stores them in a format that can be easily interpreted and exported, e.g., to an Excel spreadsheet.

4.3.1. Questionnaire design

The paper-based questionnaire had two sections. The introductory section consisted of a one-page covering letter and an additional page where information about the test person was requested. This included questions on gender, age, location of residence and workplace, frequency of visitation to the site, travel mode and occupation. To provide an impression of the range of images, people were asked to have a quick look through all the images before filling out the questionnaire.

In the main section of the survey, the respondents were asked to indicate their ratings for landscape preference ('How do you like the above landscape?'), recreation preference ('Would you enjoy walking in the above landscape?') and nature conservation ('What value do you think the above landscape has in terms of nature conservation?') by rating a series of 49 color images. All images had horizontal orientation and were provided on separate A4 sheets allowing postcard-sized formats of the picture and high quality reproduction. Below each image, participants were provided with a verbally anchored rating scale ranging from 1 (very low value) to 5 (very high value). Although rating scales with more intervals can be used (e.g., Roth, 2006, who uses a 10-point scale), Miller (1956) points out that too many gradations within a scale make it difficult for test persons to differentiate. By using a five-point scale, each number on the categorical scale corresponds to a verbal description, suggesting an underlying quasi-metric scale (Stadtler, 1980, 1983).

The Internet version of the survey (Fig. 1) was set up in the same style as the paper-based version. To get an impression of the range of images used in the survey, four images were presented as a warm-up (e.g., Reips, 2002). In order to keep the survey short and to reduce the time needed to do the test (important for slow Internet connections), each time a user clicked on the link for the survey a reduced test set of 20 images (600 × 400 pixels in size) was selected randomly from the overall database of 49 images. This procedure allowed us to include all 49 images in the test on the Internet. The survey was designed to take around 15–20 min to complete.

The paper-based questionnaire was produced in the German language only, since the majority of the green space users in Zürich speak German. The online version was made available both in German and in English. This way it was ensured that an international group of persons interested in green space issues could participate in the survey.

4.3.2. Sample frame and sampling procedure

As potential respondents to our survey, the 'Quartiervereine' (community associations) from the direct neighborhood of the site (i.e., Höngg, Wipkingen and Affoltern) were identified. The 'Quartiervereine' are representative groups of active citizens present in each of the city districts. Also, members of the association for protection of local and cantonal heritage took part. These participants were contacted beforehand in order to facilitate a greater response. In addition, walkers were contacted directly at the Käferberg site. Survey forms were also distributed in the university restaurant of the campus ETH Hönggerberg, as this is a very popular place used by people frequenting the site.

The Internet version of the survey was publicized in several online and print media (e.g., *Neue Zürcher Zeitung* NZZ), some of which have a daily readership of over 300,000. In the Internet survey, people from outside Zürich



	Ranking	Mean
	web / paper	web / paper
Landscape preference	46 / 44	2.42 / 2.38
Recreation preference	45 / 44	2.51 / 2.48
Nature conservation	48 / 40	2.25 / 2.77

Fig. 7. Scenario wind turbines.

and even outside Switzerland took part. Nearly 10% of the respondents completed the English language version of the survey.

For neither the paper-based nor the Internet-based parts of the survey were incentives (monetary or otherwise) provided to those who filled out the forms.

4.3.3. Sample characteristics

In total, 90 paper-based questionnaires were distributed of which 55 were returned.

Altogether 358 responses were obtained from the online survey. Most forms were completed correctly, but a few people only gave scores for a small number of images. So as long as the personal data were provided, these forms were included in the analysis. There was about the same number of hits (accesses) on the website that could not be used. These hits produced empty forms where the Internet user only had a quick look at the survey and then left.

Typically, the test took around 10 min to complete, i.e., slightly less than the indication given on the introductory page.

The demographic characteristics evident in the Internet survey confirm the findings of other studies (Höhn et al., 2002; Brenner, 2003) about responses gathered via the Internet. The demographic profile of the Internet users does not represent the general population. In the paper-based survey, the proportion of males and females was nearly equal, while in the Internet survey, about two-thirds were males and only one-third females.

Two hundred and twenty-two respondents via the Internet visit the case study site sometimes or often (category 'local'), whereas 136 Internet respondents never visit the site (category 'non-local'). Fifty-three people taking the paper-based survey can be placed in the category 'local'.

Regarding the expert/lay person categorization, a distinction was made between environmental expert (e.g., biologist, landscape architect, geographer) and built environment expert (e.g., architect, civil engineer). In the paper-based survey 42 lay persons, 1 environmental expert and 8 built environment experts participated. One hundred and twenty-nine lay persons, 88 environmental experts and 17 built environment experts took the Internet-based survey. One hundred and twenty-four test persons could not be assigned to either group as they did not fill out the field concerning occupation.

Note that differences between the distribution of respondent types between the surveys will be taken into account in the statistical analysis which follows by including respondent-specific information as independent variables.

4.4. Statistical methodology

An analysis of variance was conducted in order to test the effects of the different variables and their respective attribute levels in order to see whether socio-demographic background or the test modus influenced the results. For this purpose, the statistical software GenStat 6.2 was used (Harding et al., 2000). Since our data set is unbalanced, we performed our analysis of variance using the regression facilities in GenStat. As we have more than one independent variable, we performed multiple linear regression. There were a large number of potential independent variables to consider when trying to model the response (the dependent variable).

In our (unbalanced) analysis of variance, the order in which terms enter the model is important. It is important to account for the order when interpreting the results, and hence we shall report accumulated analysis of variance tables.

5. Results

5.1. Paper-based survey and Internet-based survey

The mean scores for the paper-based survey ranged from 1.91 to 4.02 for landscape preference, 1.99–4.04 for recreation preference and 2.19–4.00 for nature conservation on the five-point scale. The mean scores in the online survey ranged from 2.07 to 4.04 for landscape preference, 2.16–3.99 for recreation preference and 2.02–3.73 for nature conservation.

The overall tendency for rating the three aspects is fairly similar. One notable exception is the rating for nature conservation in the web-based survey (Fig. 8). There, the values given are almost consistently ca. 0.25 lower, in some cases nearly 0.5 lower (e.g., test images 12 and 43) than the ratings for the other dimensions. A possible cause is that ecological information might be difficult to communicate with images only and needs textual explanation in addition (see Lange, 2005). Also, the web-based survey might have

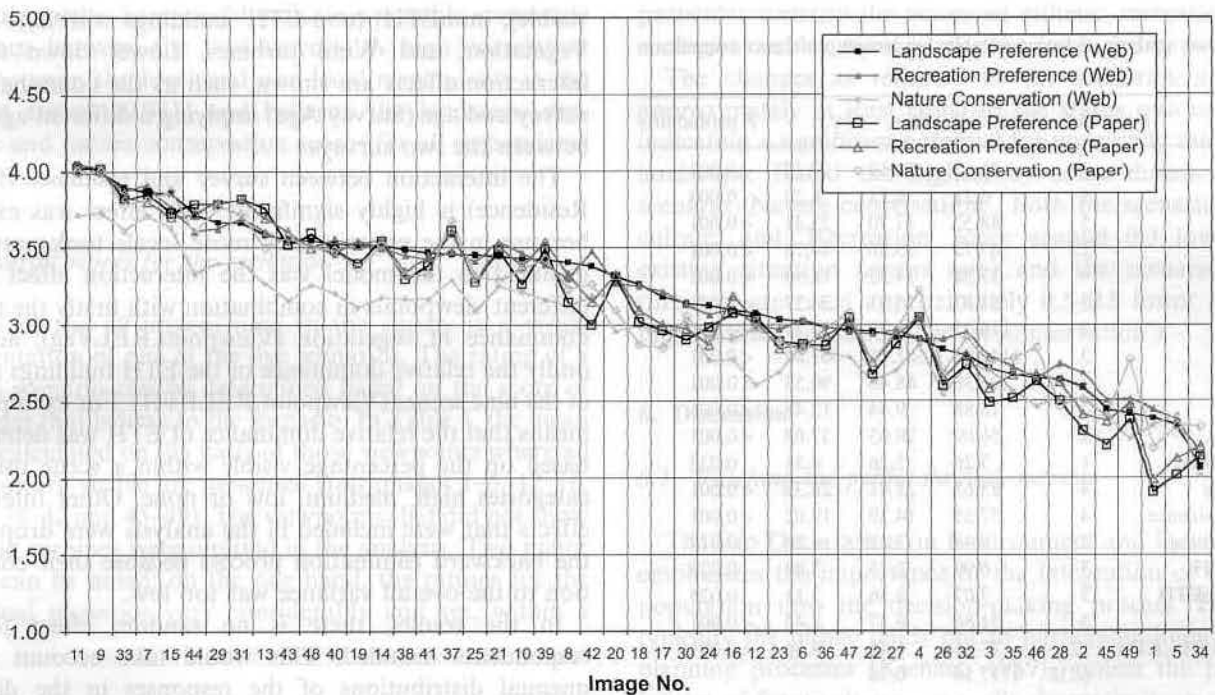


Fig. 8. Rating for the Internet and the paper survey regarding landscape preference, recreation preference and nature conservation.

been influenced by the comparatively high share of participating environmental experts.

As noted previously by Steinitz (1990) and Lange (2001), the standard deviations are relatively low for those images scoring in the high or low ranges.

5.2. Lay persons, environmental experts and built environment experts

There is a tendency that in the higher to middle range of scores lay persons give slightly higher ratings than environmental experts or experts for the built environment. In some cases, the built environment experts provide ratings noticeably different to the environmental experts. For example, an image showing the existing situation with very open landscape in the foreground and ETH and Käferberg forest in the background received a score for landscape preference of 2.39 from the environmental experts, a score of 2.70 from the lay persons and 3.80 from the built environment experts, thereby being among the top-rated images overall.

In contrast, another image showing a richly structured landscape with vegetation elements was rated extremely poorly by the built environment experts (2.00 for landscape preference) compared to a rating of 2.90 by the environmental experts and 3.20 by the lay persons.

5.3. Local vs. non-local

Based on the Internet survey, the influence of familiarity and knowledge of the site was studied. This is because the paper survey was distributed to the local community only.

The answers for the question on how often a person goes to the Käferberg recreation area were grouped into the category 'local' ($n = 222$) if the respondents sometimes or often visit the site, or put into the category 'non-local' ($n = 136$) if they never visit the site.

In terms of landscape preference, the locals almost unanimously scored their green space higher than non-locals (up to around 0.6 on the five-point scale). For questions 2 (recreation preference) and 3 (nature conservation) neither of the two groups displayed a rating pattern that gave much higher scores over the other.

5.4. Analysis of variance

In an accumulated analysis of variance table, the sequential effects of variables, i.e., the order in which they are listed, can be shown. In addition, interactions, i.e., the combination effects of independent variables, can also be assessed. Interactions are represented using the dot operator (Tables 1–3).

The top row of Tables 1–3 shows the headings for the degrees of freedom (d.f.), the sum of squares (s.s.), and the mean square (m.s.). The variance ratio (v.r.) is the ratio of the current row mean square divided by the residual mean square, and theoretically follows an F distribution. The measure of the F probability (F prob) shows the level of significance of the independent variable. Broadly, an effect is considered significant if the value is below 0.05 and highly significant if it is less than 0.01. For clarity, we have performed some backward elimination among the interaction terms, removing those that were not significant.

Table 1
Accumulated analysis of variance table: landscape preference (significant terms)

Change	d.f.	s.s.	m.s.	v.r.	F probability
Survey	1	20.62	20.62	27.27	<0.001
Gender	1	6.21	6.21	8.22	0.004
Age	5	88.52	17.70	23.41	<0.001
Expertise	2	67.72	33.86	44.78	<0.001
Residence	4	57.30	14.32	18.94	<0.001
Visiting	2	51.83	25.91	34.27	<0.001
Animals	3	116.32	38.77	51.27	<0.001
ETH	3	1143.02	381.01	503.84	<0.001
nonETH	3	205.38	68.46	90.53	<0.001
Roads	2	18.88	9.44	12.48	<0.001
Vegetation	2	56.09	28.05	37.09	<0.001
Wind turbines	1	3.26	3.26	4.31	0.038
Survey.Age	4	85.65	21.41	28.32	<0.001
Survey.Residence	4	57.55	14.39	19.02	<0.001
Survey.Visiting	2	6.44	3.22	4.26	0.014
Survey.ETH	3	6.99	2.33	3.08	0.026
Survey.nonETH	3	7.07	2.36	3.11	0.025
Viewpoint	5	31.86	6.37	8.43	<0.001
Viewpoint.RELETH	12	77.41	6.45	8.53	<0.001
Residual	6238	4717.54	0.76		
Total	6300	6825.66	1.08		

Table 2
Accumulated analysis of variance table: recreation preference (significant terms)

Change	d.f.	s.s.	m.s.	v.r.	F probability
Survey	1	10.70	10.70	15.07	<0.001
Gender	1	24.96	24.96	35.16	<0.001
Age	5	85.16	17.03	23.99	<0.001
Expertise	2	46.55	23.28	32.79	<0.001
Residence	4	101.14	25.29	35.62	<0.001
Visiting	2	67.69	33.85	47.68	<0.001
Animals	3	108.40	36.13	50.90	<0.001
ETH	3	927.73	309.24	435.64	<0.001
nonETH	3	187.96	62.65	88.26	<0.001
Roads	2	18.86	9.43	13.29	<0.001
Vegetation	2	45.82	22.91	32.27	<0.001
WindTurbines	1	0.43	0.43	0.60	0.437
Survey.Age	4	59.96	14.99	21.12	<0.001
Survey.Residence	4	66.57	16.64	23.45	<0.001
Survey.nonETH	3	9.64	3.21	4.53	0.004
Viewpoint	5	33.53	6.71	9.45	<0.001
Viewpoint.RELETH	12	74.50	6.21	8.75	<0.001
Viewpoint.RELVeg.	4	9.27	2.32	3.26	0.011
Residual	6180	4387.81	0.71		
Total	6241	6266.70	1.00		

The left-hand column in Tables 1–3 shows the independent variables, added in order to the current model—hence we have an accumulated analysis of variance table. Based on the survey information and on the results of an image analysis, a list of factors with different attribute levels was compiled. These factors are: Survey (paper or web); Gender; Age; Expertise; Residence; Visiting (frequency of visitation); Animals (farm animals); ETH (ETH buildings

visible); nonETH (non-ETH buildings visible); Roads; Vegetation; and Wind turbines. Lower down the list interaction effects are shown, such as the combination of survey and age (Survey.Age) implying a different age effect between the two surveys.

The interaction between survey and residence (Survey.Residence) is highly significant. This effect was expected because in the paper survey more locals took part. Also included in the model was the interaction effect of the different viewpoints in combination with firstly the relative dominance of vegetation (Viewpoint.RELVeg), and secondly the relative dominance of the ETH buildings in each of the nine scenes (Viewpoint.RELETH). For example, this means that the relative dominance of ETH was determined based on the percentage visible within a scene using the categories high, medium, low or none. Other interaction effects that were included in the analysis were dropped by the backward elimination process because their contribution to the overall variance was too low.

In the results, there is no random effect for the respondents included. This would take account of the unequal distributions of the responses in the different categories being looked at between respondents. If a random effect for the respondents had been included, some of the categories that are significant now but show a low sum of squares might become non-significant.

The R^2 is a measure which shows to what degree the variance in the evaluation of the images can be explained by the multiple regression model. It is calculated as follows:

$$\text{Raw } R^2 : \left(1 - \left(\frac{\text{Residual s.s.}}{\text{Total s.s.}} \right) \right) \times 100\%$$

(as used in this case).

Taking into account that the variation in the depicted landscapes in the image set overall is not extreme (for a test set with distinct extremes, see Lange, 2001), a high R^2 was not expected. In the Käferberg study, there is an R^2 of ca. 31% for landscape preference, 30% for recreation preference and 26% for nature conservation. Apart from wind turbines, all listed effects are significant or highly significant (Tables 1–3).

The contribution that a particular effect has on the rating is illustrated by the sum of squares. The factor ETH shows by far the highest sum of squares. It accounts for one-seventh to one-fourth of the total sum of squares. This means that this variable is the most important in explaining the variance of the dependent variables landscape preference, recreation preference and nature conservation. The second most important variable is the factor non-ETH buildings. Of least importance is the variable wind turbines.

Finally, we report some correlations on mean image scores. The Internet survey scores are highly correlated with those from the paper survey (correlation = 0.929), suggesting that, for example, images rated highly in the Internet survey are very likely to be rated highly in the paper survey also; this is reassuring, since a lower

correlation value here would indicate a possible systematic difference between the two surveys. A high correlation exists between the local and non-local respondents in the Internet survey (0.941) and between the landscape preference and nature conservation scores for all respondents (0.970).

5.5. Overall scores for the scenarios

Each of the 49 images used in the survey is a visual representation of one of the five scenarios. The rating of a specific scenario can be determined based on the score of all images that belong to the scenario. In Table 4, the mean values calculated on the basis of those viewpoints where all scenarios are visible are presented (test images 1–5, 12–16, 22–26, 38–42 and 45–49). The viewpoints that did not show the wind turbines were omitted in the analysis. Two major trends can be noted: on the one hand, the ratings for the individual scenarios vary considerably and yet, within a

particular scenario the perceived esthetic, recreational and ecological values show relatively similar rating patterns.

The changes as reflected in the scenarios are rated approximately at least equal to the status quo or higher, indicating a significant potential for improving the existing landscape. Rated the highest by some distance is the scenario 'Nature conservation'. Both the scenarios 'Agriculture' and 'Recreation' score around 0.3 lower. The existing situation (status quo) and the scenario 'Wind turbines' are rated approximately 0.5–0.8 lower than the highest rated scenario ('Nature conservation').

6. Discussion

6.1. Reaching the public through surveys

The Rio Declaration on Environment and Development emphasizes the importance of the integration of the local population into the decision-making process. However, typically the public tends not to participate intensively in planning processes (Kienast, 1989)—unless the potential impact of future changes is really dramatic, such as in the context of hydro-power projects (Lange, 1994), or open-cast mining (Hehl-Lange and Lange, 1999) for example. Even then participation often plays a rather minor role.

Urban green space has been proven to be highly important for human well-being (e.g., Kaplan, 1999), but there is a tendency for the public to take these benefits for granted. In order to raise awareness and to inform and reach a large proportion of the population about our study, we publicized the Internet survey by writing several articles in the mass media. If we had had to pay for equivalent advertising space, the Internet survey would have been very expensive. Contrastingly, the paper-based part of the survey generated considerable extra costs, in particular the printing of color copies and the conversion of data into electronic form.

Several authors have claimed that surveys provided on the web can be a very efficient way to test preferences of a (potentially) large number of people (e.g., Wherrett, 2000; Davies and Laing, 2002; Ulm and Lange, 2002). In our research, publicizing the survey in the mass media was certainly successful. We noticed a tendency for participation in the test to increase considerably just after publication, but to drop to a low level within 2 or 3 days.

Table 3
Accumulated analysis of variance table: nature conservation (significant terms)

Change	d.f.	s.s.	m.s.	v.r.	F probability
Survey	1	33.14	33.14	43.44	<0.001
Gender	1	21.22	21.22	27.81	<0.001
Age	5	122.66	24.53	32.16	<0.001
Expertise	2	106.19	53.09	69.60	<0.001
Residence	4	27.18	6.80	8.91	<0.001
Visiting	2	27.36	13.68	17.93	<0.001
Animals	3	90.77	30.26	39.66	<0.001
ETH	3	659.14	219.71	288.00	<0.001
nonETH	3	224.78	74.93	98.21	<0.001
Roads	2	18.72	9.36	12.27	<0.001
Vegetation	2	40.11	20.05	26.29	<0.001
WindTurbines	1	0.19	0.19	0.25	0.618
Survey.Gender	1	19.66	19.66	25.77	<0.001
Survey.Age	4	73.17	18.29	23.98	<0.001
Survey.Expertise	2	4.60	2.30	3.01	0.049
Survey.Residence	4	32.57	8.14	10.67	<0.001
Survey.Visiting	2	7.66	3.83	5.02	0.007
Survey.nonETH	3	7.46	2.49	3.26	0.021
Viewpoint	5	21.73	4.35	5.70	<0.001
Viewpoint.RELETH	12	85.43	7.12	9.33	<0.001
Residual	6120	4667.78	0.76		
Total	6182	6291.53	1.02		

Table 4
Overall ratings for the five scenarios

Scenario	Landscape preference		Recreation preference		Nature conservation	
	Paper	Internet	Paper	Internet	Paper	Internet
Nature conservation	3.40	3.45	3.40	3.40	3.45	3.20
Recreation	3.11	3.17	3.12	3.15	3.15	2.93
Agriculture	3.01	3.05	3.03	3.06	3.04	2.82
Wind turbines	2.61	2.82	2.72	2.88	2.79	2.63
Status quo	2.63	2.87	2.70	2.87	2.73	2.63

According to our experience, it is clearly not enough just to create a website and then hope to get a high response rate. Without publicity through other (traditional) media channels, the response is likely to be very low.

Even when high numbers of responses can be generated, as in our case, it appears that in Internet surveys generally, young males are over-represented whereas females and older age groups are under-represented. In this particular case, the Internet survey had a high proportion of environmental experts. The so-called expert/lay person paradigm implies that due to their extended knowledge-base, experts of a specific field can submit different rating patterns to lay persons (see Lange, 2001). This pattern is also evident in our findings. We also found that experts of different backgrounds, e.g., environmental expert vs. built environment expert, exhibit different preferences. Furthermore, the knowledge of a landscape is certainly of importance when value judgments are made (see e.g., Buhyoff et al., 1979; Nohl, 1990).

In a sense, our sample of respondents is non-random. However, we have obtained responses from a broad set of people, especially in the paper survey, as detailed earlier. The fact that we have an unbalanced data set is of no importance, since our regression analysis accounts for any imbalance across the independent variables and calculated effects after adjusting for different numbers of respondents in different (for example, age) classes. The analysis of variance suggested factors that are important in forming opinions on landscape, but it should be borne in mind that the figures for the percentage of variation explained (R^2) were typically around 30%; it would be difficult therefore to use our modeling as a basis for making accurate predictions of respondent scores. However, the general trends and the group averages gained through our study can be fed into public policy.

6.2. Judgments on the basis of virtual landscapes

The differentiation by the test persons in the evaluation of the scenarios from the different viewpoints indicates that the test persons did not evaluate the degree of realism of the visualizations when asked for landscape preference, recreation preference and perceived ecological value. Otherwise, the overview visualizations (e.g., Fig. 2) that all have a higher degree of realism (see Lange, 2001; Appleton and Lovett, 2003) because of the relative distance of the viewing position to foreground objects, would have scored much higher. Instead, they received the lowest scores in the survey.

The eight ground-level views are more in the range of medium realism. Here, terrain in the foreground can sometimes appear pixelated. This was noted by some participants in the survey. However, these scenes generally get higher scores. This means that the test persons are able to base their judgments on visualizations with a medium degree of realism. This topic certainly deserves further attention. In the EU research project VisuLands, the role

of different degrees of realism and detail in terms of assessing different landscape characteristics is investigated (Wissen et al., 2005).

Levi and Kocher (1999) state that the widespread use of virtual environments could potentially reduce support for the preservation of local natural environments. This is certainly a danger if people are less and less aware of the real environment. On the other hand, virtual environments can help to envision future landscapes (e.g., Lange and Wissen, 2004; Perkins and Barnhart, 2005; Schofield and Cox, 2005; Stock and Bishop, 2005). In our example, the use of virtual environments in landscape planning could potentially help improve real local environments through the engagement of the public.

6.3. Towards a future landscape

Our case study site is a typical example within the sequential variation of the types of green spaces, from predominantly formal green spaces in city centers to more natural looking green spaces such as forests and farmland at the urban–rural fringe.

In our study, scenarios provide synthetic 3D representations of a real landscape as a visual outline of a spectrum of alternative futures for the landscape at the Käferberg. It is often said that people do not like change. However, our results show that this is not necessarily the case. If it had been, the status quo would have scored higher. Instead, the scenario that changes the landscape the most, the scenario 'Nature conservation' received by far the highest scores. In this scenario, a green corridor linking the Käferberg and Hönningerberg forest can be established, thereby providing improved circulation for wildlife, but also facilitating an improved movement of humans, e.g., through cycling, jogging or walking.

Looking at the scores from the viewpoint of sustainable energy and food production, the two production-oriented scenarios received higher scores (in the case of agriculture) or were at least equal (in the case of wind turbines) in terms of landscape preference, recreation preference and nature conservation value to the existing situation.

MacFarlane (2000) notes that farmers are often tainted with a bad public image and are seen as stumbling blocks on the path to a better rural future. Some reasons for the poor public image can be associated with media coverage addressing genetically modified crops, large scale "factory" farming, use of chemicals, etc. In our case study, the scenario 'Agriculture' can only illustrate a limited range of visual attributes of farming, but the rating provides an indication that the perceived effect of measures taken in the scenario 'Agriculture' is quite positive in terms of esthetics, recreation and nature conservation.

Our findings provide indications for improvement of the existing situation and what measures of landscape planning should be considered for change. It is important to recognize that the 'real' future developed from the

scenarios and their evaluation might not rely on a single scenario, but the actual preferred option could contain elements of several scenarios. These include vegetation elements such as meadows with orchards, single trees, shrubs or more forest. In the lowest-rated scenes buildings are dominant or else the landscape is characterized through a lack of vegetation elements. The importance of visual variation coincides with findings reported in, for example, Axelsson-Lindgren and Sorte (1987) and Hoisl et al. (1987). The planting of new fruit trees and hedgerows would be a practical measure that is easy to realize at low cost in order to improve the existing situation. In a number of countries such measures could even receive subsidies.

7. Conclusion

This study can be seen as a basis for a continuous process of designing and planning a green space at the urban–rural fringe. It lays a broad empirical foundation that is not normally available in landscape planning and it provides an approach that can be pursued if a suitable data set is (or can be made) available and if public interest is raised.

With the virtual landscape model of the Käferberg green space and possible future scenarios at hand, this has the potential to support a prospective approach to planning in a highly creative way. Decision-making could be assisted by exploring different scenarios of landscape change, giving an understanding of a range of possible futures.

Our results suggest that measures for landscape improvement such as planting new fruit trees or hedgerows in most cases will benefit the perceived value of green space qualities not only in one dimension but equally in terms of esthetic, recreational and nature conservation value.

Surveys can be seen as an initial step for participation, in the sense of gaining insight into general attitudes by the public. The important follow-up step (see e.g., Selle, 2005) to put measures into practice could be achieved through a continuous involvement of the public, perhaps by setting up a series of workshops (Lange and Hehl-Lange, 2005), where the public gets the opportunity to directly interact with the planners. Here, further research on the integration of new media in decision-making is needed (e.g., Schroth, 2007).

In our study, Grün Stadt Zürich, the green space department of the City of Zürich, has proposed a “Käferberg Landscape Development Concept”. The principle of landscape development concepts is to pursue a participatory planning approach incorporating the views of the public and to form partnerships to put jointly elaborated measures into practice, while at the same time improving the landscape in terms of ecological, recreational and amenity purposes. Such an approach could then function as the instrumental basis to support the sustainable planning and design of our future landscapes.

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Visual preference and ecological assessments for designed alternative brownfield rehabilitations

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Abstract

This paper describes an integrative method for quantifying, analyzing, and comparing the effects of alternative rehabilitation approaches with visual preference. The method was applied to a portion of a major industrial area located in southern Italy. Four alternative approaches to rehabilitation (alternative designs) were developed and analyzed. The scenarios consisted of the cleanup of the brownfields plus: (1) the addition of ground cover species; (2) the addition of ground cover species and a few trees randomly distributed; (3) the addition of ground cover species and a few trees in small groups; and (4) the addition of ground cover species and several trees in large groups. The approaches were analyzed and compared to the baseline condition through the use of cost-surface modeling (CSM) and visual preference assessment (VPA). Statistical results showed that alternatives that were more ecologically functional for forest bird species dispersal were also more visually preferable. Some differences were identified based on user groups and location of residence. The results of the study are used to identify implications for enhancing both ecological attributes and visual preferences of rehabilitating landscapes through planning and design.

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Keywords: Alternative landscapes; Visual preferences; Cost-surface modeling; Urban forests; Brownfield sites

1. Introduction

There is a growing public awareness of the irreplaceable role of 'nature' in and near the city. Recently, many areas in major industrialized cities have undergone a dramatic transition in human activities and land uses. Significant and rapid changes in industry have resulted in under-utilized lands such as decommissioned industrial areas and abandoned aggregate pits. These lands offer an opportunity to increase the ecological integrity of urban landscapes. Many recent studies have concluded that actions taken on these 'idled' landscapes should involve the use of landscape ecological principles (Hobbs, 1999; Hobbs and Lambeck, 2002; Opdam et al., 2001). Through the lens of landscape ecology, these *brownfield* sites (US-EPA, 1997) could be conceived as elements that are critical to the

composition and configuration of ecosystem patches in urban and periurban contexts (Laforteza et al., 2004).

Remediated brownfield sites may contribute, in conjunction with other landscape elements (De Sousa, 2003), to the creation of an urban landscape mosaic that is more permeable to species. However, rehabilitation sites are often perceived by the public as being messy and unattractive (Hands and Brown, 2002). Although these areas may provide opportunities for landscape planners and designers to apply methods based on landscape ecology, they need to be done in a way that is visually acceptable to the general public. Based on these considerations, this paper describes an integrative method to quantify, analyze, and compare the effects of alternative designed landscape rehabilitation patterns on visual preference, to address the question: *do people visually prefer brownfield landscapes that are more ecologically functional to dispersing species?*

Based on a study conducted by Schroeder and Orland (1994), we expected that visual preference for landscapes

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with many trees would be high, and that people would prefer spatial clumping of habitat patches (more ecologically functional landscapes) over fragmented vegetation.

This paper reports the findings of a case study focusing on part of a major industrial area. Brownfield sites embodying idled or abandoned lands were selected and used to develop alternative approaches to rehabilitation suitable for this area. Such approaches were analyzed and compared using cost-surface modeling (CSM) and visual preference assessment (VPA).

2. Landscape ecology and visual preferences

The idea to integrate landscape ecological principles and methods with socio-cultural needs, like visual preferences, has been the subject of recent research (Hands and Brown, 2002; Schroeder, 1986; Schroeder and Orland, 1994) and projects in landscape planning and designing (Ahern, 1999; Nassauer et al., 2002), but the overlap between the two approaches remains largely untested in the brownfield context.

Brownfield remediation requires special attention to ecological and visual preference effects because these areas are often derelict, undervalued, or misunderstood. In fact, brownfields are described as “*abandoned, idled, or under-used industrial and commercial facilities where expansion or redevelopment is complicated by real or perceived environmental contamination*” (US-EPA, 1997; emphasis added), a definition that incorporates people’s perceptions. In addition, brownfields offer an ecological opportunity because of their relatively large sizes, locations (e.g., along waterfronts, within urban areas, etc.), or patterns of clustered abandoned land.

Several recent studies have suggested that an appropriate approach to the rehabilitation of landscapes to increase the ecological integrity would be through the application of landscape ecological principles (Botequilha Leitão and Ahern, 2002; Hobbs and Lambeck, 2002; Nassauer et al., 2002; Opdam et al., 2001). One way to investigate this relationship would be to analyze the effect of varying landscape patterns on both ecological processes and visual preferences. This could help to establish whether landscape patterns that are more ecologically functional (e.g., enabling flow of species across the landscape) could achieve public approval and/or consensus (i.e., shared perception). As an example, vegetation patterns made up by trees and/or shrubs arranged to ensure appropriate habitat for certain species might attain public disapproval and be difficult to implement. This is because what people perceive as the ‘most attractive’ landscape might be something different from what landscape ecologists advocate as the ‘most functional’ landscape for dispersing species.

The integration between landscape ecology and visual preferences requires these two components to be investigated: landscape ecological patterns are typically assessed using techniques that quantify patterns in relation to processes (e.g., spatially explicit ecological models),

whereas visual preferences are often assessed using simulated photographs along with questionnaires, surveys or interviews (Kaplan and Kaplan, 1989).

2.1. Cost-surface modeling (CSM)

The principles of landscape ecology suggests that large, heterogeneous habitat patches and networks of habitat connections support more biologically diverse plant and animal populations by facilitating species dispersal (Gergel and Turner, 2002; Jongman and Pungetti, 2004). Dispersal allows for gene exchange in meta-populations (Hanski, 1998), range extension of populations, and reduced competition in natal areas (Gadgil, 1971). When applied to human-dominated landscapes (e.g., industrial landscapes), this basic principle requires an ecological understanding of the landscape mosaic to identify larger habitat patches and corridors that may be locally important. CSM is a way to predict species (or energy, or material) movements across the landscape considering: (1) landscape composition and configuration, such as: amount of habitat (source patches), distance between source patches, matrix composition, and (2) behavioral aspects and habitat preferences (a consequence of the friction or resistance of different land-cover types to movement). CSM estimates the minimal or least “ecological cost” to reach a certain spot in the landscape from a source patch or set of source patches (e.g., nest sites) (Adriaensen et al., 2003).

In applicative terms, this approach involves the assignment of an impedance value representing the relative permeability (or resistance per unit-distance) to moving through a given land cover for a particular ecological entity (Corry and Laforteza, 2007; Laforteza and Brown, 2004). Friction values are preferably based on empirical data, or else on expert knowledge of a particular species or guild of species (Chardon et al., 2003).

The outcome of the CSM is a *cumulative cost-surface map* that is demonstrative of the ‘effective geographical distance’ that separates landscape elements supporting species dispersal or other ecological processes. Through CSM analysis, patterns of dispersal impedance could be compared for various planning and design options that may have negative effects on animal dispersal by interrupting travel corridors, destroying habitat, or causing direct mortality (Knaapen et al., 1992; Shippers et al., 1996).

2.2. Visual preference assessment (VPA)

Generally described, landscapes are made and shared by society and reflect the changing social and cultural attitudes towards the environment (Antrop, 1993; Lynch, 1971). Landscapes are therefore more than mere assemblages of spatial elements; cultural identity and human perception constitute essential parts of the whole paradigm as they motivate the scope of planning, design, and management.

In the recent past, studies of landscape preference have become widely used in landscape research with emphases at both coarse and fine scales of analysis/intervention (Hands and Brown, 2002; Steinitz, 2003; Tress and Tress, 2003). Determining visual preferences of human observers for various landscape elements and for the landscape as a whole is crucial to an efficient planning and designing process (see Hehl-Lange, 2001; Lange, 2001; Misgav, 2000).

Visual preferences are commonly assessed using photographs associated with questionnaires, surveys, or interviews. Photographs may represent landscapes as they currently appear (without intentional alterations) or provide visual simulations of prospective landscapes as a consequence of alternative planning and designing options.

While the most commonly highly preferred landscapes have typical savanna-like qualities (Appleton, 1975), preference is also clearly linked to neatness, order, and care (Nassauer, 1995). However, landscapes that have been remediated to be more ecologically functional are often perceived as messy and unkept (Gobster, 1994; Hands and Brown, 2002; Nassauer, 1997).

In order to learn if preferences are linked to ecological functions, the extraneous variables of neatness, order, and care must be controlled while only the landscape pattern varies. Landscape pattern refers to the composition and configuration of ecosystems across broad areas (Turner et al., 2001). As landscape pattern varies, the composition and configuration of ecosystems changes to affect ecological functions and possibly visual preferences.

Landscape ecology has, since its beginning, been founded on the premised link between pattern and process (Risser et al., 1984). The location, shape, size, and proximity of habitat patches are therefore important attributes for understanding the flow of species across

landscapes (Forman and Godron, 1986), and empirical research continues to develop this understanding (Wu and Hobbs, 2002). Taking into account the stimulus–reaction generated by such attributes on human observers will contribute to expanding this knowledge.

3. Methods

This investigation used ecological models and social science methods to learn if there exists a relationship between landscape patterns and visual preferences in the context of brownfields rehabilitation.

3.1. Study site

A major industrial area located at the edge of the city of Bari, Italy (Fig. 1) acted as a baseline landscape for this investigation. The area of study covers approximately 1410 ha (Fig. 2). In the study area, more than 630 ha (45%) are covered by: industrial units still in use (161 ha), paved areas annexed to industrial units (328 ha), and transport network (143 ha) (see Table 1). Abandoned or under-used brownfields, cover approximately 80 ha (6%), whereas ‘greenfields’ (i.e., sparsely vegetated areas and open spaces) cover nearly 257 ha (18%). The study area also contains extensive olive plantations (17%), urban green spaces (3%), and two forest patches (sclerophyllous vegetation, Fig. 2) covering about 10 ha (less than 1%).

This area is under the guidance of the local industrial corporation (*Consorzio Sviluppo Industriale-Bari; CSI-Bari*) that co-ordinates the development of new facilities and infrastructures serving as basic elements for industrial activities and logistics. In co-operation with the Urban and Town Planning offices of the Bari and Modugno municipalities (the area of study covers portions of these towns),

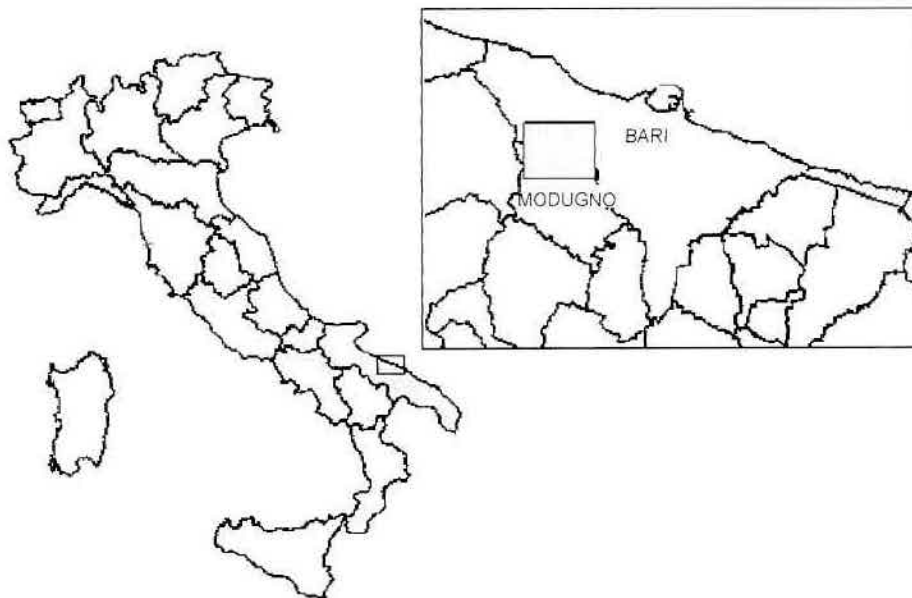


Fig. 1. Location of the study area.

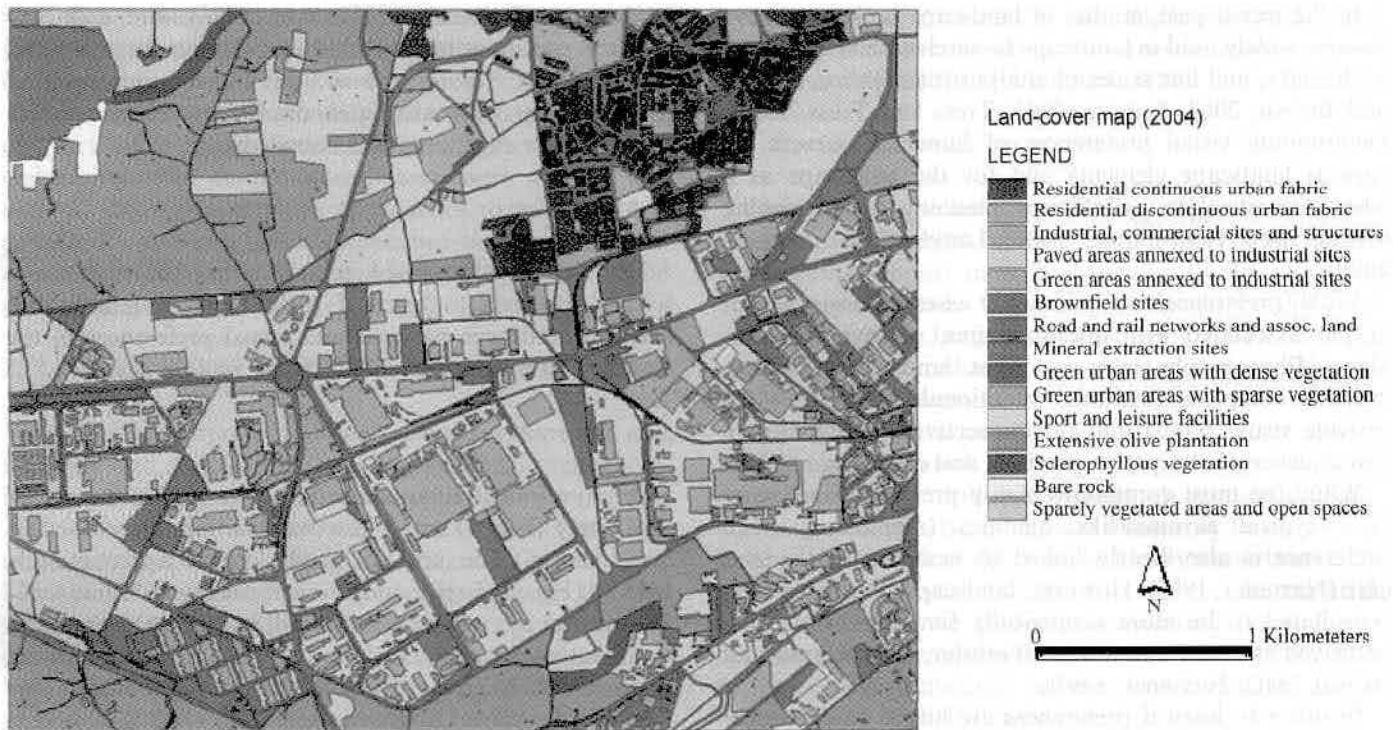


Fig. 2. Land-cover map of the study area.

the industrial corporation supervises the rehabilitation of brownfield sites, turning them into industrial units or green spaces depending on the site characteristics, position, and industry demand (e.g., expansion of existing industries).

3.2. Alternative designed patterns

Four different alternatives were designed for rehabilitation: *alternative 1*, cleanup of brownfields plus ground cover species; *alternative 2*, cleanup of brownfields plus ground cover species and a few trees (5–7 trees) randomly distributed; *alternative 3*, cleanup of brownfields plus ground cover species and a few trees (5–7 trees) in small patches; *alternative 4*, cleanup of brownfields plus ground cover species and several trees (>8 trees) in larger patches (Fig. 3).

With the term “cleanup” we intended all the practices required to de-contaminate brownfields to tolerable limits. This process commonly involves excavating and removal of contaminated soil and sludge, and pumping and treating near-surface water. On the other hand, planting ground cover species and trees necessitate soil preparation (e.g., soil aeration, soil biochemical activity, percolation of water, pH regulation, nutrient application, etc.) and vegetation establishment (e.g., plant selection, maintenance, etc.).

In consultation with the CSI-Bari, plausible examples of designed rehabilitation alternatives were developed for this area. Brownfield sites were identified following the specifications brought by the CSI-Bari, thus considering

those that have the potential to be turned into ‘greenfields’ by ground cover species or trees.

Alternatives were designed to represent vegetation patterns of increasing landscape ecological functionality: larger vegetation patches (as in *alternative 4*) tend to support more suitable habitats for a wider range of species (such as those preferring connected tree canopies), and are more likely to be intercepted and colonized by dispersing species (e.g., Lindenmayer et al., 2000; Schultz and Crone, 2005).

Alternatives were then analyzed and compared over the baseline condition using CSM and VPA.

3.3. Cost-surface modeling

In the CSM analysis, each land-cover type has been assigned a friction value (the so-called ‘cost’) representing the relative permeability or resistance to moving through that land cover for a particular species or guild of species. In this study, we based friction values (ranks from 1 to 5) on both expert and literature-based knowledge of species representative of a target group like forest passerines: Saridinia Warbler (*Sylvia melanocephala*), Blackcap (*Sylvia atricapilla*), Eurasian Jay (*Garrulus glandarius*), European Goldfinch (*Carduelis carduelis*), European Greenfinch (*Chloris chloris*), and Great Tit (*Parus major*). In urban landscapes, these birds commonly occur in scattered and small forest fragments (i.e., urban forests) of mainly holm oaks (*Quercus ilex*) and pines (*Pinus* spp.) (Fernández-Juricic, 2004).

Table 1
Friction values (i.e., cost) assigned to land cover classes

Land cover class (class code)	Total area (ha)	%	Baseline	Alternative approach			
				1	2	3	4
Residential continuous urban fabric (1.1.1.0)	52.70	3.73	5	5	5	5	5
Residential discontinuous urban fabric (1.1.2.0)	10.02	0.71	4	4	4	4	4
Industrial, commercial sites and structures (1.2.1.1)	160.60	11.38	5	5	5	5	5
Paved areas annexed to industrial sites (1.2.1.2)	328.29	23.25	5	5	5	5	5
Green areas annexed to industrial sites (1.2.1.3)	62.29	4.41	3	3	3	3	3
Brownfield sites (1.2.1.4)	79.88	5.66	5	4	3	2	1
Road and rail networks and assoc. land (1.2.2.0)	143.24	10.15	4	4	4	4	4
Mineral extraction sites (1.3.1.0)	24.57	1.74	5	5	5	5	5
Green urban areas with dense vegetation (1.4.1.1)	11.66	0.83	2	2	2	2	2
Green urban areas with sparse vegetation (1.4.1.2)	28.90	2.05	3	3	3	3	3
Sport and leisure facilities (1.4.2.0)	4.01	0.28	4	4	4	4	4
Extensive Olive plantation (2.2.3.1)	233.06	16.51	3	3	3	3	3
Sclerophyllous vegetation (3.2.3.0)	10.28	0.73	1	1	1	1	1
Bare rock (3.3.2.0)	5.36	0.38	3	3	3	3	3
Sparely vegetated areas and open spaces (3.3.3.1)	256.97	18.20	2	2	2	2	2
Total	1411.84	100					

In operative terms, each rehabilitation alternative was generated by assigning decreasing values of friction to land-cover types labeled as “brownfields” (Table 1): in the *baseline condition*, brownfields were assigned a friction value of 5 (very low suitability); in *alternatives 1–4*, brownfields were assigned friction values of 4 (low suitability), 3 (moderate suitability), 2 (high suitability), and 1 (very high suitability), respectively. The friction value assigned to land-cover classes different from brownfields remained constant over the four alternatives. The assignment involved considerations on how land-cover types might facilitate or impede dispersal of forest passerines in the area of study.

Cost-surface maps were then computed for the five landscapes (baseline plus four alternatives) considering forest patches as “source areas” for passerines. The higher the level of connectivity among these patches, the higher the probability that dispersing species can successfully disperse to these patches.

Because friction values were assigned according to design, CSM rank outcomes are mathematically predictable (Corry and Laforteza, 2007; Laforteza et al., 2005). Nevertheless, differences among CSM maps were analyzed statistically: 1000 randomly generated points were used to extract the corresponding CSM class (five classes from very low resistance to very high resistance with equal intervals) from each CSM map, with three iterations. A one-way ANOVA with repeated measures was performed to test differences among mean values of CSM considering: (1) rehabilitation approach (or alternative brownfield design), expressed in terms of friction value as independent variable, and (2) resistance category, expressed in terms of CSM class as dependent variable.

Normal probability plots and Levene’s test revealed no substantial deviation from normality and homogeneity of variance, thus the use of this parametric test was justified.

As null hypotheses (H_0) for the CSM analysis, we stated that alternative brownfield designs will not provide significantly improved measurements of landscape pattern (expressed in terms of CSM) than those without as much diverse vegetation.

3.4. Visual preference assessment

For five replicate brownfields within the area, selected in an opportunistic way (within the group of sites spatially identified in Fig. 2), digital photographs were taken in January 2005. Photographs are representative of typical brownfield scenes, embodying idled or abandoned lands that have spontaneous ruderal vegetation, irregular terrain, and disturbed substrate (Fig. 3). Photographs were taken from common viewpoints such as streets and sidewalks. Digital photographs were then used to create simulations of each alternative rehabilitation design for the five replicates with a combination of Adobe PhotoShop® and Art-lantis® rendering software. The vegetation simulated in photographs is typical of this context and was described both visually and verbally during data collection. We intentionally avoided the inclusion of vegetative elements such as shrubs, rows of plants with attractive flowers, and other independent variables as these could divert the scope of the VPA: evaluating the preference of different vegetation patterns. When implemented, alternatives will have additional design elements like undergrowth vegetation and more heterogeneous ground cover species.

Manipulated images were printed at 21 cm × 30 cm dimensions in color. Five photos, representing an ordered sequence of alternatives (for each brownfield site, were displayed on 84 cm × 119 cm poster paper.

We sought the most highly impacted respondents for the VPA. Respondents for the survey were identified by a list of industries provided by the local industrial corporation

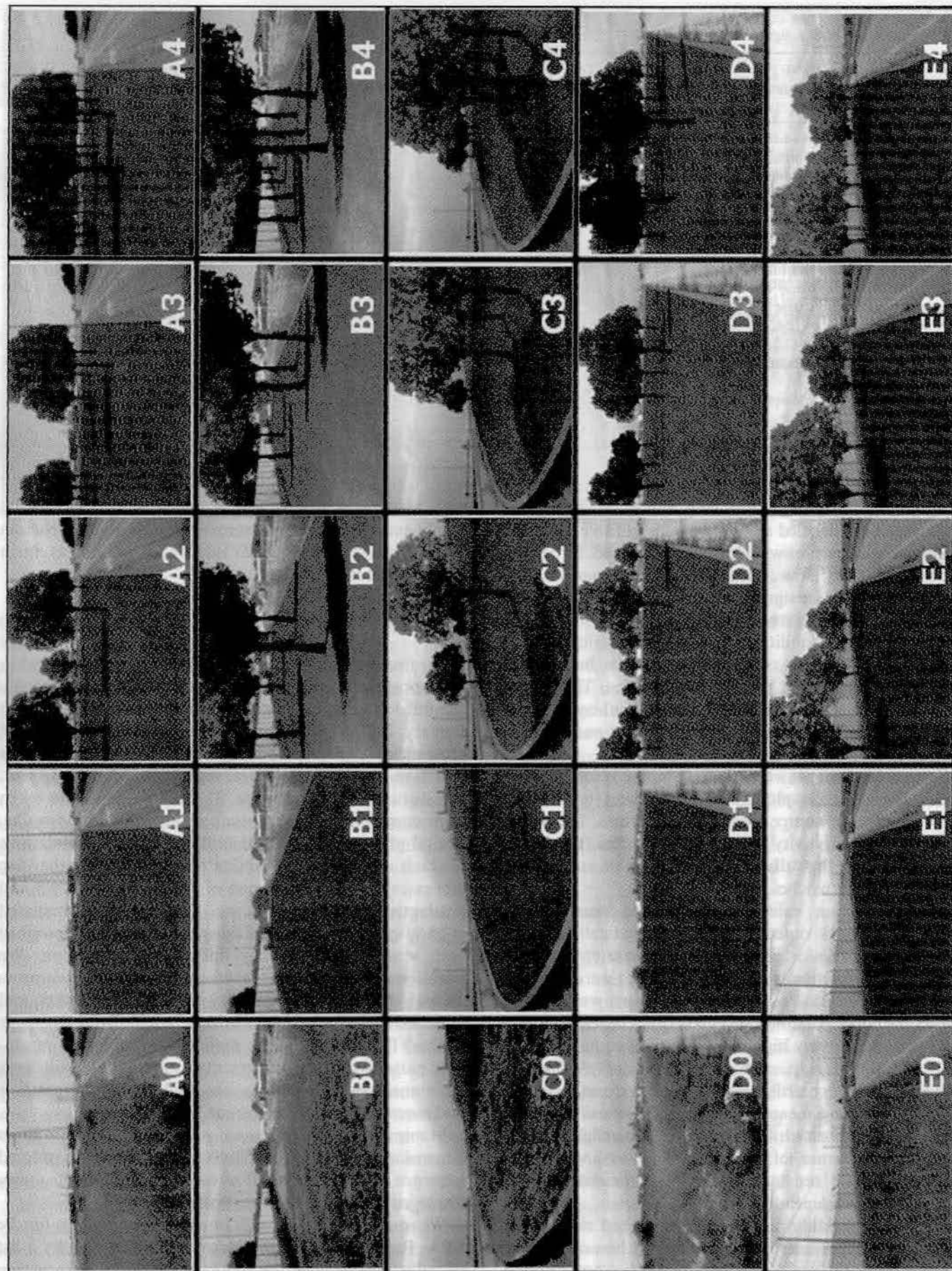


Fig. 3. Alternative design patterns for brownfields rehabilitation. Replicates are identified by letters (e.g., A); alternatives by numbers (e.g., 3).

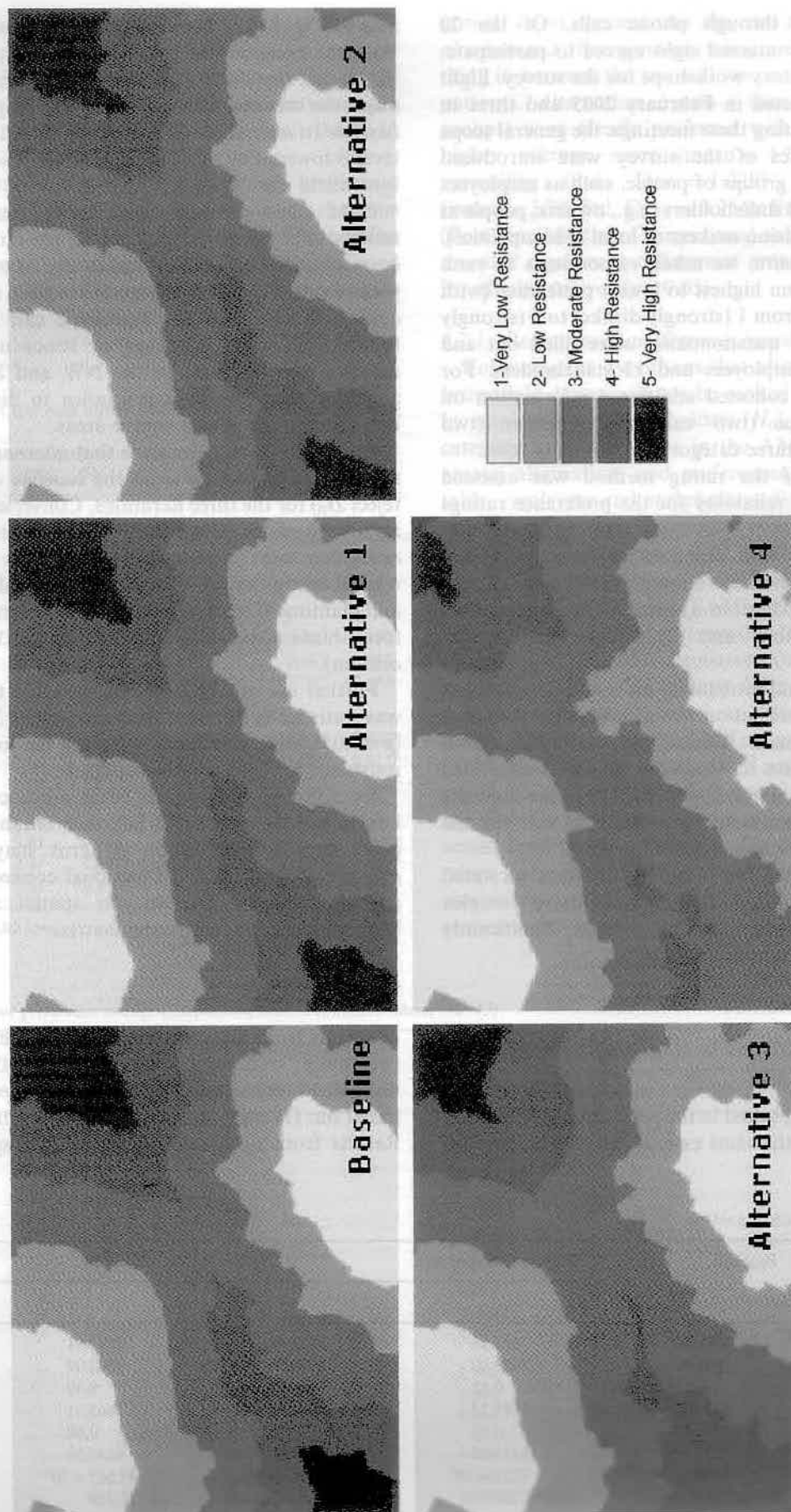


Fig. 4. Cumulative cost lattices for the five landscapes (baseline plus four alternatives) and the corresponding legend.

and then contacted through phone calls. Of the 20 industries that were contacted eight agreed to participate, thus hosting participatory workshops for the survey. Eight meetings were conducted in February 2005 and three in early March 2005. During these meetings, the general scope and specific objectives of the survey were introduced (verbally) to different groups of people, such as employees of local industries and stakeholders (e.g., owners, people at the CSI-Bari, and decision makers of local municipalities). Through a questionnaire, we asked respondents to rank alternative designs from highest to lowest preference (with no ties) using a scale from 1 (strongly dislike) to 5 (strongly like). A total of 127 questionnaires were filled out and collected from 114 employees and 13 stakeholders. For each respondent, we collected additional information on location of residence (two categories), gender (two categories), and age (three categories).

The consistency of the rating method was assessed computing inter-rater reliability for the preference ratings of respondents.

One-way ANOVA with repeated measures was performed to test differences among preference ratings considering: (1) rehabilitation approach (i.e., alternative) as independent variable; and (2) visual preference as dependent variable.

In some cases, normal probability plots and Levene's test revealed substantial deviation from normality and not homogeneity of variance. Although research has shown that ANOVA is robust to violations of its assumptions (e.g., Aron and Aron, 1994; Lindman, 1974), we used the Kruskal–Wallis nonparametric procedure to test for the significance of the difference between groups.

As null hypotheses (H_0) for the VPA analysis, we stated that alternative brownfield designs with more complex vegetation patterns will not be ranked significantly different by respondents.

4. Results

4.1. CSM results

The CSM analysis resulted in the generation of five CSM maps (Fig. 4) having the same extension as the land-cover

map in Fig. 2. CSM outcomes are summarized in Table 2. With the exception of few variables (e.g., minimum CSM value) that remain constant over the five *cumulative surface maps*, the other statistics exhibit decreasing trends from the *baseline* to *alternative 4*. Dispersal impedance at landscape level is lowered by decreasing values of friction assigned to brownfield sites.

CSM maps provide visual indications of the spatial relationship of habitat patches in the landscape. Patches corresponding to lighter zones are those with a high potential to support focal-species in their movements. The current situation in the landscape can be described as follows: (1) poor incidence of zones of relatively low resistance to dispersal in the NW and SE portions; (2) zones of relatively high resistance to dispersal centrally between the two major source areas.

Results in Table 3 indicate that *alternatives 1 and 2* did not differ significantly from the *baseline condition* (fail to reject H_0) for the three iterations. Conversely, *alternatives 3 and 4* provided significant decrements of *cumulative resistance* over the baseline condition (reject H_0); a rehabilitation design of brownfields based on site cleanup and planting of trees in groups could potentially ameliorate forest-birds dispersal in this landscape (theoretical amelioration).

Further use of ANOVA demonstrated that *alternative 4* was statistically different from *alternative 3* in all iterations ($p < 0.05$), with *alternative 4* having the lowest cumulative resistance for forest-birds dispersal.

Even though brownfields cover a limited portion of the landscape (6%; approx. 80 ha), their rehabilitation towards more complex vegetation patterns may contribute to enhance the spatial and functional connectivity of source patches. This is due to the spatial arrangement of brownfields in the landscape matrix.

4.2. VPA results

Results from the VPA analysis have been organized into two main sections corresponding to the influence of brownfield rehabilitation design on preference ratings based on: (1) user category, and (2) location of residence. Results from other group factors like age category and

Table 2
Summary statistics for the CSM analysis

Statistical measure	Baseline	Alternative approach			
		1	2	3	4
Mean	3718.07	3698.21	3652.44	3517.81	3241.62
Median	3669.00	3653.00	3610.00	3502.00	3294.00
Std. error of mean	0.53	0.53	0.52	0.49	0.44
Std. deviation	2007.49	1995.22	1964.55	1865.51	1663.15
Minimum	0.00	0.00	0.00	0.00	0.00
Maximum	8477.00	8421.00	8289.00	8285.00	7507.00
Sum	5249×10^6	5221×10^6	$51,566 \times 10^6$	$49,665 \times 10^6$	$45,766 \times 10^6$
Count	14,118,359	14,118,359	14,118,359	14,118,359	14,118,359

gender were not included because of the lack of implications for the scope of this paper.

As shown in Table 4, the rating method in the survey provided reliable responses (both within and between user groups) with Cronbach's alpha ranging from 0.634 to 0.880.

Table 5 illustrates descriptive statistics of preference ratings gained by showing 25 photos: 5 control (baseline conditions) plus 20 simulated (alternatives). The *baseline condition* (the current landscape) was the lowest preferred situation among alternatives; *alternative 1* (cleanup plus

ground cover species) was also not much preferred, while *alternative 2* (few random trees) was perceived as something in between the less and the more complex vegetation patterns. *Alternatives 3* and *4* (few and several trees in groups) were clearly preferred with *alternative 4* having higher average score (mean = 4.21) but also higher variability (Std. Dev. = 1.028) than *alternative 3* (mean = 3.90; Std. Dev. = 0.754). Further use of ANOVA (Post Hoc-Multiple Comparison) and Kruskal–Wallis Test revealed significant differences among preference ratings for all alternatives ($p < 0.05$).

Table 3
ANOVA analysis of CSM rank outcomes for the three iterations (baseline condition)

Alternative	N	Mean	Std. Dev.	Std. error	F test	Sig.
<i>Alternative 1</i>						
1	1000	2.74	1.202	0.038	0.028	0.867
2	1000	2.73	1.191	0.038	0.051	0.921
3	1000	2.70	1.166	0.037	0.106	0.745
<i>Alternative 2</i>						
1	1000	2.71	1.186	0.038	0.617	0.432
2	1000	2.71	1.175	0.037	0.487	0.485
3	1000	2.66	1.145	0.036	1.045	0.453
<i>Alternative 3</i>						
1	1000	2.60	1.089	0.034	8.640	0.003*
2	1000	2.62	1.103	0.035	5.902	0.013*
3	1000	2.57	1.072	0.034	8.675	0.003*
<i>Alternative 4</i>						
1	1000	2.41	0.968	0.031	46.937	0.000*
2	1000	2.47	1.009	0.032	31.331	0.000*
3	1000	2.41	0.950	0.030	41.646	0.000*

*Significant at the 0.05 level.

Table 4
Reliability statistics of preference ratings (Employees, No. 114; Stakeholders, No. 13)

Observation	No. of items	Cronbach's alpha	Summary item statistics (mean values)		
			Item mean	Item variance	Inter-item covariances
<i>Baseline</i>	5	0.782	1.010	0.014	0.007
Employees		0.782	1.011	0.015	0.007
Stakeholders		—	1.000	—	—
<i>Alternative 1</i>	5	0.801	2.414	0.788	0.352
Employees		0.788	2.400	0.759	0.323
Stakeholders		0.874	2.538	1.087	0.631
<i>Alternative 2</i>	5	0.657	3.474	0.773	0.214
Employees		0.659	3.461	0.770	0.215
Stakeholders		0.667	3.585	0.785	0.224
<i>Alternative 3</i>	5	0.634	3.898	0.570	0.146
Employees		0.634	3.898	0.570	0.146
Stakeholders		0.859	3.938	0.723	0.397
<i>Alternative 4</i>	5	0.816	4.206	1.047	0.491
Employees		0.816	4.206	1.047	0.491
Stakeholders		0.880	3.938	1.226	0.730

Table 5
Descriptive statistics of preference ratings considering answers from all replicates

Observation	No.	Mean	Std. Dev.	Std. error	95% Confidence interval for mean		Minimum	Maximum
					Lower bound	Upper bound		
Baseline	635	1.01	0.105	0.004	1.00	1.02	1	3
Alternative 1	635	2.41	0.893	0.035	2.34	2.48	2	5
Alternative 2	635	3.47	0.879	0.035	3.41	3.54	1	5
Alternative 3	635	3.90	0.754	0.030	3.84	3.96	1	5
Alternative 4	635	4.21	1.028	0.041	4.13	4.29	1	5
Total	3175	3.00	1.414	0.025	2.95	3.05	1	5

Table 6
One-way ANOVA and Kruskal-Wallis Test of preference ratings

Observation	Group factor	Category	No.	Mean	Std. Dev.	Std. Error	ANOVA		Kruskal-Wallis Test	
							F	Sig.	χ^2	Asymp. Sig.
Baseline	User	Employees	114	1.01	0.111	0.005	0.409	0.523	0.458	0.498
		Stakeholders	13	1.00	0.000	0.000				
	Location	< 30 km	107	1.01	0.114	0.005	0.670	0.413	0.751	0.386
		> 30 km	20	1.00	0.000	0.000				
Alternative 1	User	Employees	114	2.40	0.878	0.037	1.402	0.237	0.869	0.351
		Stakeholders	13	2.54	1.017	0.126				
	Location	< 30 km	107	2.42	0.906	0.039	0.087	0.768	0.187	0.666
		> 30 km	20	2.39	0.827	0.083				
Alternative 2	User	Employees	114	3.46	0.877	0.037	1.146	0.285	1.188	0.276
		Stakeholders	13	3.58	0.900	0.112				
	Location	< 30 km	107	3.51	0.895	0.039	5.821	0.016*	7.763	0.005*
		> 30 km	20	3.28	0.766	0.077				
Alternative 3	User	Employees	114	3.89	0.743	0.031	0.212	0.645	0.413	0.520
		Stakeholders	13	3.94	0.846	0.105				
	Location	< 30 km	107	3.91	0.758	0.033	0.693	0.405	0.248	0.619
		> 30 km	20	3.84	0.735	0.073				
Alternative 4	User	Employees	114	4.24	1.017	0.043	4.946	0.026*	5.225	0.022*
		Stakeholders	13	3.94	1.088	0.135				
	Location	< 30 km	107	4.15	1.040	0.045	9.156	0.003*	11.447	0.001*
		> 30 km	20	4.49	0.916	0.092				

*Significant at the 0.05 level.

4.2.2. Respondents' preferences based on location of residence

In order to assess the influence of rehabilitation approaches on visual preferences based on location of residence, we arranged locations into two main classes depending on the traveling distance to work (along main roads): cat. 1 ≤ 30 km; cat. 2 > 30 km. In the specific context of analysis, these two categories can be assumed to be representative of "close" and "far" distance locations of residence.

From Table 6, it can be noticed that differences among respondents' preferences based on location of residence are: not significant in the case of *baseline condition*, *alternatives 1* and *3* (fail to reject H_0), and significant ($p < 0.05$) in the case of *alternatives 2* and *4* (reject H_0). The Kruskal–Wallis Test confirms these findings (Table 6).

People coming from distant locations (mainly small towns and villages) appear to be more attracted to complex vegetation patterns (i.e., several trees in large groups as in *alternative 4*) and less attracted to only few trees randomly distributed (*alternative 2*) than people living at close distance (mainly major cities). This could be explained considering the relationship with 'nature' and, specifically, with forest trees that people living in small towns and villages (countryside) traditionally have.

5. Discussion

5.1. Integration of ecological function and visual preferences

The integration of visual preference and ecological assessments for designed alternative brownfield rehabilita-

tions indicated that complex patterns of vegetation (trees in groups) were needed in order to strengthen structural and functional connectivity (as measured by CSM) as well as people's visual preferences of the landscape. Rehabilitation designs based on several trees in large groups appeared as feasible solutions for enhancing both ecological attributes and visual preferences for such rehabilitating landscapes.

In terms of ecological function, *alternatives 3 and 4* provided significantly improved measurements of dispersal impedance over the baseline condition, meaning that brownfield sites constitute relevant patterns at landscape-spatial scale as well as potential pathways (e.g., corridors and stepping stones) for species and habitat connections. In absolute terms, *alternative 4* had the highest performance for the process under consideration.

In terms of visual preferences, *alternatives 1–4* were significantly preferred by respondents over the baseline condition. Rehabilitation approach and visual preference were dependent: the higher the level of complexity of vegetation within each rehabilitation approach, the higher the visual preference of respondents. In absolute terms, *alternative 4* was the most preferred by respondents. However, such approach to rehabilitation led to some contrasting opinions in visual preference among stakeholders whose involvement in the planning and designing is of utmost importance for the success of these processes (Tress and Tress, 2003).

5.2. Limitations

The findings of this paper are based on a case study application and caution should be placed in generalizing results to other locations having different composition and spatial configuration of landscape elements. In order to explore the overlapping between landscape ecological principles and visual preferences, the study employed two different analytical methodologies, each with inherent data modeling and management limitations.

The cost-surface methodology involves numerical manipulations of landscape elements that are ranked based on facilitation or hindrance properties for a specific species or guild (Adriaensen et al., 2003). Setting appropriate criteria to appraise such properties is therefore a crucial step as this could limit the applicability of the model. In the context of this study, the assignment involved considerations on behavior aspects and habitat preferences of species representative of forest passerine group. Further investigation and testing were not conducted as these were out of the scope of this paper and could be the subject of future research studies.

The VPA conveys the assumption that (manipulated) images are representative of both the site experience of the scene and the rehabilitation design simulated. In creating alternatives, we sought to generate stimulus–reactions to vegetation patterns (i.e., spatial clumping vs. fragmented vegetation), thus controlling for other additional design elements. Despite images and visual preferences were limited by the lack of such elements (e.g., undergrowth vegetation), they created perceptions of realism with subtle

shading, texture details, colors, tones, and viewpoints. In further application, other vegetation should be introduced and kept constant across scenes.

Stimulus–reactions were generated by showing a sequence of alternatives (from *baseline* to *alternative 4*) to observers. This may have introduced a bias into the ratings. In addition, images were taken during the winter season (January 2005) and likely were less appealing than images taken later in the spring. Further investigation and testing should include random presentation of alternatives and seasonal images of brownfield sites.

Results from the VPA find a limitation in the number of *stakeholders* that were interviewed. Only 13 *stakeholders* were involved in the survey because, in the area of study, rehabilitation plans are undertaken by these people. These plans may impact on ecological patterns and people's perceptions of the landscape.

5.3. Implications for planning and designing brownfield rehabilitation

This research has demonstrated that patterns of aggregated vegetation, in addition to having potential positive effects on dispersing populations of target species, can significantly improve visual preference. Trees in groups are needed in order to provide stepping-stones for forest specialists in urban-fragmented landscapes, but also to ameliorate the visual appearance of rehabilitating landscapes. Landscape planners, designers and managers can expect that increasing the aggregation of habitat patches in the brownfield context will increase visual preference.

Based on the results of this study, implications for planning and designing brownfield rehabilitation can be summarized as follows: (1) brownfield sites should be analyzed at the landscape scale in order to understand their spatial arrangement and the locations of neighboring patches and corridors (i.e., greenfields) that may be locally important; (2) spatially explicit ecological models (like CSM) should be used to predict dispersal pathways of species moving through the intervening landscape matrix; (3) spatial clumping of habitat patches are preferred over disaggregated vegetation in order to add ecological and visual benefits to the rehabilitating sites.

However, where brownfield sites (especially soils and water) have been contaminated, connecting habitat patches or corridors could bring wildlife in contact with water or plants that contain contaminants. In such a situation, maintaining separation will reduce the risk of transport of contaminants by wildlife. Thus there may be cases where reducing the connectedness (i.e., increasing the dispersal resistance) among potentially contaminated and 'clean' sites is advisable.

6. Conclusions

The way landscapes change has to do with many driving factors that operate synergistically. Socio-economic and

policy factors are those that predominate (especially in the developed world) in the process of shifting land mosaics from one time to another, thus influencing characteristics like composition and configuration of landscapes. Establishing a temporal scale of reference is therefore a prerequisite to understand consequences of land-use policies and plans on current landscapes as well as on alternative development patterns. When considering landscapes in a future time scale, simulating landscapes is a practical technique enabling planners and designers to create 'images' of a range of plausible alternatives in a given ecological and cultural context.

In this paper, we used scenario techniques to simulate alternative brownfield rehabilitation designs. Our results show that ecological functions like forest-birds dispersal and visual preference can be aligned for brownfield rehabilitation: alternatives that were more ecologically functional (e.g., alternatives 3 or 4) were also more visually preferable. Some differences were apparent for different stakeholder groups, but in general we found that visual preference and cost-surface measures ranked the alternative approaches similarly. The most direct way to enhance visual preference is therefore by changing the baseline conditions to an alternative land cover that is more orderly and suitable to dispersing species.

The findings of this study could equally well imply which brownfield sites should be remediated to the highest standards and re-vegetated to approach habitat-patch conditions. Brownfields that can significantly contribute to ecological functionality and visual preference could be targeted for intensive and complete remediation (e.g., alternative 4) whereas brownfields that cannot contribute significantly to ecological permeability could be cleaned to industrial standards and re-used as new industrial sites or could be re-vegetated with species that are less attractive to target species (e.g., alternative 1).

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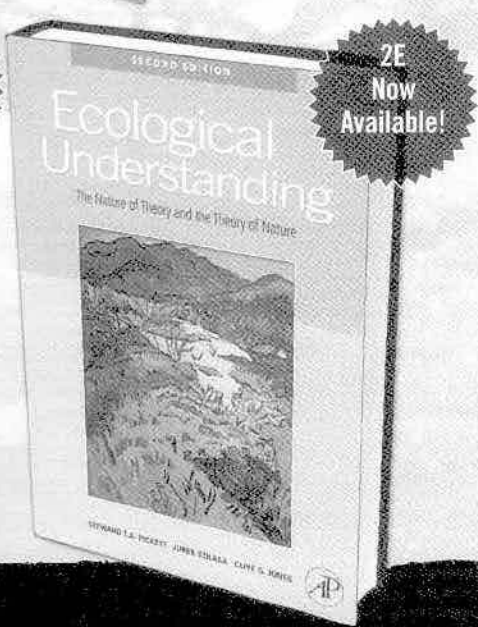
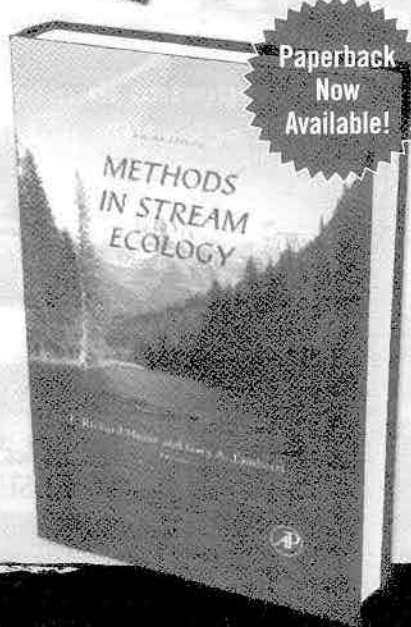
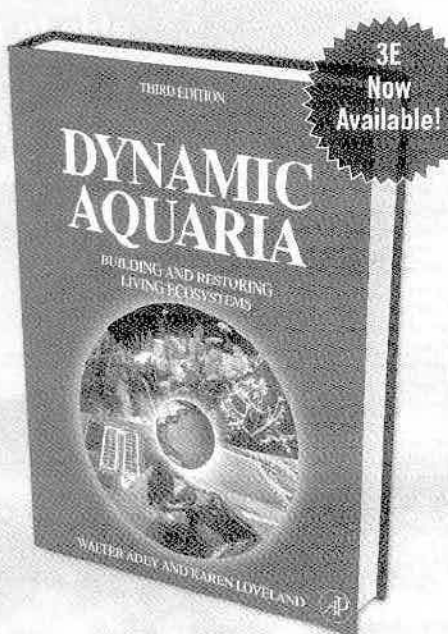
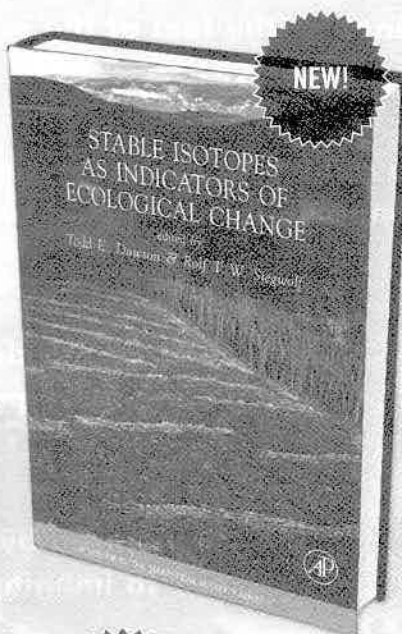
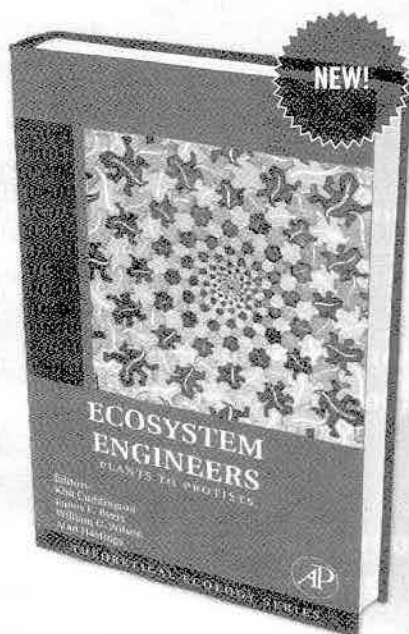
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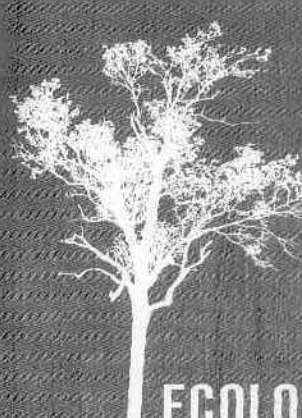
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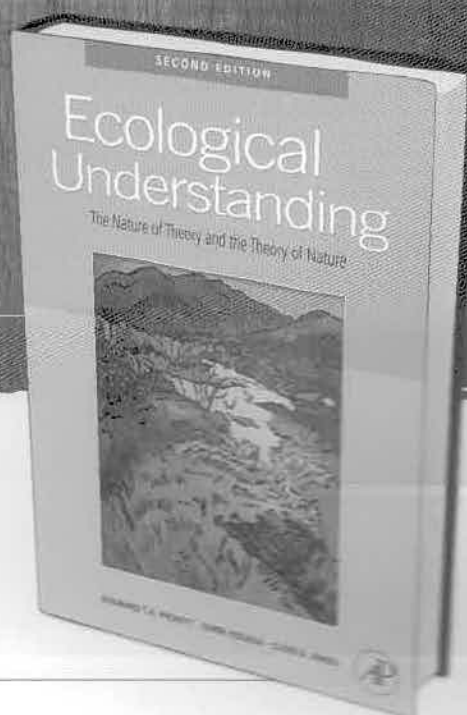
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