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Increasing the credibility of expert-based models with preference surveys — Mapping recreation in the riverine zone

Abstract

Recreation is a basic human need and therefore must be considered in spatial planning, which requires spatially explicit mapping of the recreation suitability of a landscape. The current methods for this type of mapping have limitations: On one hand, widely used expert-based models for large scale suitability assessments often suffer from discrepancies between the mapped values from expert assessment and actual user preferences. On the other hand, elicitation of personal preferences of potential users is complex and time-consuming, and their applicability to larger scales is limited.

In this paper, we demonstrate the development of a spatially explicit model for the recreation suitability of the riverine zone that integrates the preferences of the users with an expert-based modeling process. First, we conducted an analytic hierarchy process (AHP) with experts to generate four different model variants based on physical variables. These model variants differ in terms of the strength of the influence of the variables on the recreation suitability. Second, an online survey was used to gather data on user preferences for various river sections with regard to recreation. A comparison of the expert model results with the preferences of the potential users shows a clear correlation between one model variant and the users' preferences. This result suggests that it is possible to elaborate an expert model which corresponds to the preferences of users.

We made the model results available for the planning and development of the riverine zone in the canton of Zurich. To this end, they were integrated in a decision support platform together with other planning-relevant information.

1 Introduction

Recreation and physical regeneration are considered basic human needs that can be satisfied by outdoor activities such as walking and jogging (Zeidenitz, 2005; Mönnecke et al., 2006; Arnold et al., 2009). Nature-based recreation provides many benefits, such as physical exercise, aesthetic experiences, intellectual stimulation, and inspiration (Kareiva et al., 2011; Daniel et al., 2012) and has been shown to positively affect an individuals' emotional well-

being and health (Bowler et al., 2010; Korpela et al., 2014; White et al., 2015). It is also well documented that people benefit from access to water bodies (Volker and Kistemann, 2011, 2013; White et al., 2015; Nutsford et al., 2016), especially near-natural rivers (Junker and Buchecker, 2008; Arnold et al., 2009).

Ecosystem services have been increasingly used as a concept to describe the benefits people gain from ecosystems and landscapes. Ecosystem services are commonly divided into provisioning, regulation and maintenance, and cultural services (Haines-Young and Potschin, 2013). Recreation is allocated into the cultural ecosystem services (CES) category. CES are often underrepresented in assessments, which can result in biased planning decisions when conflicting interests have to be weighed against each other (Hernández-Morcillo et al., 2013; Pleasant et al., 2014).

For example, the development of watercourses often faces challenges related to conflicting interests. The use of watercourses for recreational purposes opposes other interests, such as flood protection, nature conservation, as well as settlement or infrastructure development. To develop and prioritize the measures for water development and satisfy multiple interests, reliable and precise information regarding ecosystem services and different interests is indispensable to support decision making. To date, recreation and other CES have often been treated on an abstract level that has limited usefulness for spatial planning and decision making and does not meet the needs of local actors. Therefore, an adequate representation of CES in decision making is an urgent need (Chan et al., 2012; Bagstad et al., 2013; Ruckelshaus et al., 2013; Hauck et al., 2015; La Rosa et al., 2015; Scholte et al., 2015). This requires that the CES are integrated into maps to show their spatially explicit values. This mapping is necessary not only for decision support but also to raise awareness and set priorities (Hauck et al., 2013; Burkhard and Maes, 2017).

Hernández-Morcillo et al. (2013), La Rosa et al. (2015), Wolff et al. (2015), and Crossman et al. (2013) present in their reviews a variety of existing approaches on how the recreation potential of a landscape can be quantified and mapped. These authors also highlight the limited comparability of the different methods. The approaches can be split into two groups: A majority of the existing studies use physical landscape characteristics, such as accessibility or land cover to model recreation suitability in a spatially explicit manner (Kienast et al., 2012; Nahuelhual et al., 2013; Paracchini et al., 2014; Albert et al., 2015; Peña et al., 2015). These studies are based on the assumption that people's preferences can be assigned to an array of physical characteristics in a landscape. Such approaches are efficiently applicable from smaller to larger scales. The second group of approaches directly maps user preferences and shared values (Junker and Buchecker, 2008; Raymond et al., 2009; Kienast et al., 2012; Plieninger et al., 2013; van Berkel and Verburg, 2014). These methods use in-depth interviews, participatory mapping, or empirical surveys of a large number of people, for example, on the recreation behavior or aesthetic preferences for the landscape. Directly mapping users' preferences requires a high number of respondents and highly differentiated surveys to adequately capture all aspects of a landscape that might be relevant to recreation. On the other hand, expert-based assessments relying on physical criteria are restricted by the uncertainty whether they actually represent subjective perceptions of user groups (Riechers et al., 2016).

Despite the existence of those different approaches, water-related recreational services or recreation suitability have not yet been mapped with high resolution across Switzerland, or not even at a regional scale. Spiess et al. (2008) examined the potential of water-related recreation areas for improvements in a pilot study in three Swiss municipalities. Their method aims at the required level of detail by developing a spatially explicit GIS-based logic-model; however, it does not include users' preferences, is only optimized for one specific agglomeration area, and is not usable in non-settlement areas. Within the scope of a systematic assessment of ecosystem services, an indicator based on accessibility of the waterfront areas has been previously suggested, but it has not been mapped (Kienast and Steiger, 2013; Grêt-Regamey et al., 2014a). Furthermore, approaches that link user preferences with spatial data to identify recreation areas have been applied (Kienast et al.,

2012; Buchecker et al., 2013), but they are often not sufficiently detailed in scale to be used in river development and thus support planning processes.

In this paper, we present an approach to map the recreation suitability of watercourses at a regional level in the canton of Zurich in Switzerland that combines the two approaches outlined above. We first apply an expert-based modeling approach to spatially assess recreation suitability in different sectors of the riverine zone using different model variants. We then select the most suitable variant by comparing the modelling results with the preferences of potential users from a user survey. We show that this procedure benefits from the advantages of both methods and can be applied with a reasonable effort in a region at a detailed scale. We further demonstrate that our approach allows for the selection of the best model variant with regard to consistency with user perception, which then can be integrated into decision support platforms for supporting planning processes.

2 Methods

2.1 Process for mapping the recreation suitability in the riverine zone

The presented study follows several steps, which are shown in Figure 1. The first six steps are part of the expert-based approach, while steps seven and eight belong to the user-based approach. Subsequently, the results of both approaches are compared (in step 9), and the best model variant is chosen for implementation into a decision support system (steps 10 and 11). The different steps are described in detail in the following sections.

Figure 1: Schematic and conceptual representation of the different steps performed in this study

2.2 Study area

Changes to the Swiss legislation on water protection (Waters Protection Act, Waters Protection Ordinance) in 2011 called for the designation of space for all watercourses as well as for revitalization and quality improvements to rivers (Göggel, 2012; AWEL, 2015b). Watercourse development measures must be implemented at a cantonal level (i.e., regional); thus, we focused our study on this level. Recently, the canton of Zurich initiated and implemented a decision support system (available at: gr-vis.ethz.ch) to be used for the future planning of watercourses, so we used this canton for testing our mapping approach. The size of the canton of Zurich is 1,729 km², approximately one-fifth of the canton is settlement area

(378 km²), and the length of the considered watercourses is approximately 3,600 km (Figure 2). We used watercourse segments as the spatial units for the recreation mapping. Therefore, we split the watercourses into 143,145 50-meter sections on both sides.

In the canton Zurich, recreation is a highly demanded service, since this region is densely populated and demand will continue to grow as a result of population growth (Meier et al., 2013). Leisure and recreational use is thus an important part of the spatial development and water-related planning in the canton of Zurich (Kanton Zürich, 2014). Accordingly, the recreation suitability has to be taken into account during the implementation of the revitalization planning (Göggel, 2012; AWEL, 2015b).

Figure 2: Overview of the watercourses in the canton of Zurich, Switzerland (data source: swisstopo; 2017)

2.3 Expert-based approach

2.3.1 Step 1: Literature review

To define a first set of criteria, which may affect the recreation suitability of watercourses, we conducted a literature review (step 1). We searched Google Scholar and ScienceDirect for the keywords “recreation”, “mapping”, “cultural ecosystem services”, “river”, “water”, “stream”, and “revitalization”. We only considered literature that focused on the mapping of recreation if the described methods or criteria were related or were transferable to the riverine zone. This was the case if general aspects (e.g., recreation facilities, distances) were addressed and if the literature did not explicitly deal with specific forms of recreation which do not take place in the riverine zone (e.g. skiing).

The aspects found in the literature which might have an effect (positive or negative) on the recreation potential were first harmonized into a preliminary set of criteria to measure the recreation suitability of the riverine zone. For example, the aspects “noise load” or “acoustic level” from literature were only included as “noise” in the preliminary set of criteria in order to avoid content redundancies. In order to improve clarity and to facilitate the evaluation of the

criteria in step 2, the criteria were grouped into thematic classes. For example, all criteria which influence the accessibility of the waterbodies were listed in the class “reachability and accessibility”.

2.3.2 Steps 2-3: Review of criteria and classes

To review these criteria, four experts were identified and selected based on their expert knowledge and activities in the field of recreation and water development, following Mieg and Näf (2006). The group of experts in our study covers the areas of research, administration, planning, and implementation. In an initial questionnaire (step 2), these experts reviewed the preliminary set of indicators identified in step 1. Specifically, they were asked whether they considered the proposed criteria reasonable for application in the study area, whether others were needed and whether the criteria were grouped appropriately into the proposed classes.

The first questionnaire was sent to the experts and answered either electronically or in a personal interview. Based on this review, the criteria were adjusted (i.e., the data basis of criteria) and the assignment of criteria to classes was adapted based on the experts’ feedback. Since there were no inconsistencies in the feedback, further iterations of the review process were not necessary. Afterwards, the spatial data needed to calculate the criteria were processed in ArcGIS 10.4 (ESRI, 2015) (step 3).

2.3.3 Step 4: Weighting of the criteria and classes

In a second interview, the physical aspects underlying the criteria, such as access to public transportation or stream regulation, were normalized and the experts weighted the criteria and their classes within an analytical hierarchy process (AHP), following Malczewski and Rinner (2015) (step 4). For this purpose, personal interviews with the experts were conducted, which lasted between 40 and 80 minutes. Following the methods described in Laux (2014), the experts delineated how the physical aspects (e.g., the distance to roads or the land use class) should be normalized on a scale from 0 to 10 (Figure A 1 in the appendix). This rating resulted in a value function for each physical aspect, which describes how an increase or decrease of an aspect’s value leads to a change in the recreation suitability (Malczewski and Rinner, 2015). The experts conducted this normalization twice, once for watercourses in settlement areas and once for watercourses in non-settlement areas. The settlement and non-settlement watercourses were separated as the experts assumed different requirements for both areas concerning the recreation suitability. To aggregate the value functions, we formed an averaged value function for each criterion from the individual value functions of the different experts (Bogner et al., 2002; Altwegg, 2014).

The criteria and their classes were weighted by the experts, using a pairwise comparison (Figure A 2 in the appendix) (Chen and Pu, 2004; Malczewski and Rinner, 2015). The experts first compared the pairs and weighted the upper hierarchy level—the classes—and then the lower hierarchy level—the criteria—against each other (Figure A 3 in the appendix). To distinguish between settlement and non-settlement areas, the experts conducted this weighting twice.

Following Malczewski and Rinner (2015), Equation 1 describes how the recreation suitability (RS) is calculated based on the value functions $f(k_{ik})$, the weight of the c^{th} class w_c ($c = 1, 2, \dots, p$) and the weight of the k^{th} criterion $w_{k(l)}$ ($k = 1, 2, \dots, n$).

$$RS(K_i) = \sum_{k=1}^n w_c w_{k(c)} f(k_{ik}) \quad \text{Equation 1}$$

In cases when the experts defined contrasting weights, i.e., they disagreed significantly, the disagreements were later transformed into variants of the model (the differing values of criteria and classes for the variants are shown in Table 1 in the results section). A

consistency rating according to Saaty (1987) and Alonso and Lamata (2006) was carried out to check the consistency of the weighting decisions.

2.3.4 Step 5: GIS model

The results of the AHP were implemented into ArcGIS ModelBuilder in four models, each representing a variant of the experts' weighting (see section 2.3.3). The preliminary values for the recreation suitability of the riverine zone were calculated using these models (step 5). The results are reported below.

The recreation suitability of the riverine zone was modeled in all 143,145 50-meter sections (28,566 of them in the settlement area). We normalized the model results by the following range score transformation to a span of 1 to 100 (Equation 2).

$$\frac{max_{new} - min_{new}}{max_{old} - min_{old}} \cdot (v - max_{old}) + max_{new} \quad \text{Equation 2}$$

The highest recreation suitability corresponds to the value 100, whereas the lowest suitability corresponds to the value of 1. The width of the sections was defined based on the width of the streambed in accordance with the Swiss legal regulations on water bodies and varied between 7.5 and 270 m.

2.3.5 Step 6: Plausibility check

The model distinguishes between locations inside and outside settlement areas as defined by the topographic landscape model (Swisstopo, 2015). Depending on the location, the physical variables are weighted differently (Table 1 in the Result section). To identify a potential overestimation or underestimation of the recreation suitability, the model results at the transitions from settlement to non-settlement areas were compared (step 6). Wherever a river crosses the border from settlement to non-settlement area, the sections of the river that touch these boundaries were compared on both sides of the boundary. We then identified the frequencies of the value changes between the different sections. Using descriptive statistics (mean, kurtosis, skewness, and distribution), we checked that there was no systematic over- or underestimation of the recreation suitability for either the settlement or the non-settlement area.

2.4 Steps 7-8: User-based approach

For the online survey, 30 sample sites out of all river sections were selected using a stratified random sample (Atteslander and Cromm, 2010) (step 7). The strata were formed by subdividing the sites into settlement and non-settlement areas, as well as by the mean model results. For this purpose, the averaged results were grouped into six classes using the equal interval method (Slocum, 2010).

The online questionnaire (step 8) was structured into the following independent parts:

The first part focused on the spontaneous and holistic evaluation of the recreation suitability of a section in the riverine zone. Six of the 30 study sites were presented in each questionnaire using an aerial photo, a topographical map, two photos from the human perspective, and a brief description (Figure A 4 in the appendix). A rotation in the order in which the sites were presented was used to counteract primacy and recency effects as well as contrast and consistency effects (Krosnick and Alwin, 1987; Schwarz et al., 1992). For each questionnaire, either sites in the settlement area or the non-settlement area were shown; the allocation of the type of questionnaire to the interviewee was random. Based on the definition of recreation according to Yucic (1970) and Mönnecke et al. (2006), participants were asked to provide their individual perceived recreation suitability of these

areas. We used a rating scale ranging from 1 to 100 (from very bad to very good). Furthermore, if participants knew the presented area, they were asked whether it was adequately represented.

In the second part of the questionnaire, demographic and social data were collected. Here, participants could also extend the scope of the questionnaire to another nine of the 30 sites.

The questionnaire was evaluated by two pre-tests: the first pre-test was used to determine the average survey time and to define the most appropriate survey structure (e.g., the number of sites). This first detailed pre-test was carried out with five people. In the second pretest, 21 persons evaluated the overall quality of the questionnaire on the criteria of comprehensibility, unambiguity, and effort.

The survey was carried out using SoSci Survey 2.6.00-i. We used post-incentives (providing the opportunity to participate in a draw when the questionnaire was completed) to increase the predisposition to participate and to reduce the number of incomplete responses (Ryu et al., 2006; Sánchez-Fernández et al., 2010; Massey et al., 2012). The invitation to the survey took place via e-mail distribution using mailing lists (from the university and professional associations), social networks, and link distribution via flyers on the street. In the invitations, we briefly provided the topic of the survey, mentioned its relevance, the incentives, the time required, and the link to the survey.

The main test was carried out from 30 March 2017 to 16 April 2017. A total of 551 people participated. Since not all sites were queried in each questionnaire, 6990 site evaluations were completed.

2.5 Step 9: Statistical analysis and comparison of the approaches

Friedman tests and post-hoc Dunn-Bonferroni tests were carried out to test the results of the four model variants for dissimilarity. We used the Friedman test because the model results are in a quasi-metric scale, i.e., we cannot unequivocally assume an interval scale for our data, which would be a requirement for an analysis of variance. The post-hoc test is needed to evaluate which model variants differ significantly.

For the comparison of the expert-based model results and the spontaneous, holistic evaluation in the online survey, box plots and scatterplots were created. To test for correlations between the two, a Spearman rank correlation analysis (excluding pairwise cases; 2-tailed significance) was used. The mean values from the survey were compared with the values of the model variants and the mean value across all models. Based on these statistics, we selected the model variant, whose results showed the greatest consistency with the results of the user surveys for the later use in a decision support tool.

A comparison between the values of the different age groups of the interviewees (<30 years, 30-50 years, >50 years) and between the values of those who knew a site with the values of those who did not was carried out using a Kruskal-Wallis test and post-hoc Dunn-Bonferroni tests and a Mann-Whitney U test, respectively.

The following software products were used for the analysis described above: ArcGIS 10.4, Excel 2016, RStudio Desktop 1.0.136 using R 3.3.3 and SPSS 22.

2.6 Steps 10-11: Mapping and integration into a decision support platform

The final model was selected from the four variants based on the statistical analyses and was used to calculate the values of the recreation suitability for each watercourse segment for the canton of Zurich (step 10). These values were grouped into six classes using the equal interval method (Slocum, 2010) for display purposes.

We integrated the data on recreation suitability into a platform (step 11) developed by Wissen-Hayek et al. (2016). This platform aims to provide information about the important services of the riverine zone for the entire area of the canton as a basis for spatial planning.

3 Results

3.1 Expert-based approach

The experts identified twelve criteria as relevant to recreation in the riverine zone; the criteria were grouped into four classes differentiated into settlement area and non-settlement area (Table 1).

Table 1: Criteria and their classes with the weights from the AHP for the four model variants

classes criteria	weights (settlement / non-settlement)			
	variant 1	variant 2	variant 3	variant 4
reachability and accessibility	0.31 / 0.14	0.30 / 0.14	0.10 / 0.14	0.09 / 0.14
distance to settlement	0.11 / 0.21	0.11 / 0.21	0.11 / 0.13	0.09 / 0.14
distance to road network	0.33 / 0.28	0.33 / 0.28	0.33 / 0.28	0.23 / 0.28
slope of the streambank	0.18 / 0.13	0.18 / 0.13	0.18 / 0.22	0.18 / 0.22
access to public transport	0.37 / 0.38	0.37 / 0.38	0.37 / 0.37	0.37 / 0.37
naturalness	0.11 / 0.35	0.12 / 0.37	0.23 / 0.37	0.23 / 0.35
stream regulation & material	0.73 / 0.67	0.73 / 0.67	0.73 / 0.67	0.73 / 0.67
variability of width and depth	0.27 / 0.33	0.27 / 0.33	0.27 / 0.33	0.27 / 0.33
use of the riverine zone	0.29 / 0.10	0.40 / 0.16	0.40 / 0.16	0.27 / 0.10
catering facilities	0.22 / 0.12	0.23 / 0.12	0.23 / 0.20	0.22 / 0.20
recreation infrastructure	0.25 / 0.27	0.38 / 0.39	0.38 / 0.40	0.25 / 0.28
land use	0.14 / 0.20	0.13 / 0.20	0.13 / 0.12	0.14 / 0.12
protected area	0.39 / 0.41	0.26 / 0.29	0.26 / 0.28	0.39 / 0.40
disturbance	0.29 / 0.41	0.18 / 0.33	0.27 / 0.33	0.40 / 0.41
noise	0.70 / 0.73	0.70 / 0.73	0.70 / 0.73	0.70 / 0.73
distance to sewage treatment plant	0.30 / 0.27	0.30 / 0.27	0.30 / 0.27	0.30 / 0.27

In the settlement area, the most important classes are reachability and accessibility in variant 1, the use of the riverine zone in variant 2, the use of the riverine zone also in variant 3 but with a strong weight on the naturalness and the disturbances in variant 4. In the non-settlement area, variants 1 and 4 have the greatest weights on disturbances, while variants 2 and 3 have the highest weights on naturalness. The noise and stream regulation criteria are particularly important in the non-residential area. In the settlement area, noise is also an important variable along with the recreation infrastructure.

The results of the consistency evaluation of the weighting decisions are mostly within consistency levels of 95 % (18 out of 40 cases) or 80 % (21 out of 40 cases), while only one case has a consistency level of 60 %. None of the model variants shows an inconsistent weighting of criteria or classes.

The statistical distribution of recreation suitability values of all four model variants for all sections over the canton of Zurich is shown in Figure A 5 in the Appendix. The four model variants differ slightly in their statistical characteristics. For example, the mean recreation value ranges between 68.06 and 71.45 where 100 corresponds to the maximum and 1 to the minimum recreation suitability (see also Table A 1 in the Appendix). While the histograms

show a clear similarity between the model variants' results, the Friedman test indicates significant differences between the four model variants. The post-hoc Dunn-Bonferroni tests show that the differences in the paired comparison of all model variants are significant (adjusted asymptotic significances: $p < 0.01$) (compare to Figure A 6 in the appendix). These results indicate that the variants of the model do matter, as they—even if they show the same trend—rate the sites differently.

Figure A 7 and Table A 2 (in the Appendix) illustrate the statistical characteristics of the river sections at the transition between settlement and non-settlement areas. The values show that there is no systematic over- or under-estimation of one of the two areas by one of the four model variants.

3.2 User-based approach

A Mann-Whitney U test shows that there is no significant difference in the rating between people who know a site and those who do not know it.

A Kruskal-Wallis test showed that there is no significant distinction in the rating between the age groups for 23 of the 30 sites (the distribution of the age groups is shown in Figure A 8 in the Appendix). For the other sites, the post-hoc Dunn-Bonferroni tests showed that the differences between the groups are small and the differing groups change from site to site, so no clear picture of these differences emerges.

3.3 Statistical comparison of the approaches

Figure 3 shows that the expert-based model results and the spontaneous, holistic evaluation in the survey show a distinct conformity. The results show that the spontaneous evaluation by the users—presented in the boxes and whiskers—show an agreement with the four variants of the expert models—shown as red symbols—with clear differences between the variants. The model results are predominantly slightly above the values of the user survey, especially in the middle range of recreation suitability. For the non-settlement area (left side of the figure), all four model variants provide similar results; the values differ more at the sites in the settlement area (right side of the figure) especially at sites D2, E2 and E4.

Figure 3: Boxplots of the modeled recreation suitability and the survey results. The boxes show the spontaneous evaluation of the sites from the survey (whiskers extend to the most extreme data point that is no more than 1.5 times the interquartile range from median; the data points outside this range are considered to be outliers and are displayed as individual data points). The red symbols represent the results from the expert model variants. The left side of the figure shows the non-settlement sites (light grey), the right side the settlement sites (dark grey). The sites are ordered by the value of the model variant 2. Reading example: Site C1 (far left in the figure) is located in the non-settlement area. For this site, all four model variants give nearly the same values (red symbols), which are also close to the median (black horizontal line) of the user surveys for this site. At location B4 (also non-settlement area), however, all model values are above the values indicated by most respondents.

A Spearman's rho test for the correlation between the four model variants and the users' rating of the different sites from the survey shows that model variant 2 has the highest correlation of .958 (Spearman; significant at the 0.01 level (2-tailed)) with the user rating. The linearity of this correlation is also clearly visible in Figure 4. While the correlation of variant 3 is almost as high as that of variant 2 (.956), those of variants 1 and 4 are clearly smaller (.945 and .930). Considering not only the rank correlation, but the absolute differences visible in the boxplots, the difference between the variants becomes even clearer.

Figure 4: Correlation of modeled values (model variant 2 on the left; all model variants on the right) and the results of the online survey for all sites

3.4 Mapping and integration of the results in a decision support system

Based on the statistical analysis, model variant 2 was selected as the most suitable of the four variants. Using this model, we calculated the final values for recreation suitability for each section of riverine zone in the canton of Zurich, such that they were made spatially explicit and stored in a geodatabase. Afterwards, the data were processed cartographically and included into the decision support platform (Figure 5). The resulting geodata are available as KML/KMZ-files in the digital appendix; the decision support platform can be accessed at <http://www.gr-vis.ethz.ch>. This platform contains data on flood protection, revitalization, natural and landscape protection, water use, and settlement (Wissen-Hayek et al., 2016). The platform is already in use and is officially recommended by the canton as a tool for planning authorities to define and develop revitalization measures.

Figure 5: Platform showing the recreation suitability in the riverine zone (translated version, original in German)

4 Discussion

Mapping of CES is urgently needed to emphasize their importance for human well-being (Egoh et al., 2012) and to enable decision making that better considers these services in planning (Maes et al., 2012; Albert et al., 2015). This need particularly applies to recreation services (Brown and Raymond, 2007; Kienast et al., 2012; Paracchini et al., 2014) and requires methods that result in precise, spatially explicit information at an appropriate scale (Pleasant et al., 2014). With our approach, we endeavor to meet these demands. However, despite its simplicity, efficiency, and transferability, our approach has several limitations. First, only a limited set of criteria relevant to recreation suitability could be included in the model, and other criteria, which could have an influence on recreation, were neglected. In the expert interviews, the importance of further aspects was discussed. For example, the importance of a riverine zone as an identity-creating place, uniqueness, the quality of the local architectural and urban context, visual relationships, walking comfort and the suitability for individuals, groups, different age groups, people with disabilities, and users of vehicles (e.g., strollers) were all discussed. The experts noted that even though these factors cannot be included in a regional modeling of recreation, they would need to be considered for site-specific measures.

Second, the weighting of the selected criteria is contextual and subjective. Accordingly, the weights given by the experts differ—albeit only slightly. We addressed this discrepancy by creating four model variants and comparing their results with the users' ratings. Even if—as in our case—the differences between the variants are small, it is nevertheless important to model them separately. Thus, a comparison can be carried out with the users' preferences, and the most suitable variant for a given region can be selected. A contextual aspect was taken into account by distinguishing between settlement and non-settlement areas. In this way, it could be considered that, for example, the naturalness of a watercourse in settlement areas is weighted lower than in non-settlement areas, but accessibility is weighted higher. In principle, there is the risk that these two sub-models (settlement and non-settlement) will

evaluate comparable situations at the border between settlement and non-settlement areas differently. However, our results show that there is no systematic over- or underestimation of any model variant.

A fundamental criticism of expert-based assessments is that they often differ significantly from the opinions and assessments of users (Hunziker et al., 2008) by neglecting or ignoring relevant criteria. To handle this problem, it is important to combine both approaches (Riechers et al., 2016). A large part of the discrepancy can be attributed to the fact that the objective quality of a specific location is less important for somebody's landscape experience than their personal preference, making it difficult to map CES (Weichhart, 1990; Hunziker et al., 2008; Riechers et al., 2016). In the case of our investigations, however, this did not seem to cause a problem; we found a very similar evaluation of the recreation suitability with both methods. Nevertheless, the fact that the vast majority of respondents only had an external view of the sites that they had never visited and, hence, had no direct relation to them must be considered. We therefore investigated whether groups who know the site rated the watercourses differently than those who did not know the site. Although a statistically significant difference between both groups could not be determined, the ratings for some sites were higher by people who know them than by those who did not. These ratings corresponded closer to the expert model values, which were in general slightly higher, than the ratings from the rest of the interviewees. A reason for this effect might be an insufficient description in the survey, which does not adequately reflect the positive aspects of the sites. Site B3 (non-settlement), in contrast, was rated lower by people who knew it, whereas the model suggests a better recreation suitability. One reason for this could be that the model assumes a good accessibility to the water, while in reality the access to the water is restricted by bushes. The first aspect is relevant for the setup of further studies since it highlights the importance of precise description of the sites, which could be improved by a systematic review of the site descriptions. For the second aspect, a better database for small structures could be helpful.

The similarity of the suitability ratings from the models and users suggests that the local experts have adequately taken into account the preferences of the users in the modeling process. For further mapping, the comparison can help identify which variables in the expert-based approach leads to differences to user surveys, and thus need to be taken into account.

Despite the clear consensus of the expert model with users' preferences, the resulting values differ for some sites. The supposed reasons for this are case specific. For example, at one location, the railway line parallel to the footpath was prominently visible in the survey's pictures and is mentioned in many comments in the questionnaire. Clearly, this feature is interpreted by most interviewees as a significant degradation in recreation suitability. In the model, the disturbance was classified as medium, since the local railway line caused limited noise; for the users, the visual impression of the railway infrastructure on the picture was apparently more important than the actual disturbance. From this finding, it can be concluded that the photos must be supplemented by a more precise textual description. Abstract descriptions such as "the railway line causes moderate noise" must be supplemented by more concrete descriptions such as the frequency of a train passing the site. At other locations, a lack of accessibility to the water (small-sized separating elements and unfavorable embankments) and the lack of amenities are criticized. This appears to be particularly significant in narrow waters. This result suggests that on the one hand, the geodata as a model input would have to be even more precise to include even small barriers and on the other hand, that potentially very narrow waters have to be included as a separate category with different weightings.

5 Conclusions and recommendations

Integrating CES in assessments and decision support tools is essential for ensuring that they are considered equally with other aspects in land management decisions (Chan et al., 2011). In particular, the CES, which as soft criteria provide vital services to society, must be systematically considered in landscape development in order to illustrate where interventions can take place and which services would be restricted by an intervention (Keller, 2016). This applies especially to the development of rivers since different interests meet here, and appropriate considerations are needed regarding different prioritizations and measures (see chapter 1 Introduction). To this end, it is not sufficient to address recreation in an abstract way. An adequate representation of CES is needed (Chan et al., 2012; Bagstad et al., 2013; Ruckelshaus et al., 2013; Hauck et al., 2015; La Rosa et al., 2015; Scholte et al., 2015). Depending on the purpose of the mapping or assessment, it must be adapted to the respective needs to make sure the information relevant for the related decision-making process is provided (Grêt-Regamey et al., 2017). This means that it is first necessary to determine whether only a rough overview of the topic is required, for example, when raising awareness for a specific topic. Correspondingly, the mapping can be carried out using comparatively simple methods. However, if a deeper understanding of processes is needed (e.g., to understand how the management of the riverine zone can influence recreation) and in order to deal with explicit management questions the mapping method must support these complex requirements (Grêt-Regamey et al., 2014b).

The project that underlies this paper aims at two aspects: the first aim is to sensitize the planning agencies and authorities involved in the planning to the issue of recreation in the riverine zone. This requires, in particular, a high clarity of the modeling process and the resulting maps to communicate the recreation potential. The second aim is to provide a basis for concrete management options and their legally binding implementations. This requires a high reliability and accuracy of the used method and the resulting maps (Jacobs et al., 2017). Since the conditions for recreational use along rivers can vary on a small scale and even from one side of the river to the other, a high spatial resolution of the model results is also required. The presented combined approach fulfills these requirements as the underlying model depicts the various conditions of suitability for recreation, the model is applicable at a small scale, the results have been checked with regard to their reliability, and they are easy to use for planners and decision makers.

We integrated the results from our model into a decision support platform. This platform is intended to provide the relevant information for the legal safeguarding of the riverine zone and the revitalization of rivers in a bundled form. In the required planning processes, the users (authorities and planners) must initially determine the legal minimum of a riverine zone for all rivers. They then have to check whether this zone needs to be expanded: in the determination of the final riverine zone, various criteria regarding flood protection, revitalization, nature and landscape protection as well as the use of rivers—which includes recreation—are considered. A tradeoff between these topics may then be necessary. This means for example, that the arrangement of recreational areas must be defined taking into account their expected use as well as the potential disturbance of the natural environment. In case of a conflict, the tie to the particular location must also be considered, e.g., whether the recreation has to take place at the specific section of a river or whether it is also possible at another location. Based on this consideration, it has to be decided whether the previously determined minimum riverine zone is sufficient or whether an enlarged zone has to be protected to provide space for specific uses and functions (AWEL, 2015a). In order to carry out such a tradeoff, it is necessary to oppose precise data concerning recreation to those of e.g. flood and nature protection.

Our approach allows spatially explicit modeling of the recreation potential based on a variety of factors. If different measures regarding the river or in its environment are discussed in a planning process, the model can easily be used to develop different variants or scenarios

and assess their influence on recreation. Regarding the transfer to other projects and regions it can be said that the combination of the two approaches—expert- and user-based methods—is useful even if as in our case the results may not differ much between the two methods. This combination of the two approaches is helpful to develop different expert-based model variants and compare the results with the users' preferences to identify which modeling variant fits best for a region.

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7 Appendix

Supplementary material associated with this article can be found in the online version. This material includes geodata representing the recreation suitability as kml-files.

Figure A 1: Example of the normalization of one physical variable (access to public transport on the x-axis and the value for the recreation suitability on the y-axis) by an expert

Ziele	Erreichbarkeit & Z	Natürlichkeit	Gewässerraumnutzung	Störungen	Gewicht
Erreichbarkeit & Z	1	$1/3$ $1/5$	2 $1/3$	$1/3$	
Natürlichkeit	3 5	1	4	1	
Gewässerraumnutzung	$1/2$ 3	$1/4$	1	$1/4$	
Störungen	3	1	4	1	
Summe					1

Erreichbarkeit & Z					
Attribute	Distanz Siedlung	Distanz Wegnetz	Steigung Ufer	ÖV-Erschliessung	Gewicht
Distanz Siedlung	1	$1/3$	$1/3$	$1/2$	
Distanz Wegnetz	3	1	2	$1/2$	
Steigung Ufer	3	$1/2$	1	$1/2$	
ÖV-Erschliessung	2	2	2	1	
Summe					1

Natürlichkeit			
Attribute	Verbauungsgrad & Mat	B- & TVAR	Gewicht
Verbauungsgrad & Mat	1	3	
B- & TVAR	$1/3$	1	
Summe			1

Figure A 2: Example of the pairwise weighting of the four classes (upper table) and two criteria (accessibility in the second table and naturalness in the third table) by an expert

Figure A 3: Schematic representation of the Analytical Hierarchy Process (AHP) with four classes and twelve criteria for modeling the recreation suitability in the riverine zone

Chriesbach bei Dübendorf

Die Natürlichkeit des Chriesbach ist in diesem ländlichen Gebiet beeinträchtigt (keine Verbauungen, aber eingeschränkte Entwicklung des Gewässers). Dieser Ort ist gut zu Fuss oder mit dem Velo erreichbar, weniger gut mit dem ÖV (ca. 10 Min. entfernt). Der Fluss besitzt einen engen und steilen Uferbereich. Es gibt einen Uferweg, aber keine Erholungsinfrastruktur. Es gibt keine Beeinträchtigung durch Strassen- oder Bahnärm.

Erholungseignung an diesem Standort

Die Erholungseignung an diesem Standort ist ...

sehr schlecht sehr gut

Begründung/Kommentare (freiwillig)

Kennen Sie dieses Gebiet?

- ☐ Ja
☐ Nein

Weiter

Sven-Erik Rabe, ETH Zürich – 2017

Figure A 4: Screenshot of the survey with the description of a site, the possibility to evaluate and comment on it, and the question whether the location is known to the interviewee.

Figure A 5: Histograms of the results of the model variants (x-axis shows the values for recreation suitability, y-axis shows the number of river sections)

Table A 1: Descriptive statistics of the model results (values range between 0 (worst suitability) and 100 (best suitability))

	variant 1	variant 2	variant 3	variant 4
mean	71.45	68.24	68.06	71.38
standard deviation	16.47	17.74	18.11	17.02
variance	271.24	314.59	328.11	289.67

Figure A 6: Related-samples Friedman's two-way analysis of variance by ranks for the four model variants

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Table A 2: Statistical description of the model behavior at the transition from settlement area to non-settlement area

	variant 1	variant 2	variant 3	variant 4
mean	-3,2	-4,53	-2,12	-0,66
kurtosis	4,953	3,199	12,071	16,766
skewness	,486	,328	,949	1,114

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Figure A 7: Histogram of the model behavior at the transition from settlement area to non-settlement area (variant 3)

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Figure A 8: Gender and age ratio of the interviewees

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