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THE USE OF RIVERS AS RECREATIONAL AREAS AND RESTORATIVE SETTINGS

LINKING GIS-BASED MODELLING TO LOCAL CONTEXT ANALYSES

Master thesis ETH

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Cover page pictures

Left: The Aare at the foot of the old town

Picture taken by Sophie Rudolf, 2012

Middle: The Stadtbach south of the old town

Picture taken by Sophie Rudolf, 2012

Right: GIS-based model developed for the analysis

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Summary

Most of Switzerland's population lives in urban areas. This affects not only the country's landscape, but also its population's lifestyle. Even if living in cities can be fulfilling and guarantee access to many services, it can also lead to a sedentary way of life linked to stress-related and non-infectious diseases. Under these conditions, urban planning can have a significant positive influence by designing public spaces fostering psychological restoration and encouraging the practice of regular physical activity. More specifically, the promotion of near-natural landscape features in built-up environments has a positive effect on well being. Rivers are a good example of such elements because they are widespread across Switzerland and easily accessible to the population. For these reasons, this master thesis focuses on the use of rivers as recreational areas and restorative settings in the context of short nearby recreation in peri-urban areas.

This study includes both "space" and "place" approaches towards landscape perception within a robust and holistic conceptual framework, bridging the gap between modelling and local context analyses. This enhances the understanding of which empirical physical properties drive people's preferences regarding their use of river settings and also reveals which values people attribute to watercourses. GIS-based tools were developed to calculate river accessibility depending on four different means of transportation and to map the use of rivers as recreational areas or restorative settings. To do so, a straightforward and transparent method relying on the combination of the three parameters "accessibility", "landscape suitability" and "infrastructures" was set up. The many approaches incorporated into the conceptual framework – historical, local knowledge and local context analyses – helped define patterns of specific river use, advocating corresponding enhancement measures and identifying potential conflicts that might arise when planning for recreation along rivers.

The results of the accessibility calculation demonstrated that a minimum radius of 3 km around the most populated areas should be accounted for when planning for recreation along rivers. The analysis further highlighted the importance of considering the extension and the connectivity of residential areas in planning decisions. After evaluation, it became apparent that the GIS-based model produced a fairly good representation of the use of rivers by pedestrians, but that it encountered difficulties when representing river use by cyclists. In the general context of urbanization, the conceptual framework emphasized the importance of (a) planning for enhancing the restorative functions of landscape features in urban areas and (b) prioritizing these enhancements for already existing features. In fact, urban landscape elements are widely visited as a part of the everyday landscape and their structural improvement would further provide people with micro-restorative experiences. This is also a cost-effective approach because it prevents having to design new recreational installations, makes cities denser and preserves the cultural and historical heritage of the urban centres.

In conclusion, this master thesis delivers an array of GIS-based tools well embedded within a conceptual framework including both "space" and "place" approaches towards landscape perception. It further facilitates decision-making in the fields of urban planning and small-scale river restoration.

Résumé

La majeure partie de la population suisse est aujourd'hui urbaine. Cette situation engendre des impacts non seulement sur le paysage, mais aussi sur la vie quotidienne de ses habitants. En effet, même si vivre en ville peut être très enrichissant, cela peut également affecter la santé. Ces dernières années, une augmentation du nombre de maladies non infectieuses liées au stress et à la sédentarité est ainsi constatée. Une planification urbaine adéquate peut cependant aider à pallier ce problème. Elle encourage l'aménagement d'espaces publics qui permettent la résilience psychologique et incitent à la pratique d'une activité physique régulière. Le développement d'espaces verts à caractère naturel dans les zones urbaines est particulièrement reconnu comme ayant des répercussions positives sur la qualité de vie. Les abords de rivières sont représentatifs de tels espaces, puisqu'ils sont abondants en Suisse et sont facilement accessibles. Ce travail de mémoire se concentre sur leur utilisation comme zones récréatives de proximité ou comme support de restauration psychologique en milieu péri-urbain.

Cette étude inclut deux conceptions différentes du paysage. L'une le considère comme un « espace », et l'autre comme une « place ». Ces deux approches sont intégrées dans un cadre conceptuel robuste et holistique qui permet de faire le lien entre modélisation et analyses locales. Cette intégration permet de mieux comprendre les propriétés physiques qui influencent les préférences des individus en termes de paysages alluviaux. En outre, elle rend possible l'identification des valeurs que la population attribue aux rivières. Pour ce faire, des outils SIG ont été développés afin de calculer l'accessibilité des rivières, ainsi que leur utilisation comme zones récréatives ou comme support de restauration psychologique pour les piétons et les cyclistes. Pour représenter cette utilisation récréative et restauratrice, une méthode simple et transparente basée sur la combinaison des paramètres « accessibilité », « aptitude paysagère » et « niveau d'infrastructures » a été mise sur pied. Les différentes analyses constituant le cadre conceptuel ont quant à elles permis de définir divers types d'utilisation spécifique des rivières. Par conséquent, il est possible de suggérer des catégories de mesures d'amélioration qui correspondent à chaque type particulier d'utilisation. De plus, l'identification des conflits potentiels qui peuvent surgir dans le cadre de l'usage récréatif des paysages de rivières est facilitée.

Les résultats de ce travail indiquent que tous les cours d'eau situés dans un rayon de trois kilomètres autour des principales zones habitées devraient être pris en compte dans la planification de l'utilisation récréative des rivières. L'analyse souligne également qu'il est important de considérer l'extension spatiale et la connectivité des zones résidentielles dans la planification urbaine. L'évaluation du modèle SIG démontre qu'il est bien adapté pour représenter l'utilisation des rivières par les piétons. En revanche, ce travail met en évidence qu'il rencontre des difficultés à le faire dans le cas des cyclistes. Dans le contexte général de l'urbanisation croissante, le cadre conceptuel révèle l'importance de bien planifier l'amélioration de la fonction restauratrice des éléments paysagers. De plus, il relève la nécessité d'entreprendre ces mesures en priorité pour des éléments déjà intégrés dans le paysage urbain. En effet, ces derniers sont souvent très fréquentés puisqu'ils font déjà partie du paysage familier de la population. Leur amélioration structurelle peut alors offrir des opportunités de micro-restauration psychologique.

De plus, de tels aménagements réduisent les coûts supportés par la société puisqu'ils limitent la construction de nouvelles infrastructures récréatives, ils densifient les villes et préservent leur héritage historique et culturel.

En conclusion, ce travail présente un panel d'outils SIG bien intégrés au sein d'un cadre conceptuel innovant. Il permet de faciliter les processus de décision en matière de planification urbaine et de restauration de rivières en milieu péri-urbain, en combinant à la fois modélisation et analyses locales.

Zusammenfassung

Ein Grossteil der Schweizer Bevölkerung wohnt in urbanen Gebieten. Dies hat nicht nur einen Einfluss auf die Landschaft, sondern auch auf den Lebensstil der Gesellschaft. In der Stadt zu leben eröffnet den Zugang zu vielen Dienstleistungen und kann sehr erfüllend sein, doch kann es gleichzeitig gesundheitlich auch weniger positive Auswirkungen mit sich bringen, insbesondere mit Stress zusammenhängende und nicht-infektiöse Erkrankungen. Hier kann die städtebauliche Planung eine entscheidende, positive Rolle spielen, indem der öffentliche Raum so gestaltet wird, dass psychologische Erholungsprozesse gefördert werden und zur regelmässigen Ausübung körperlicher Aktivitäten animiert wird. Insbesondere hat die Förderung von naturnahen Landschaftselementen inmitten menschlich gestalteter Umgebungen einen positiven Einfluss auf das Wohlergehen. Ein gutes Beispiel für solche Elemente sind Flüsse: sie sind in der ganzen Schweiz meist leicht für die Bevölkerung zugänglich. Diese Masterarbeit rückt daher Flüsse und ihre Nutzung als Naherholungsgebiete im peri-urbanen Raum in den Fokus.

Diese Studie greift zwei verschiedene Ansätze der Landschaftswahrnehmung auf, nämlich der Landschaft als „Ort" wie auch als „Raum". Darauf abzielend, die Lücke zwischen Modellierung und lokaler Kontextanalyse zu schlagen, sind diese beiden Ansätze in ein robustes und ganzheitliches konzeptuelles Framework eingebettet. Dies führt zu tieferem Verständnis über die Vorlieben von Erholungssuchenden bezüglich physikalischer Eigenschaften von Flussgebieten, aber auch darüber, welche Werte man Gewässern attribuiert. Um die Zugänglichkeit von Flüssen zu berechnen und ihre Erholungsnutzung zu kartieren wurden GIS-basierte Tools für vier verschiedene Transportmittel entwickelt. Zu diesem Zweck wurde eine einfache und transparente Methode erstellt und angewendet, welche die drei Parameter „Zugänglichkeit", „Landschafts-Eignung" und „Infrastruktur-Angebot" kombiniert. Des Weiteren erlaubte das konzeptuelle Framework, welches lokalhistorisches Wissen und eine lokale Kontextanalyse in sich vereinigt, Muster für spezifische Nutzungen von Flüssen zu entdecken. So können entsprechende Optimierungsmassnahmen vorgeschlagen oder auch potenzielle Konflikte identifiziert werden, welche im Rahmen der Erholungsplanung entlang von Flüssen entstehen können.

Die Resultate der Zugänglichkeits-Berechnung ergaben, dass für die Erholungsplanung entlang von Flüssen ein minimaler Radius von 3 km um die am dichtesten besiedelten Gebiete berücksichtigt werden sollte. Weiter zeigte die Analyse auf, wie wichtig es ist, die Ausdehnung und Konnektivität von Wohngebieten zu berücksichtigen. Die GIS-basierte Evaluation des Modells zeigte, dass die Erholungsnutzung von Flüssen durch Fussgänger ziemlich gut repräsentiert wurde, wohingegen bei der Repräsentation der Velofahrer Schwierigkeiten aufgetreten sind. Im globalen Kontext der Urbanisierung betonte das konzeptuelle Framework die Wichtigkeit der folgenden beiden Punkte: a) die Optimierung funktioneller, städtischer Landschaftselemente sollte gut geplant sein und b) sollten solche Massnahmen prioritär auf bereits existierende Elemente angewendet werden. Tatsächlich werden gerade solche, vor allem als Teil der alltäglichen Landschaft wahrgenommenen Elemente, stark frequentiert. Deren strukturelle Verbesserung kann Passanten Mikro-Erholungs-Erfahrungen bescheren.

Dies kann Kosten reduzieren, weil so auf Neugestaltungen von Erholungsinstallationen verzichtet werden kann. Gleichzeitig werden dadurch einerseits die Städte verdichtet, und anderseits kann so das kulturelle und historische, urbane Erbe erhalten bleiben.

Die vorliegende Masterarbeit liefert eine Sammlung von in einem konzeptuellen Framework eingebetteten, GIS-basierten Tools, welche die beiden Ansätze zur Landschaftswahrnehmung „Ort" und „Raum" vereinigt. Somit kann sie dazu beitragen, die Entscheidungsfindung in der städtebaulichen Planung und bei klein-skaligen Flusssanierungen zu erleichtern.

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I. Introduction

I. 1 Research context

Nowadays, most of the Swiss population – as in many other European countries – is urban. According to the Population and Households Statistics, the proportion of permanent residents in urban areas reached about 75% of the overall population by the end of 2010 (FSO, 2011). In addition, most of the transport infrastructures, the economic activities and the housing facilities of the country are situated in the central Plateau due to the physical restrictions presented by the Alps. The concentration of intense land-use activities on this narrow stretch of land accounting for less than 27% of Switzerland's total surface area makes it one of the most densely populated regions in Europe (FSO, 2001).

I. 1. 1 Impacts of urbanization on health and well being

This high level of urbanization not only affects the landscape of the area, but also its population's lifestyle. Physical activities, working patterns or food habits are in fact highly influenced by the urban environment, as reported in 2005 by Gunnar Tellnes, president of the European Public Health Association. In his article, Tellnes states that the repercussions of urbanization on public health are both positive and negative. On the one hand, living in cities offers a rich, diverse and fulfilling environment through the many practical, social, recreational and interactional opportunities it provides. On the other hand, urban lifestyles are often associated with sedentary and stressful living conditions, linked to the presence of chronic and non-infectious diseases, such as cardiovascular diseases, diabetes 2, cancers or chronic stress. In this regard, the Swiss Federal Office of Public Health (FOPH) estimates the annual number of premature deaths caused by the global sedentary way of life to be more than 2,900. In addition, it assesses the direct treatment costs produced by this phenomenon to reach about 2.4 billion CHF annually (FOPH, 2007). In parallel, chronic stress is also becoming a challenge for public health. In 2010, the State Secretariat for Economic Affairs (SECO) mandated a study to assess the extent of this trend. In the study's final report, it states: "In 2010, about one third of the employed working population in Switzerland (34%) declared being often or even very often stressed" (Grebner, Berlowitz, Alvaredo, & Cassina, 2011, p. 5, translated from German). Therefore, the consequences of chronic stress (irritability, depression, lower working efficiency, etc.) and its cost to society are recognised more and more as being a public issue (Ramaciotti & Perriard, 2000).

To tackle these new problems, it is necessary to involve different fields of study and develop an interdisciplinary and integrative analysis of the situation. The promotion of an active lifestyle that encourages physical and mental health should encompass the social, natural and built environment of urban populations. In fact, the way cities and their surroundings are designed can greatly influence the behaviour of their inhabitants (Edwards & Tsouros, 2006, p. vii). In this context, inputs from clinical medicine, psychology or other health-related fields are needed, as well as the account of the interrelationship between societies and their natural or built environment (Edwards & Tsouros, 2006, p. x).

> This relationship was recently the subject of an international conference entitled "Landscape and Health: effects, potential and strategies" held in January 2012 at the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL). Among the many conclusions of this conference (Bauer & Bernasconi, 2012), three are of particular interest in the context of the present master thesis. Firstly, it appears that the positive influences of landscapes on people are not only due to their physical characteristics, but also to the individuals' mental representations of these landscapes. Secondly, the main positive impacts of near-natural landscapes on people are of two types. On the one hand, they provide spaces encouraging regular physical activity, thus reducing the risks of chronic and non-infectious diseases. On the other hand, they offer a space for recovery from daily stress and hassles. Finally, it also became apparent in the course of the conference that it is necessary to find a way to better apply these theoretical findings in practice. These three aspects are core elements of the present master thesis.

I. 1. 2 "Space" and "place" approaches towards landscape perception

Many studies have already investigated the complex relationship linking people and their surrounding landscapes. Hunziker, Buchecker & Hartig (2007) established a comprehensive synthesis of these pieces of work in their article "Space and place – two aspects of the human-landscape relationship". According to them, two main categories of landscape perception theories can be distinguished: those considering landscape as "place" and those considering landscape as "space".

The former category interprets landscape preferences as reflecting mainly the biological needs of individuals (Hunziker et al., 2007, p.59). In line with these theories, people would tend to prefer landscapes having physical characteristics fulfilling their needs and whose particular features would have helped the survival of the first humans. Some notable theories that arise from this category of landscape perception include the Savannah theory (Orians, 1986, as cited in Hunziker et al., 2007), the prospect-refuge theory (Appleton, 1975, as cited in Hunziker et al., 2007) and the information processing theory (Kaplan & Kaplan, 1989, as cited in Hunziker et al., 2007).

The latter ("landscape as space") category considers landscape preferences as reflecting people's values, norms, and their intrinsic need for internal (self-reflexion) as well as external (integration) identification processes (Hunziker et al., 2007, p.61). In other words, they assume that people take their surrounding landscapes and transform them through personal, social and cultural mechanisms. In this way, they turn "spaces" into "places" that reflect their norms and values and allow them to strengthen and stabilise essential constituting processes such as the sense of belonging and the sense of self (Hunziker et al., 2007, p.61).

That said, not all landscapes have the same potential of imparting a positive impact on individuals. Matsuoka & Kaplan (2008) reviewed 90 articles published in *Landscape and urban planning* over the past 16 years. Their conclusions are clear: There is strong evidence that natural landscapes have a positive impact on human wellbeing, and this to a significantly larger extent than built environments.

This need for natural landscapes seems to be particularly important to urban populations. In addition, the authors also determined that the need of urban individuals to have frequent exposure to nature is very similar across various political and social systems.

> For example, Annear, Cushman & Gidlow (2009) conducted a study in New Zealand and concluded that the promotion of physical activities in deprived neighbourhoods could be fostered by an appraisal of their physical and natural environment. Korpela, Ylen, Tyrvainen & Sylvennoinen (2010) assessed the importance of natural settings on restorative experiences in Finland and found that the benefits were higher in extensively managed water and forest settings than in urban settings such as parks. More recently, Buchecker, Degenhardt & Kienast (2012) found evidence that Swiss people performing outdoor recreational activities consider their wellbeing and their resilience as being significantly higher than those performing alternative indoor activities. Furthermore, studies (Jerret & Wolch, 2012; Pirchio, Passiatore, Scapelliti, & Carrus, 2012) performed in the United States and in Italy tend to demonstrate a positive relationship between the visitation of green outdoor areas and the physical and mental health of children. Lastly, the preference for natural settings is also revealed in several studies by greater housing property prices (Jim & Chen, 2006; Lange & Schaeffer, 2001; Luttik, 2000) as well as by a propensity of urban inhabitants to possess leisure homes outside of the cities (Hartig, Fransson, & Amcoff, 2012).

I. 1. 3 Mapping landscapes' recreational potential

Based on the knowledge of the positive influence of natural settings on people, many efforts have been made to assess the potential of different landscape features to provide the population with recreational opportunities. In this context, recreation can be considered as an important landscape service in that it encourages both physical and mental wellbeing (Kienast, Degenhardt, Weilenmann, Wager, & Buchecker, 2012). To spatially map those landscape features most appreciated by people, three groups of approaches can be differentiated.

The first one consists of the "space" approach towards landscape. It uses physical landscape characteristics to model the recreational suitability of different kinds of landscape settings (Bestard & Font, 2009; de Vries & Goossen, 2002; Gul, Orucu, & Karaka, 2006; Kienast et al., 2012; Kliskey, 2000; Ode & Fry, 2006). It is based on the hypothesis that people's preferences are driven by the array of physical characteristics in a landscape.

The second set of approaches can be defined as the "sense of place" (Raymond et al., 2009) approach and consists of the GIS-based mapping of community values (Alessa, Kliskey, & Brown, 2008; Brown & Raymond, 2007; McIntyre, Moore, & Yuan, 2008; Raymond et al., 2009; Tyrvainen, Makinen, & Schipperijn, 2007). Following this approach allows for better understanding and spatially displaying the values people attribute to their surrounding landscapes in order to define places that accumulate a high diversity of values, e.g. "hotspots". This category of approach is in line with the perception of landscape as "place".

Finally, a third orientation of the research field can be defined as those approaches that try to combine both ways of reasoning. For example, Alessa et al. (2008) defined "[…] geographical areas where both human-perceived and physically measured ecological values overlap and are referred to as social–ecological hotspots" (p.27). Similarly, Caspersen & Olafsson (2010) as well as Kurdoglu & Kurdoglu (2010) incorporated both physical and socio-cultural landscape proxies into their mapping of recreational suitability in Great Kopenhagen and along a portion of the ancient Silk Road in Turkey, respectively. The integration of these different approaches results in a more comprehensive understanding of a landscape's potential to fulfil the recreational needs of humans.

I. 2 Goals and scope of the study

In line with these previous studies, the aim of the present master thesis is to define the recreational use and the further recreational or restorative potential of a specific landscape feature. In order to better understand the appeal of a particular landscape feature to people, both approaches towards landscape perception – "space" and "place" – are integrated into the analysis. This combination is, however, not performed in the same way as Alessa et al. (2008), Caspersen & Olafsson (2010) or Kurdoglu & Kurdoglu (2010); instead of directly combining both objective landscape physical attributes and people's values into the same model, two complementary approaches are used.

In a first step, a GIS-based model of the actual and potential recreational use including objective physical landscape characteristics is set up. This step consists of a simple and transparent model that includes only a few parameters. In a second step, different methods - including the mapping of observed recreational use, a questionnaire survey, an interview and a short historical assessment - are used to gain further insight into the relationship between the population and the given landscape feature. Combining these methods allows for the incorporation of local knowledge and expertise into the study. Indeed, the integration of local stakeholders and their broad knowledge of the local context enhances the understanding of the complex relationship between a population and its environment. This necessity of recognising and empowering local expertise in environmental management was already acknowledged by Raymond et al. (2009) in their study on the mapping of community values.

However, this study is not just about recreation. It also incorporates landscape features with low recreational use, but whose potential to provide psychologically restorative experiences is high and should thus be accounted for in urban planning.

Before concluding, it is necessary to emphasize that an exhaustive analysis of community values and the psychological bond between people and the selected landscape feature would be beyond the scope of this master thesis. Consequently, the analysis of the landscape as "place" should be considered more as an important complement to the modelling approach rather than as a complete and independent assessment.

I. 2. 1 The meaning of "recreation"

As already mentioned, recreation can be considered as an important landscape service (Kienast et al., 2012). Nonetheless, "recreation" is a rather imprecise term and requires a more specific definition relevant for this study. Recreation in peri-urban areas can be classified based on its geographical scope as follows (Schubert, 2000, as cited in Spiess, Wasem, & Burkart, 2008, translated from German):

- Proximity recreation areas: recreational areas situated in the immediate vicinity of the place of residence
- Nearby recreation areas: recreational areas situated within or in the vicinity of the city
- Distant recreation areas: resort areas used during holidays

In the context of this master thesis, only nearby recreation is considered, since spatial planning in peri-urban areas is mainly dealing with this form of recreation. More specifically, nearby recreation areas can be further defined as the following:

> Recreation areas situated in the vicinity or in the surroundings of the urban settlement, serving mainly as end-of-the-day and weekend recreation areas. Nearby recreation areas are usually connected to the urban settlement. In order to reach them, no more than 60-90 minutes per public transport or private means of transport are needed (Mönnecke, Wasem, Spiess, & Kumin, 2006, as cited in Spiess et al., 2008, p.11, translated from German).

Another characteristic of recreation is its time scope. As specified by Schubert (2000, as cited in Spiess et al., 2008), the following kinds of recreations can be defined: short recreation, end-of-the-day recreation, half-day recreation and daylong recreation. In this study, only short recreation of a maximum of 1.5 hours is taken into account. In fact, questionnaire surveys conducted in Swiss peri-urban cities (St. Gallen, Frauenfeld, Langenthal and Delémont) revealed that most respondents remained in their nearby recreation areas for this amount of time (Irngartinger, Degenhardt, & Buchecker, 2010; Kienast et al., 2012).

Finally, the main recreational activities accounted for in the framework of this master thesis are: walking, jogging, biking, inline skating, bathing, playing at playgrounds, and relaxing.

I. 2. 2 Rivers as important landscape features in the context of nearby recreation

In the Central Plateau, the landscape accessible to people for short nearby recreation is characterized by a large diversity of features: forests, agricultural lands, settlement areas, urban green areas, lakes, and rivers. For several reasons discussed below, the specific landscape feature on which this master thesis focuses consists of watercourses.

Firstly, Switzerland contains a dense hydrographical network as a result of its geographical and climatic characteristics. Several of the main rivers of the country are situated in the Central Plateau and many of its cities are built along them. Rivers are therefore present almost everywhere and are usually highly accessible to the population.

Secondly, rivers and other watercourses are heavily impacted by human activities and have been at the centre of human settlement for several centuries. On the one hand, they have been necessary water provisioning systems, transport and communication networks, and protective defensive barriers. But on the other hand, they have also been responsible for destructive flooding incidents, diseases and other damages. Today, after having been strengthened, canalised and diverted in the course of the 19th and 20th centuries, many watercourses are being restored (Hobi, 2008). These restoration efforts started in the 1990s and follow a philosophical change in the Swiss flooding protection paradigm towards giving more space to watercourses (Hostman, 2005). While flood protection is often the main motivation for restoration, these projects must also include an appraisal of the river's ecological functioning (Hostman, 2005). Even if federal prescriptions stipulate that the recreational use of rivers should also be accounted for in restoration projects, its practical inclusion is often still problematic (Junker, 2008). A better understanding and integration of this aspect could help to increase the acceptance of such realisations by the population (Junker, 2008).

Lastly, rivers are continuous elements whose recreational use and potential are rather difficult to model. While an example of mapping landscape value along a river can be found in the literature (Zhu, Pfueller, Whitelaw, & Winter, 2010), no attempt to map a river's recreational use exists in the international literature. Such examples only exist for discrete landscape elements such as woodlands (Colson, Garcia, Rondeux, & Lejeune, 2010; Ode & Fry, 2006), beaches (Coombes et al., 2009), agricultural farmlands (Gimona & van der Horst, 2007), urban green areas (Caspersen & Olafsson, 2010) or nature parks (Gul et al., 2006).

To sum up, rivers are especially interesting to study because of their broad distribution range in the Swiss Plateau, the many restoration projects focused on them and their continuous character, which makes them only partially studied at the international level.

I. 2. 3 Previous studies on the recreational potential of rivers in Switzerland

At the Swiss scale, however, a few studies already exist regarding rivers and their use as recreational areas. In 2011, Benkler performed an assessment of the recreational value of the Sense (Canton of Fribourg) to observe which stretches of the river were most well-known, which kinds of activities where performed by people visiting them, and which landscape properties in their vicinity where most attractive to their visitors.

Spiess et al. (2008) were commissioned by the Canton of Zürich's Department for Waste, Water, Energy and Air to conduct a pilot study on the recreational potential of rivers in the region. They assessed the improvement potential of rivers and streams for recreation in the Canton of Zürich, tackling the following questions: "How can the actual and the potential nearby recreation value be assessed?" and "What is the improvement potential of the individual rivers and streams for recreation?" (Spiess et al., 2008, p. 6, translated from German).

> By means of a GIS-based model - tested in three urban cities – Spiess et al. (2008) managed to define which river stretches already have a high recreational value and which of them have the potential to improve their recreational capacity. This pilot project was developed because the Canton of Zürich wanted to establish cantonal maps that would enable them to spatially prioritise restoration projects along rivers according to their ecological, recreational and flood protection potential.

More recently, Huber (2012) developed GIS-based models to assess both rivers suitability for recreational purposes and the potential number of people able to reach each river stretches. This analysis is based on 16 physical landscape characteristics combined in different GIS-layers and tested at a regional scale in the Canton of Zürich.

I. 3 Research questions and structure of the report

This master thesis builds up on previous studies and especially on the modelling approaches of Spiess et al. (2008) and Huber (2012). It combines a variety of different approaches in order to assess the recreational value, the recreational potential and the psychological restoration potential of rivers at a study site in the Swiss Plateau. In particular, the following research questions are addressed:

1. How to model the accessibility of watercourses for pedestrians, cyclists, car drivers and users of public transport?

2. How to model the actual and the potential nearby recreational use of rivers by pedestrians and cyclists in and around the city of Aarau?

3. How to combine the "space" and "place" approaches towards landscape perception in order to better understand the potential of rivers for providing short nearby recreation and psychological restoration in and around the city of Aarau?

4. What is the improvement potential of rivers regarding short nearby recreation and psychological restoration in and around the city of Aarau?

Only pedestrians and cyclists were accounted for in the modelling approach of the recreational and restorative potential of rivers, for practical reasons. In fact, it is easy to identify these two categories of users when observing people present along watercourses. Conversely, it is impossible to assess which individuals are actually car drivers or users of public transport. In consequence, it would have been difficult to evaluate the model for these two categories of users without conducting time-consuming interviews.

In the first section of this thesis, a description of the study area, together with its rivers characteristics and the geographical repartition of its population, is given. The conceptual framework of the analysis is then presented, followed by a detailed description of the methods used for the different approaches. Because of the interdisciplinary nature of the study that prevents a stricter distinction between results and interpretation, the findings are directly accompanied by their interpretation. In the next section, a more comprehensive discussion of the results broadens the scope of the study and links the findings to their applicability in planning. Finally, a synthesis of the analysis is presented along with some practical recommendations.

II. Material and methods

II. 1. Study area

The GIS-based model and the conceptual framework developed in this study were applied to the city of Aarau. This city was chosen as a test site because of its central position in the Swiss Plateau and its many rivers and watercourses of different sizes and various eco-morphological qualities.

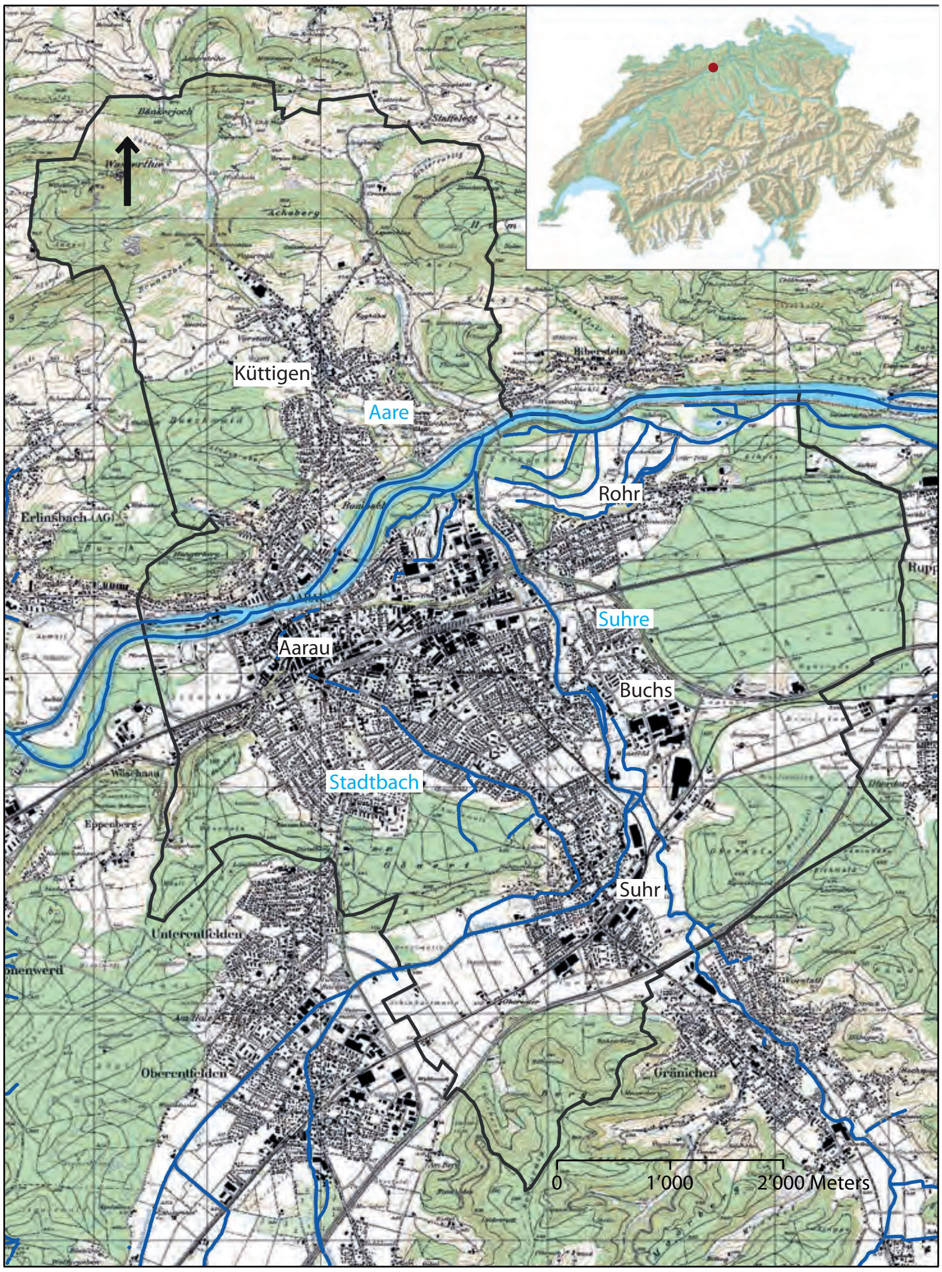

Fig.1. Location of the city of Aarau (red circle, upper-right corner) and the source population area. The black perimeter delimits the extent of the source population area, with the main rivers displayed in dark blue. City names are written in black, river names in blue. The village of Rohr – which officially became part of Aarau's community in 2010 – is included in order to facilitate the spatial localisation of the rivers in the next chapters. Sources: © 2005 Swisstopo (Upper right image), © 2008 FOEN (Eco-morphological state of Swiss rivers), © 2012 Swisstopo (Topographical map).

Aarau is a middle-sized city located west of Zürich in the Aare valley, between Olten and Brugg. The historical centre is built on a rocky outcrop dominating the river on its right bank. The modern city is still situated mainly on the river's right bank, except for a few estates established across the main bridge crossing the Aare.

As the urban settlement of Aarau spreads outside of the strict boundaries of the city, the neighbouring villages of Kütigen, Suhre and Buchs were also included in the analysis. In practical terms, this means that the study was conducted in reference to the population of these four communities. For that reason, they are referred to as the "source population area" in this study (Fig. 1). In addition, even if the study perimeter is often referred to as "Aarau", this term refers to all communities of the source population area.

The complete study perimeter actually entails all river stretches accessible to the source population for short nearby recreation. As car drivers have a high mobility and can easily reach distant destinations, the overall study perimeter covers about 90 km² and extends approximately from Olten to Brugg. A comprehensive view of this perimeter is available for consultation in appendix A 1, p. 106.

II. 1. 1. Description of Rivers

Rivers can be characterized most notably by their morphological (length, width, number of meanders, etc.), hydrological (average debit, peek debits, etc.) and eco-morphological characteristics.

> Eco-morphology describes the structural state of watercourses and their banks (state of the riverbed, presence of artificial steps, dams, etc.). It gives an indication of the level of impact that human activities have had on the river, without accounting for their chemical or biological quality (Hütte & Niederhauser, 1998). In Switzerland, the eco-morphological state of each watercourse is evaluated according to 5 classes (Hütte & Niederhauser, 1998, p. 34):
>
> - Class 1: The watercourse is natural or near-natural
> - Class 2: The watercourse is little affected by human influence
> - Class 3: The watercourse is highly affected by human influence
> - Class 4: The watercourse is artificial
> - Class 5: The watercourse is underground

Underground watercourses were not accounted for in the present master thesis as they cannot be used for recreation. Likewise, not all streams and other watercourses flowing through Aarau were used for the analysis since many of them are very narrow and dry out during certain periods of the year, making them unsuitable for an assessment of their yearly recreational potential. Therefore, only three main rivers were chosen to assess in this study based on their central position within the urban settlement of Aarau and their perennial character. These three rivers are displayed in figure 2 and briefly described below:

Aare: The Aare (Fig. 2. A) is about 288 km long, making it the second longest river in Switzerland after the Rhein (FOEN, 2006). It rises in the Bernese Alps, flows across the Swiss Plateau and finally joins the Rhein in Koblenz (Aare, 2012). Its average annual debit in 2010 was 284 m^3/s at the Brugg measuring station, just downstream of Aarau (FOEN, n.d.). The section of the Aare situated at the foot of the old town, i.e. where the river is united into a single branch, is referred to as "Aare's central section" in this study.

The width of the river varies in the vicinity of Aarau from 40 m when the river is separated into branches, to 90 m when it is unified, while its eco-morphological quality (Fig. 3) usually varies from "little affected" to "highly affected" (© 2008 FOEN). Several dams are located along the river for the exploitation of hydroelectric power (R. Strebel, personal communication, June 22, 2012). In these areas and around the bridges crossing the river, the watercourse is artificial.

Suhre: The Suhre (Fig. 2. B) is about 34 km long (FOEN, 2006). Its source is in the lake of Sempach (Canton of Luzern) after which the river flows across the Suhre valley and meets with the Aare in Aarau (Suhre, 2012). Its average annual debit in 2010 was 1,46 m^3/s at the Oberkirch measuring station, upstream from Aarau, near its source (FOEN, n.d.). In the vicinity of Aarau, the river's width varies between 10 and 15 m, while its eco-morphological quality is generally better than in the case of the Aare (© 2008 FOEN). It is mainly "little affected", except for the stretch situated near the village of Suhr, which is "highly affected" (Fig.3).

Stadtbach: The Stadtbach (Fig. 2. C) is a small stream arising near the village of Suhr, crossing the city of Aarau and flowing into the Aare. It is only about 4.5 km long (Stadtbach, 2012) and its width varies between 2 and 4 m (© 2008 FOEN). At the level of the old town, it separates into several branches.

The first branch flows around the old city from the west and directly flows into the Aare. The other branches are partly underground and cross the old city, where some of their water is being pumped and diverted into open canals indicating the presence of the stream (R. Strebel, personal communication, June 22, 2012). The remaining water flows underground, and the different branches unify at the foot of the old town. The stream then flows eastwards and crosses the modern estates of the city before finally meeting with the Aare. This last stretch was restored and belongs to the eco-morphological class "little affected" (Fig. 3). In contrast, the southern segment of the Stadtbach – i.e. near the village of Suhr – remains "highly affected", while its northern stretch is "artificial" (© 2008 FOEN).

Fig. 2. **Main watercourses assessed in the study**. The Aare at the level of the old town, with a hydroelectric power plant in the background (A), The Suhre, east of the village of Suhr (B), The Stadtbach, south of the old town (C). Sources: Pictures taken by Sophie Rudolf, 2012.

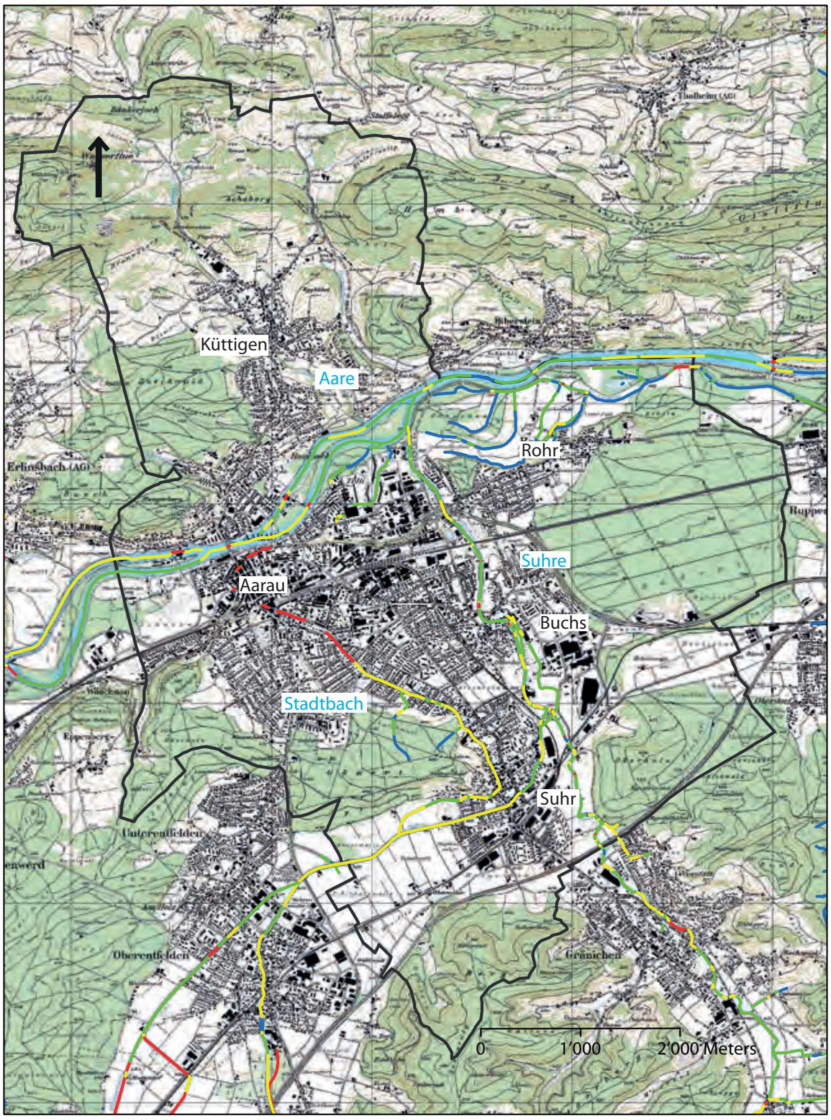

Fig. 3. **Eco-morphological quality of the main rivers and streams around Aarau**. The black perimeter delimits the extent of the source population area. Stretches of class 1 (natural or near-natural) are displayed in blue, stretches of class 2 (little affected) are displayed in green, stretches of class 3 (highly affected) are displayed in yellow and stretches of class 4 (artificial) are displayed in red. Sources: © 2008 FOEN (Eco-morphological state of Swiss rivers), © 2012 Swisstopo (Topographical map).

II. 1.2. Geographical repartition of the population

The analysis of the geographical repartition of the population was performed using the data of the federal population census of 2000, since census data for 2010 were not yet available at the beginning of the thesis. Consequently, the population numbers presented below refer to the year 2000 (© 2012 FSO GEOSTAT) with the population of Rohr counted separately, since the village was not yet part of the city of Aarau in 2000.

The total source population area comprises 37,582 inhabitants, including the population of Aarau, Küttigen, Suhr, Buchs and Rohr. Of this total, 15,838 people live in Aarau, 4,882 in Küttigen, 8,625 in Suhr, 5,726 in Buchs and 2,511 in Rohr. Figure 4 displays the geographical repartition of the population in the source population area.

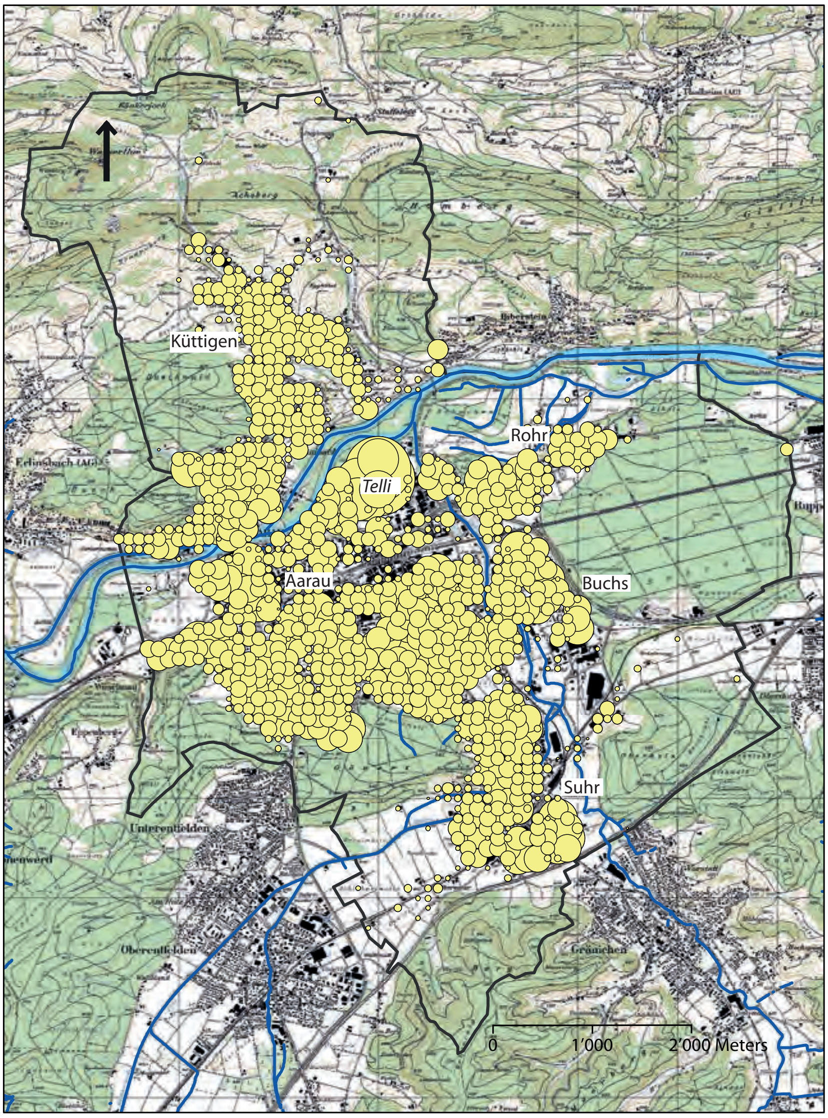

Fig. 4. Geographical repartition of the population. Each circle represents the number of people living in a 100 x 100 m square. Their radius is proportional to the number of people living in that particular 100 x 100 m square. The black perimeter delimits the extent of the source population area. The village of Rohr is displayed, as it was not yet part of the city of Aarau in 2000, and the estate of Telli is displayed in order to facilitate its location. Sources: © 2012 OFS GEOSTAT (Population census), © 2008 FOEN (Eco-morphological state of Swiss rivers), © 2012 Swisstopo (Topographical map).

Because of their very small number of inhabitants (less than 10 people per 100 m^2), the industrial estates are easily identifiable at the centre of the source population area and along the Suhre between Buchs and Suhr. A large residential area situated in the southern half of Aarau is noticeable along the Stadtbach and the Suhre, where the population density reaches between 20 and 50 inhabitants per 100 m^2. Lastly, the main populated areas (counting between 50 and 150 inhabitants per 100 m^2) are located in the old city centre of Aarau, at the extreme south of the village of Suhr and on the right bank of the Aare, just before the confluence of the Suhre. In particular, this last estate – "Telli" – has a very high population density that may be as high as 565 people per 100 m^2 (Fig. 4). "Telli" is actually composed of large buildings built between 1970 and 1990 in a modern architectural style in order to accommodate a very high number of people.

II. 2. General structure of the analysis

In order to determine each river's potential for improvement regarding recreational or restorative opportunities, a GIS modelling approach was used in combination with other analyses. The GIS model mapped the recreational use of rivers according to parameters described in the literature as having a decisive influence on recreation. In fact, several studies were conducted in Switzerland over the past 5 years in order to assess which landscape features and which socio-cultural or structural parameters have a positive or negative impact on recreation in general (Degenhardt, Frick, Buchecker, & Gutscher, 2011; Degenhardt, Kienast, & Buchecker, 2010; Irngartinger et al., 2010; Kienast et al., 2012; Wäger, 2010) or on rivers' perception in particular (Benkler, 2011; Huber, 2012; Junker, 2008; Spiess et al., 2008).

However, none of these studies give a precise assessment of the importance of each parameter relative to each other, with the exception of Kienast et al. (2012). Because of the difficulty of quantifying and weighting the relative importance of different landscape features on recreation, it was decided to retain as few parameters as possible in the GIS model. The analysis was further completed with alternative approaches (people count, local knowledge analysis, historical analysis, local context analysis) in order to compensate for the knowledge gaps and determine the improvement potential.

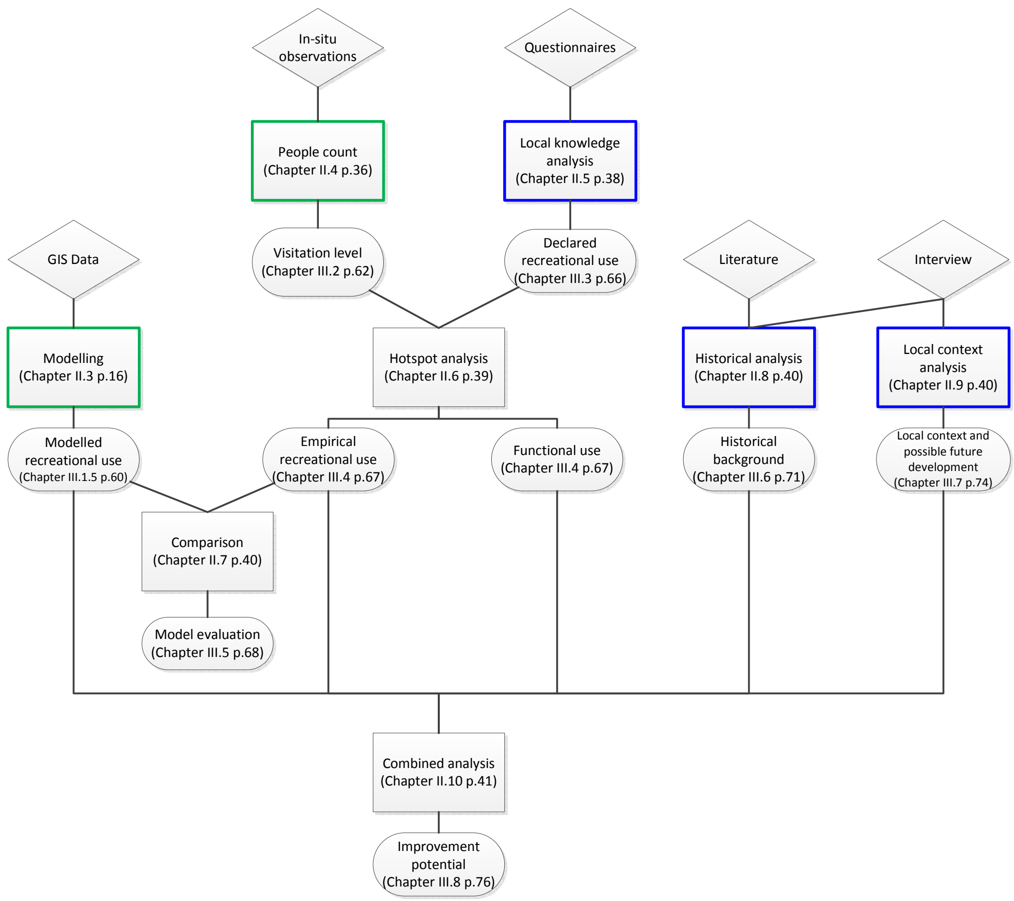

Fig. 5. Conceptual framework of the analysis. Diamonds represent input data, squares represent analyses methods and ellipses represent results. Methods in line with the representation of landscapes as "space" are circled in green, while those in line with the representation of landscape as "place" are circled in blue.

The resulting conceptual framework can be described as follows (Fig. 5):

First, the modelling approach using GIS data helped determine the recreational use of rivers around the city of Aarau both for pedestrians and cyclists. The number of individuals present along each of the rivers was then measured in order to determine the actual visitation level according to in-situ observations. In parallel, questionnaires were sent to the tourism office and to employees of Aarau's municipality in order to determine the declared recreational use of rivers according to the analysis of their local knowledge.

Based on this, it was possible to perform a combined hotspot analysis to determine a) the empirical recreational use of rivers and b) their functional use (rivers not visited for recreational purposes, but which are part of the everyday landscape of the population), characterized by a high visitation rate but a low recreational use. By comparing the results of the empirical recreational use to the model, it was then possible to make an evaluation of the modelling approach to assess its representativeness and its accuracy, both in the case of pedestrians and cyclists.

A complementary historical analysis of literature, together with an interview of the municipal representative in charge of rivers in the city of Aarau, provided insight into the historical evolution of the rivers and the values they may carry for people. In addition, the interview with the municipal representative also enabled a better understanding of the local context and an estimation of the possible future development regarding rivers in Aarau.

The use of all these different approaches in a combined analysis helped to determine which river stretches in Aarau have the potential to offer more recreational or restorative experiences to people. Each of the specific approaches is described in more detail in the following chapters.

II. 3. Modelling

II. 3. 1. Modelling approach

The approach used for the setting up of the GIS-based model follows the work of Mönnecke et al. (2006, as cited in Spiess et al., 2008). According to them, three main parameters influence the recreational use of landscape features: accessibility, landscape suitability, and level of attractions and infrastructures. In this thesis, the parameter "attractions" was not taken into account in the analysis because it was too difficult to define precisely what people find attractive and to which extent (Fig. 6).

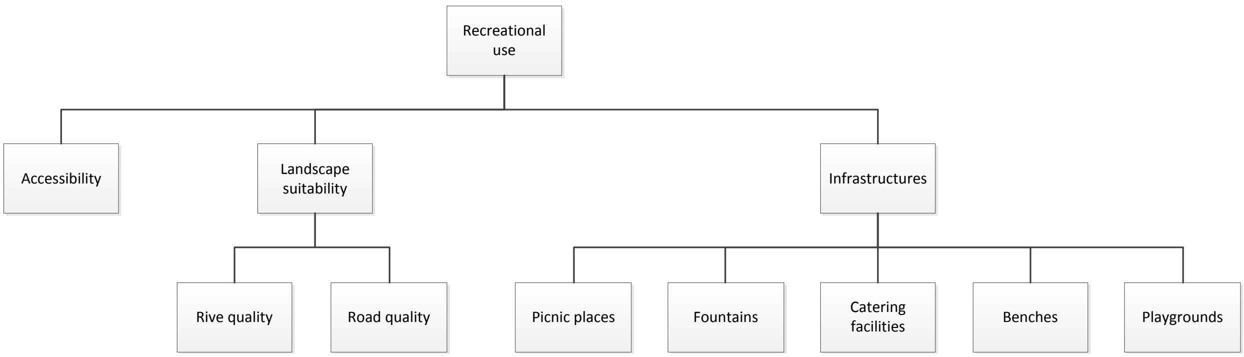

Fig. 6. Parameters influencing the recreational use of landscape features. Source: Mönnecke et al., 2006, as cited in Spiess et al., 2008, modified.

In the context of this study on recreation along rivers, several criteria were defined to represent the three main parameters:

Accessibility: Relative measure of the potential amount of people able to reach the river in the course of recreational activities.

Landscape suitability: Suitability of the river's stretch to provide recreational opportunities. In the model, this parameter depends on two criteria: the eco-morphological quality of the river itself and the quality of the road network bordering it.

Infrastructures: Amount and quality of small recreational infrastructures (picnic places, fountains, catering facilities, benches and playgrounds) distributed along the river.

Each of these criteria and parameters were represented as GIS layers and combined to obtain a final layer displaying the recreational use of rivers, as well as their improvement potential.

This report presents only the conceptual aspects of the modelling approach in order to foster its readability and understanding. The presentation of the models used for the creation of the maps as well as technical details can be obtained from the enclosed CD located at the end of the document.

II. 3. 2. GIS Data and software

The modelling approach was performed using the following GIS data layers:

- Topographical map of Switzerland, scale 1:25'000.
  Swisstopo. Raster Pixel map 1:25'000 (geolib.pk25). Map data: pixmaps © 2012 Swisstopo (5707 000 000) (map). Release: Federal Office of Topography swisstopo, Wabern, 2012.

- Swiss municipal boundaries.
  Swisstopo. Feature dataset (geolib.swissBOUNDARIES3D_2011_TLM_GRENZEN). Map data: swissBOUNDARIES3D © 2012 Swisstopo (5704 000 000) (map). Release: Federal Office of Topography swisstopo, Wabern, 2012.

- Swiss street network.
  Swisstopo. Feature dataset (geolib.str25). Map data: Vector25 © 2012 Swisstopo (DV 033594) (map). Release: Federal Office of Topography swisstopo, Waber, 2012.

- Eco-morphological state of Swiss rivers.
  FOEN. Feature class (omch_vec25_2008). Map data: © 2008 FOEN (map). Release: Federal Office for the Environment FOEN, Bern, 2008.

- Bus stops in the Canton of Aargau.
  AGIS. Feature class (bus_674_20001206). Map data: © 2006 AGIS (map). Release: Transport division, Entfelderstrasse, 5000 Aarau.

- Bus route network in the Canton of Aargau.
  AGIS. Feature class (bus_676_1_20001206). Map data: © 2006 AGIS (map). Release: Transport division, Entfelderstrasse, 5000 Aarau.

- Federal population census of 2000.
  OFS GEOSTAT. Feature class (geolib.XY_VZ00_PERS_HAUSHALT). Map data: © 2012 FSO GEOSTAT (map). Release: Federal Statistical Office FSO GEOSTAT, Neuchâtel.

The modelling, the map display and the calculations were performed using version 10.0 of ArcGIS:

- ESRI (Environmental Systems Research Institute), 2011. ArcGIS Desktop: Release 10.0. (Computer Software). Redlands, CA: ESRI.

II. 3. 3. Model accessibility

II. 3. 3. 1. Modelling the accessibility of a continuous landscape feature

As already mentioned in the introduction, few examples of recreational mapping exist for continuous features such as rivers. In fact, it is easier to model the accessibility of discrete elements (woodlands, beaches, urban green areas, etc.) because they usually possess a few distinct points of entrance, contrary to watercourses.

> For example, public parks are often enclosed by fences and include gates to access the park itself. In these conditions, it is relatively easy to identify precisely where each of their points of entrance are situated and to define the accessibility of the park as being the sum of all people potentially able to reach each gate. Such gates do not usually exist in the case of rivers because of the continuous nature of this landscape feature. In fact, they usually have their source upstream from the settled areas considered in the analysis, meeting with another watercourse or a sea downstream from it. There thus exist no clear and unambiguous points of entrance to rivers, particularly because each river segment could potentially be a point of access.

In order to assess the accessibility of rivers in the context of this study, it was decided to conceptually turn them from continuous to discrete features by determining all potential access points. This analysis was conducted for four different user types: pedestrians, cyclists, car drivers and public transport users, i.e. those user types most likely to access rivers for recreational purposes. Degenhardt et al. (2010) and Irngartinger et al. (2010) have already assessed their recreational behaviour in Swiss mid-sized cities.

The access points were determined differently depending on the user type. Two main parameters influenced their definition: the roads accessible to the different users (a description of the main Swiss road types can be consulted in the appendix C 1, p. 114) and the kind of rivers considered as being attractive to them. In the model, it was assumed that pedestrians and cyclists are attracted to all kinds of watercourses, regardless of size. Conversely, car drivers and people using public transport were considered as being mostly attracted by larger rivers. Consequently, only rivers having a width greater than 8 m were taken into account in the analysis of car drivers and public transport users, while all rivers were considered in the analysis of pedestrians and cyclists. The assumption driving this choice (Box 1) is partly based on the findings of Kienast et al. (2012).

Box 1. First model assumption.

Car drivers and people using public transport are mainly attracted by large rivers because their higher mobility allows them access to distinct landscape features. Conversely, small and narrow watercourses attract pedestrians because their reduced mobility does not allow them access to the same distinct landscape features. Likewise, the flexibility of cyclists makes them also attracted to small watercourses, in spite of their good mobility.

In their study, Kienast et al. (2012) noticed that "[…] persons reaching their locations by foot are "subjectively" more sensitive to landscape characteristics than mobile people (access by car, bicycle) but they go to close-by locations with less distinctive landscape characteristics" (p. 385). While they included cyclists in the category of "mobile people", this user group is considered as having the same characteristics as pedestrians in the context of this master thesis. In support of this, field observations in Aarau showed that cyclists were also very often observed along small and narrow rivers.

The types of roads and rivers used to determine access points to rivers for the different user groups are described in Table 1.

Table 1. Types of rivers and roads considered in the selection of access points and mean of selection for each user type.

User type	Roads considered	Rivers considered	Access points
Pedestrians	1st class, 2nd class, 3rd class, 4th class, 5th class, 6th class roads, suburban roads, isolated bridges and footbridges, park footpaths and hiking trails	All rivers	Intersection between roads along the rivers and roads not along the rivers
Cyclists	1st class, 2nd class, 3rd class, 4th class, 5th class, 6th class roads, suburban roads, isolated bridges and footbridges, park footpaths and hiking trails	All rivers	Intersection between roads along the rivers and roads not along the rivers
Car drivers	1st class, 2nd class, 3rd class, 4th class and suburban roads	Main rivers (>8 m width[1])	Parking facilities situated less than 300 m away from a road along the rivers[2]
Users of public transport	1st class, 2nd class, 3rd class, 4th class and suburban roads	Main rivers (>8 m width[1])	Bus stops situated less than 200 m away from a road along the rivers[2]

[1]The threshold of 8 m was chosen because it allows including or excluding the Stadtbach from the analysis
[2]The choice of the distance thresholds are further discussed in the next paragraphs

II. 3. 3. 2. Definition of access points

Pedestrians and cyclists:

Access points were obtained by intersecting roads situated along rivers and roads not situated along rivers (Fig. 7). The roads used for this step of the analysis were all accessible to pedestrians and cyclists; highways and second class highways – both considered inaccessible to pedestrians and cyclists – were excluded. Further, it was assumed that cyclists were not restricted to the use of cycling trails, as they often use other types of roads in practice, even if these are sometimes forbidden to them. For the same reasons, they were also given access to park roads and hiking trails.

Fig. 7. **Determination of river access points for pedestrians and cyclists**. Access points (yellow circles) were obtained by intersecting roads situated along rivers (green lines) with roads not situated along rivers (red lines). Sources: © 2012 Swisstopo (Swiss street network), © 2102 Swisstopo (Topographical map).

Car drivers:

Access points to the rivers were defined as all parking facilities situated less than 300 m away from a river in the study perimeter, i.e. the average distance that people can cover within a 5 minute walk (the time steps used in the analysis are described in detail in paragraph II.3.3.3. p. 22). The roads along which parking facilities were recorded are all accessible to cars. Highways were not taken into account because they do not have parking facilities, apart from motorway rest stops.

The parking facilities were recorded on different sources and placed manually on a GIS layer. Three different source types were used to record parking facilities in the study area:

- Parking facilities recorded by the city of Olten and the tourism office of Aarau.

Olten: Stadtkanzlei Olten. (2006). *Parkplätze, Parkhäuser und öffentliche Gebäude in Olten*. Olten. Retrieved April, 10, 2012 from https://secure.i-web.ch/gemweb/olten/de/verwaltung/publikationen/?action=info&pubid=9614&ss=1&PHPSESSID=3p1ahfjrq4u4numn3oatqnr6o1 (in German).

Aarau: Aarau Standortmarketing. (n.d.). (City maps of Aarau with indication of parking facilities). Retrieved April 10, 2012, from http://www.aarauinfo.ch/02_wohnen_arbeiten/04_mobilitaet_verkehr/mit_auto.php (in German).

- Parking places recorded by the website “Gate24”.

Map Gate24. (n.d.). (Online plan of Switzerland with indication of parking facilities. Retrieved April 10, 2012, from http://mapgate.ch/ (in French).

- Parking places recorded manually on aerial pictures of the study area.

    Federal administration. (n.d.). (Aerial pictures of Switzerland). © 2012 Swisstopo. Retrieved April 14, 2012, from http://map.geo.admin.ch/.

Table 2 presents the rules determining the manual recording of parking facilities on aerial pictures aimed at obtaining a systematic registration.

Table 2. Rules determining the manual recording of parking facilities.

Parking facilities recorded when…	Parking facilities not recorded when…
Situated within 300 m of a main river	Not situated within 300 m of a main river
Situated at proximity of public or sport infrastructures (football pitches, swimming pools, sport grounds…)	Situated in industrial areas
Situated on open ground in remote areas and at least two parked cars could be identifiable	Situated directly in front of housing buildings in residential areas
Clear white or blue marks were identifiable on the ground	Clear yellow marks were identifiable on the ground

Parking facilities were not recorded in industrial areas because they are usually designed for commercial purposes and not for public use in such sectors. Likewise, those located directly in front of housing buildings - which are usually private - and yellow parking places - which are reserved for people with specific authorisation - were excluded from the analysis.

Users of public transport:

Access points to the rivers were defined as all bus stops situated less than 200 m away from a road situated along a river, i.e. the average distance that people can cover within a 3 minutes walk (the time steps used in the analysis are described in detail in paragraph II.3.3.3. p. 22). Public transport by train was excluded from the analysis in order to simplify the calculations. Figure 8 presents Aarau's bus network.

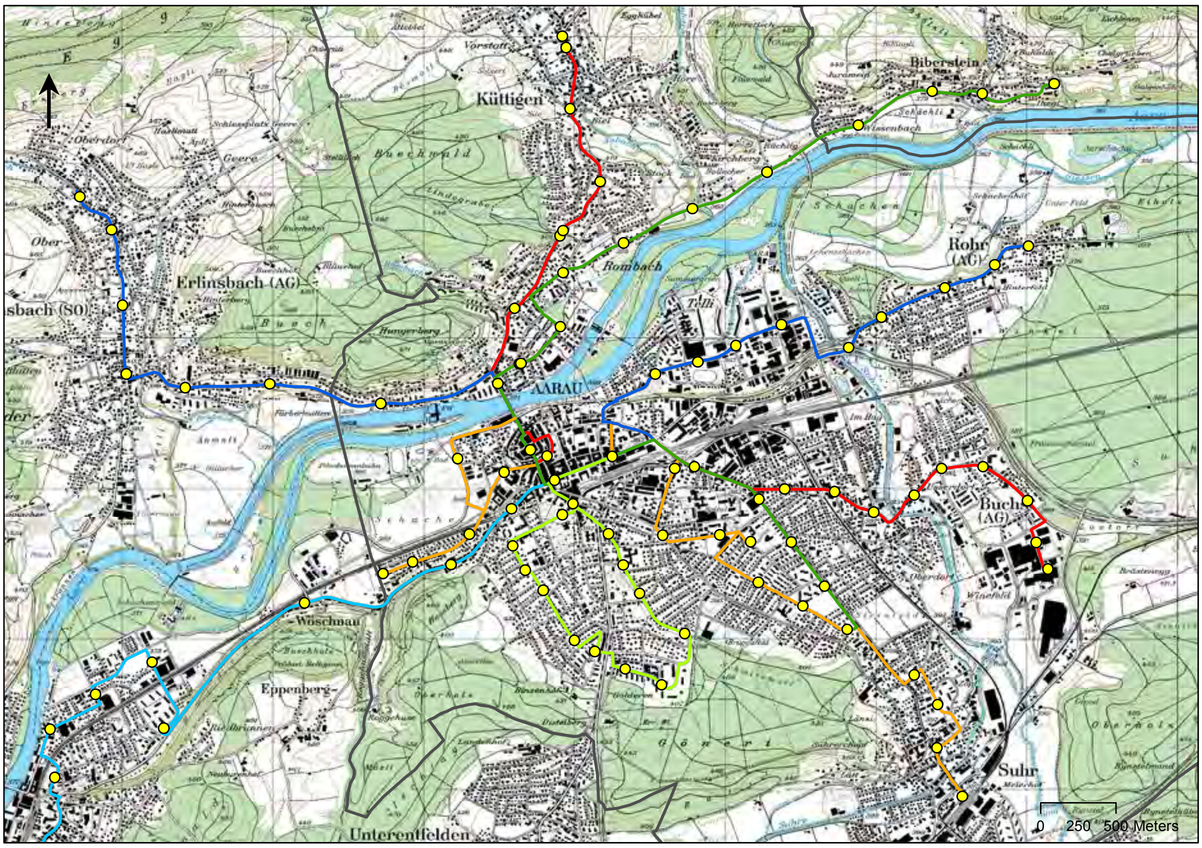

Fig. 8. **Bus network in the city of Aarau**. The black perimeter delimits the source population area. Bus stops are displayed in yellow. Bus lines are displayed in different colours. When several bus lines take the same route, only one of them is displayed. Sources: © 2006 AGIS (Bus routes network in the Canton of Aargau), © 2012 Swisstopo (Topographical map).

II. 3. 3.3. Definition of time steps

This study focuses on short term nearby recreation lasting for a maximum of $1^{1/2}$ hours. This time step includes both the time necessary to reach the river from the place of residence and the duration of the recreational activity. For the purpose of this thesis, a maximal travelling time of 15 minutes to reach the river from the place of residence was considered an appropriate threshold, in accordance with Schubert (2000, as cited in Spiess et al., 2008). This is the basis for the model's second assumption (Box 2).

Box 2. Second model assumption.

People access rivers within 15 minutes from their living place in order to start their recreational activity. The distance covered within these 15 minutes depends on people' mean of transport.

It was impossible to model the precise behaviour of people during their recreational activity. For example, some individuals may follow a river for a while and then take a different path to go back home. For the sake of simplification, it was assumed that individuals always follow rivers once they access them. For the same reason, it was also assumed that people stick to linear paths instead of making loops. This reasoning is conceptualised in figure 9.

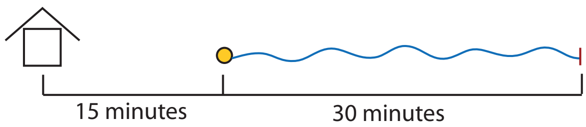

Fig. 9. **Conceptualised linear trip to the river**. The house represents the living place, the yellow circle represents the river's access point, the blue line represents the river and the red line represents the recreation end point. People need 15 minutes to reach the access point of the river from their place of residence. They then partake in some recreational activity along the river for 30 minutes after which they will reach their end point. From this end point, they return to their access point by the same path (30 minutes) and eventually reach their place of residence by taking the same route (15 minutes). The overall duration of this trip is 90 minutes, or $1^{1/2}$ hours.

The definition of the recreation route and its time steps are formalized in the third model assumption (Box 3). Rivers' accessibility was then calculated in two steps: (1) the potential amount of people able to reach the different access points from their place of residence was calculated and (2) the accessibility was calculated from the access points to the rivers themselves. These two steps are described in more detail for each user type in the next two chapters.

Box 3. Third model assumption.

People take a linear route when they visit rivers for recreational purposes and follow exactly the same path on their way back. This implies that they reach their recreation end point within 30 minutes from the river's access point. The distance covered within these 30 minutes depends on the means of transport of the different user types.

II. 3. 3. 4. Accessibility calculation: first step (from the places of residence to the access points)

The goal of this first step was to determine how many people could potentially reach the rivers from their place of residence. The population census for the year 2000 was used in order to determine the amount of people living at each location of the source population area. It consists of a 100 x 100 m grid showing the number of people living in each 100 m^2 grid cell.

For the calculation, three parameters were necessary to include:

- Source points (Where do people come from?): Records of the population census 2000.
- Sink points (Where do people go?): Defined access points to the rivers.
- Link between source points and sink points: Road network accessible to the different user types (these roads could be situated either along a river or not).

In the next paragraphs, the terms “source points” and “sink points” are used instead of “places of residence” (records of the population census) and “river access points”. As the calculation of accessibility by public transport was more complex than for other kinds of transport, the following paragraphs refer exclusively to pedestrians, cyclists and car drivers. Accessibility by public transport is tackled in a subsequent step.

Pedestrians, cyclists and car drivers:

The maximum distance covered by people within 15 minutes from their source points to their sink points was fixed depending on their means of transport. According to Schubert (2000, as cited in Spiess et al., 2008), these distances amount to 1,000 m for pedestrians, 3,000 m for cyclists and 12,000 m for car drivers.

However, a main difference exists between these means of transport: while pedestrians and cyclists can directly access the rivers, car drivers must first park their vehicle before doing so. As the maximal distance between parking facilities and rivers was fixed to 300 m in the definition of the access point, car drivers require an additional 5 minutes to walk from their parking place to the access point. Therefore, their allocated driving time from their place of residence to the parking facilities is reduced to only 10 minutes, which corresponds to a driving distance of 8000 m. Table 3 summarizes the distance used in the calculations for each user type.

Table 3. Distance thresholds used in the first step of the accessibility calculation, from places of residence to rivers' access points. They correspond to 15 minutes travelling time.

User type	Distance used in the model
Pedestrians	1000 m
Cyclists	3000 m
Car drivers	8000 m

Before starting the analysis, all GIS data were transformed to coverages (source points, sink points) or raster features (road network) using ArcGIS 10.0. (ESRI, 2011). The accessibility calculations were performed in the ArcInfo platform of ArcGIS 10.0. (ESRI, 2011) with the Arc Macro Language (aml). For each source point, the program determined all accessible sink points within the given distance thresholds while following the road network (Fig. 10). It then assigned the number of people living in the source point to the different accessible sink points.

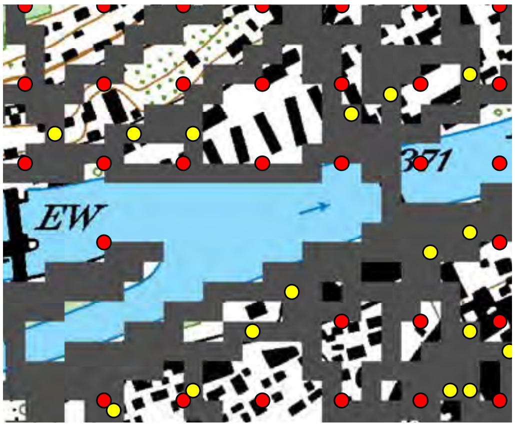

Fig. 10. **Parameters used to determine the accessibility of river access points**. Source points (records of the population census 2000) are displayed as red circles, sink points (river access points) are displayed as yellow circles, and the road network is displayed as grey lines. Sources: © 2012 FSO GEOSTAT (Federal population census of 2000), © 2012 Swisstopo (Swiss street network), © 2012 Swisstopo (Topographical map).

When several sink points were reachable from a given source point, a linear relationship leading to the fourth model assumption (box 4) was used to distribute people among them. The number of people assigned to the sink points linearly decreased with their increasing remoteness from the source point (Fig. 11 and Eq. 1).

Box 4. Fourth model assumption.

The amount of people reaching a river's access point linearly decreases with an increasing distance between the place of residence and the access point.

The operation was repeated for each source point and resulted in the distribution of the population among the access points of the different rivers. Through this process, the resulting file contained values representing the absolute number of people potentially able to reach all river access points for recreational purposes. The aml code used to perform the calculations is available in the enclosed CD.

For a visual representation, the obtained accessibility values were reclassified into six classes based on percentile ranks (the class thresholds were delimited by the 10th, 25th, 50th, 75th and 90th percentiles). This method was used because it identifies extreme values and is well adapted for making comparisons. The classes were displayed by using a scale ranging from "very low" to "very high" accessibility.

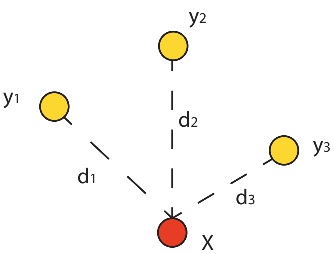

Fig. 11. Parameters driving the distribution of people among alternative sink points. The source point is displayed in red and labelled x; the alternative sink points are displayed in yellow and labelled y_i; and the respective distances separating them in meters are displayed as dashed lines labelled d_i.

$$y_i = x^2 \frac{\sum_{i=1}^{n} d_i}{d_i \sum_{i=1}^{n} \left(\frac{x \sum_{i=1}^{n} d_i}{d_i} \right)}$$

Eq. 1. Linear equation driving the distribution of people among alternative sink points. Variable x represents the number of people present in the source point, y_i is the number of people accessing a given sink point, and d_i is the distance between the source point and the sink point.

Users of public transport:

For people using the bus transportation system to reach the rivers, an additional step had to be taken into account. In reality, these people must first reach the nearest bus stop from their place of residence before taking a bus and finally accessing the river from the destination bus stop. It was therefore impossible to directly calculate the accessibility of bus users from the place of residence to the rivers' access points (i.e. destination bus stop).

According to assumption 2 (box 2, p.22), individuals require 15 minutes to access their recreation area. However, since the bus stops selected as river access points were situated at a maximum distance of 200 m from the rivers, bus users required an additional 3 minutes to reach the river from the access points. Therefore, the portion of their trip from the place of residence to the destination bus stop had to take less than 12 minutes. Of these 12 minutes, it was decided to allocate 5 minutes for bus users to reach the nearest bus stop in their neighbourhood and wait for the bus. The final 7 minutes were then allocated to the actual bus trip (Fig. 12).

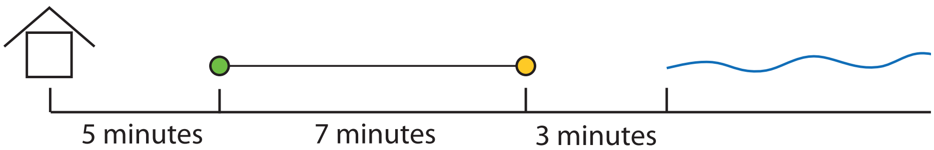

Fig. 12. Conceptualised linear trip to the river in the particular case of users of public transport. The house represents the place of residence (source point); the green circle represents the nearest bus stop in the neighbourhood (sink point); the yellow circle represents the destination bus stop; the grey line represents the bus trip between the two bus stops; and the blue line represents the river. Users of public transport need five minutes to reach the nearest bus stop from their place of residence. They then take the bus during seven minutes and need three minutes to reach the river from their destination bus stop.

For the calculation with the aml, only the accessibility between the place of residence and the nearest bus stop was calculated. The source points consisted of population census records, whilst the sink points were expressed as the nearest bus stops. The distance threshold was fixed to 350 m, which corresponds to the distance that pedestrians can cover within 5 minutes. Once the calculation was performed, the number of people potentially able to reach each of Aarau's bus stops was recorded. It was then assumed that people taking the bus at a bus station would remain in the bus for a maximum of 7 minutes and get off at a station situated in close proximity to a river (i.e. destination bus stops, considered as river access points).

When several bus stops in close proximity to the rivers existed on the same bus line, the amount of people getting off at each of these stops was determined by the same linear equation as presented in the previous paragraph, depending on the travelling time needed between the starting and the destination bus stops (Eq. 1, p.25). The allocation of people among alternative destination bus stops was performed using Microsoft Excel (2011). The excel tables used for these calculations are on the enclosed CD located at the end of the report. The travelling time between each bus stop was recorded according to the online timetable available on April 25th, 2012 (SBB, n.d.).

II. 3. 3. 5. Accessibility calculation: second step (from the access points to the rivers)

Knowing the potential number of people able to reach the different access points, the second step of the accessibility calculation was aimed at determining the accessibility of all rivers stretches from the access points. To do so, it was assumed that car drivers and users of public transport would go on foot once they had reached the access points (box 5).

Box 5. Fifth model assumption.

Pedestrians walk while cyclists travel by bicycle for the total duration of their recreational activity. Car drivers and users of public transport go on foot once they have reached the river access points.

According to the third model assumption (box 3, p.23), the distance covered in 30 minutes of travelling time along the rivers varies, depending on the transportation mode. In order to account for different walking and cycling speeds among individuals, five distance thresholds were fixed for each user type. The definition of these thresholds is in accordance with Schubert (2000, as cited in Spiess et al., 2008), who stated that the walking distance covered within 15 minutes could vary from 0.5 to 1.5 km depending on the individuals.

Based on a simple scaling operation, the walking distance covered within 30 minutes was defined to vary from 1 to 3 km. For cyclists, the thresholds were defined according to the average speed of 14 km/h described in Biret et al. (2004). Table 4 presents the distance thresholds used in this second step of the accessibility calculation.

Table 4. Distance thresholds used in the second step of the accessibility calculation. They correspond to 30 minutes travelling time.

User type	Pedestrians	Cyclists	Car drivers	Users of public transport
Distance thresholds used in the model	1000 m 1500 m 2000 m 2500 m 3000 m	4000 m 5000 m 6000 m 7000 m 8000 m	1000 m 1500 m 2000 m 2500 m 3000 m	1000 m 1500 m 2000 m 2500 m 3000 m

As in the first step, all data were transformed to coverages (source points, sink points) or raster features (road network) in ArcGIS 10.0 (ESRI, 2011) and the accessibility calculations were performed in the ArcInfo platform of ArcGIS 10.0 (ESRI, 2011) with the Arc Macro Language (aml). However, the parameters used for the calculations were different than in the first step and include the following:

- Source points (Where do people come from?): Access points to the river, containing the number of people potentially able to reach the river at each access point (former sink points)
- Sink points (Where do people go?): All raster cells of roads situated along the rivers.
- Link between source points and sink points: Road network accessible to the different user types. These roads were exclusively situated along the rivers.

In this second step of the analysis, the road network was restricted to roads situated along rivers because they represent the support for recreation. Only those roads accessible to pedestrians and cyclists were taken into account as it was assumed that people were going on foot or by bicycle to partake in their recreational activity.

The goal of this second step of the accessibility calculation was to determine all river stretches accessible within 30 minutes from each access point. To do so, the program assigned a value of 1 to each raster cell of the road network accessible from a given access point within the distance threshold corresponding to 30 minutes travelling time. Conversely, all inaccessible raster cells were attributed a value of 0 (Fig. 13). Subsequently, the values of the raster cells were multiplied by the number of people present at the access point. By doing so, inaccessible cells continued to receive a value of 0, while accessible cells were assigned a value corresponding to the number of people able to reach them from the given access point.

This process was repeated for each access point and the cell values were added up after each round. Finally, the scores obtained for the five distance thresholds were added up. Through this process, the final accessibility map contained stretch values representing the relative number of people able to reach them for recreation purpose for each raster cell of the road network.

Fig. 13. Example of accessibility calculation for a given access point. Access points are displayed as yellow circles and the particular access point used in this example is displayed as a blue circle. The inaccessible stretches of the road network are displayed as grey lines while the accessible stretches are displayed as orange lines. In this example, a fake distance threshold of 500 m was used to illustrate the process. All orange stretches are accessible from the blue access point within a distance of 500 m and are assigned a value of 1, multiplied by the number of people present in the blue access point. Conversely, all grey stretches are assigned a value of 0 because they are not accessible from the blue access point. Sources: © 2012 Swisstopo (Topographical map).

After completing the accessibility calculation, the stretch values were reclassified in order to turn them into discrete accessibility classes. From this, a condensed dataset was obtained simplifying the interpretation of the results. The number of classes chosen to represent the data was fixed to six, since this number provides a good differentiation of accessibility, without complicating the visual interpretation of the data. The choice of the classification method (i.e. quantile, natural Jenks, geometrical distribution and percentile) and the class thresholds were defined separately for the different user types, depending on the distribution of the obtained accessibility data.

II. 3. 4. Model Landscape suitability

II. 3. 4. 1. Selection of landscape features representing good proxies of landscape suitability for recreation

Preliminary analyses presented in appendix E, p. 118 revealed that many uncertainties still remained in the assessment of features driving the attraction or repulsion of rivers for recreation. Moreover, even experts from the field of river restoration or nearby recreation were unable to give an objective assessment of the relative importance of these features for river attractiveness. It was therefore decided to set up a model as simple and transparent as possible, made of only two parameters that were easy to identify and classify.

The first feature was chosen to be specific to rivers and represent their aesthetic appeal for people. According to Junker & Buchecker (2008), people's aesthetic preferences in river environments are mainly driven by their perception of rivers' naturalness. Their results further support the hypothesis that the public perception of naturalness is positively related to an expert's assessment of eco-morphological quality. That being the case, the eco-morphological state of river stretches was chosen as a first proxy to model the suitability of rivers for recreation.

The second feature was chosen to be less specific to river environments and instead represent the quality of the structural setting supporting recreation. The quality of the road network was chosen to represent this second proxy, as several authors (Irngartinger et al., 2010; Kaiser, 2005, as cited in Huber, 2012; Kienast et al., 2012; Mönnecke & Wasem, 2005, as cited in Huber, 2012) already emphasized its importance for recreation.

II. 3. 4. 2. Classification of the selected landscape features

Similar to the accessibility model, the features selected to define the landscape suitability of rivers for recreational use were transformed to raster layers in ArcGIS 10.0. (ESRI, 2011).

The eco-morphological quality of river stretches was assessed according to the classification established by the Federal Office for the Environment (© 2008 FOEN) (See p. 10). A quality score expressed in tens ranging from 40 ("very high" quality) to 10 ("low" quality) was assigned to each eco-morphological category (Table 5).

Table 5. Quality scores depending on a river's eco-morphological quality.

River quality for recreation	River eco-morphological quality	Quality score
Very high	Natural or near-natural (class 1)	40
High	Little affected (class 2)	30
Rather Low	Highly affected (class 3)	20
Low	Artificial (class 4)	10

The road quality necessary to support recreation was assessed on the basis of the Swiss street network available as Vector25 established by Swisstopo (© 2012 swisstopo). The classification was made slightly different for pedestrians and cyclists (Table 6) and the resulting quality scores were expressed in units ranging from 3 (“very high” quality) to 1 (“low” quality).

For pedestrians, it was assumed that roads banned to driving (e.g. 5th and 6th class roads and park footpaths) were the most suitable for recreation, as they are safe and free from traffic noise. Likewise, 3rd and 4th class roads as well as suburban roads were assigned a “rather good” quality because they are subject to reduced traffic conditions. Finally, 1st and 2nd class roads were assigned a “low” quality for recreation because they are characterised by a high traffic density.

For cyclists, the classification was performed in a similar way, except that park footpaths were assigned a “low” quality because their access is usually forbidden to them. This does not always prevent them from taking such paths, but it regularly leads to open conflicts with pedestrians, which lowers the suitability of such tracks for cyclists.

Table 6. Quality scores depending on road quality.

Road quality for recreation	Road categories: Pedestrians	Road categories: Cyclists	Quality score
Very high	5th, 6th class roads, Park footpaths	5th, 6th class roads	3
Rather high	3rd, 4th class roads, Suburban roads	3rd, 4th class roads, Suburban roads	2
Low	1st, 2nd class roads	1st, 2nd class roads, Park footpaths	1

II. 3. 4. 3. Mapping the suitability of a river’s landscape to provide recreation

In order to come up with a transparent model, a pivot table was used to combine the two proxies “river eco-morphological quality” and “road quality”. This method provided a cross-classification of the two parameters; by adding both of them, an overall quality score was assigned to each river stretch, representing its landscape suitability to provide recreation.

This quality score was composed of two numbers where the tenth digit represented the river’s quality for providing recreation and the unit digit represented the corresponding road quality (Fig. 14).

Although this method yielded a very transparent classification, it generated a complex map whose information density was difficult to grasp visually. In order to make a compromise between transparency and readability, the resulting scores were reclassified into only four classes ranging from “very high” to “low” suitability for providing recreation (Fig. 14).

For the reclassification, it was assumed that road quality was the most decisive factor affecting a river's suitability for providing recreation, according to findings from Irngartinger et al. (2010) and Kienast et al. (2012). Hence, all river stretches bordered by traffic intense roads were assigned a "low" landscape suitability to provide recreation, even if their eco-morphological state was natural.

		Road quality for recreation		
		Very high (3)	High (2)	Low (1)
River quality for recreation	Very high (40)	43	42	41
	High (30)	33	32	31
	Rather low (20)	23	22	21
	Low (10)	13	12	11

Fig. 14. Pivot table used for the determination of a river's landscape suitability to provide recreation. This table results from the cross-classification of the proxies "river quality for recreation" and "road quality for recreation". Dark green scores represent a "very high" landscape suitability, pale green scores represent a "high" landscape suitability, pale blue scores represent a "rather low" landscape suitability, and dark blue scores represent a "low" landscape suitability.

II. 3. 5. Model Infrastructures

No dataset listing small recreational infrastructures (e.g. picnic places, fountains, catering facilities, benches and playgrounds) around Aarau existed prior to the beginning of the study. These infrastructures were therefore manually recorded with three GPS units (Garmin eTrex Vista® HCx Topo, Garmin eTrex Vista® Cx, and Garmin Colorado™ 300). Over the course of four and a half days, field recordings were made of small recreational infrastructures along the Aare from Olten to Brugg, along the Suhre from Aarau to the village of Oberentfelden, along the Stadtbach, and along small streams in the vicinity of Aarau. Only infrsatructures situated less than 50 m away from a river were recorded and the obtained data where displayed in Arc GIS 10.0 (ESRI, 2011).

II. 3. 5. 1. Determination of the perimeter of influence and the importance of recreational infrastructures

Small infrastructures are usually considered as attractors for recreation, but their perimeter of influence can vary greatly. Data from the literature was thus used to determine the perimeter of influence for each of the infrastructure included in the analysis. A playground's perimeter of influence was fixed to 100 m, according to a Swedish norm cited in a study on playground planning and management (Jansson & Persson, 2010). For benches, an influence perimeter of 50 m was defined in agreement with the recommendations of Moro & Haeny (2007) concerning the maximal distance which should not be exceeded between two consecutive sitting facilities. Unfortunately, no guidelines were found in the literature regarding the spatial impact of the other recreational infrastructures recorded. These infrastructures were therefore assigned the same perimeters as playgrounds and benches for the sake of simplification (Table 7).

Table 7. Perimeter of influence attributed to the recorded infrastructures.

Infrastructures	Perimeter of influence
Picnic places	100 m
Fountains	50 m
Catering facilities	100 m
Benches	50 m
Playgrounds	100 m

The relevance of recreational infrastructures to the population is an additional factor that varies depending on the type of infrastructure considered. Findings from Degenhardt et al. (2010) were used to attribute a weight to each infrastructure representing its relative importance for recreation. In their study on factors influencing nearby recreation behaviour in the city of Frauenfeld, Degenhardt et al. (2010) determined which types of infrastructures where used most often. To do so, they recorded the number of times respondents to a questionnaire (N= 1594) declared their use of each infrastructure. The results were used in this thesis to weigh the relative importance of each type of infrastructure relative to each other. Benches were assigned the highest weight because they were the most widely mentioned. Weights for each of the other infrastructures (Table 8) were determined by dividing the percentage of time they were mentioned by the percentage of time benches were mentioned.

Table 8. Frequency of infrastructure use (N=1594 mentions) according to Degenhardt et al. (2010), and the corresponding weights attributed in the present study.

Infrastructures	Mention[1] (%)	Weights attributed in the present study
Benches	20	1
Fountains	12	0.6
Catering facilities	10	0.5
Picnic places	9	0.45
Playgrounds	8	0.4

[1]According to Degenhardt et al., 2010

II. 3. 5. 2. Mapping of small recreational infrastructures

For the mapping, each of the recorded infrastructures were buffered by their corresponding perimeter of influence and the road network along the river was turned into a raster file of 25 m resolution. All raster cells of the street network falling within the perimeter of influence of a given recreational infrastructure received the value of its specific weight, while other cells were attributed a value of 0. When raster cells fell within the perimeter of influence of several infrastructures, the sum of all their respective weights were attributed to them (Fig. 15).

At the end of the "infrastructures" model calculation, the resulting file consisted of stretch values representing the amount and the quality of recreational infrastructures over the whole study perimeter. These stretch values were reclassified for the same reasons as already mentioned in paragraph II.3.3.5 p. 28. But in this case, the values were reclassified into only three classes: "many" infrastructures, "few" infrastructures and "no" infrastructures at all. The choice of the classification method and the class thresholds were defined according to the distribution of the resulting data.

Fig. 15. **Example of infrastructure score calculation**. The blue dot represents a playground, while the yellow dot represents a picnic place. The perimeters of influence for both infrastructures are displayed as circles of a 100 m radius each, and of corresponding colours. All road raster cells falling within the perimeter of influence of the playground get a score of 0.4 and are displayed in blue, while all road raster cells falling within the perimeter of influence of the picnic place get a score of 0.45 and are displayed in yellow. Finally, road raster cells falling within both perimeters of influence get a score of 0.85 (equivalent to the sum of each of the respective weights) and are displayed in green, while all remaining raster cells get a score of 0 and are displayed in grey.

II. 3. 6. Mapping modelled recreational hotspots

A two-step process following the same method outlined in paragraph II.3.4.3. p. 30 was used to map the final recreational use. Pivot tables were used to combine the three models “accessibility”, “landscape suitability” and “infrastructures”.

Inputs from the literature were employed to define more precisely the relative importance of each parameter. The accessibility is cited in several studies as being one of the most important predictors of recreational behaviour (Degenhardt et al., 2010; Irngartinger et al., 2010; Kienast et al., 2012; Ode & Fry, 2006). Conversely, the level of infrastructure was assessed in Degenhardt et al. (2010) as being not very important for recreation, given that recreational infrastructures are not widely used during work days. According to these conclusions, accessibility was assumed in this thesis to be the most important factor determining a river’s recreational use, followed by landscape suitability at an intermediate level of importance and the amount of infrastructures, which was considered to be the least important factor.

In a first step, the “accessibility” and “landscape suitability” models were combined with a pivot table. The model “accessibility” consisted of 6 classes ranging from “very high” accessibility to “very low” accessibility and each class was assigned a score ranging from 60 to 10. Likewise, the model “landscape suitability” was composed of 4 classes ranging from “very high” landscape suitability to “low” landscape suitability with scores ranging from 4 to 1.

After their cross-classification, the resulting scores were reclassified into only four classes to facilitate the readability of the results. This reclassification was done differently for pedestrians than for cyclists, in line with the findings of Kienast et al. (2012). It was supposed that pedestrians, in spite of their subjective sensitivity to distinct landscape features, were more limited than cyclists in their recreational choices because of their reduced mobility.

Consequently, it was assumed that accessibility is more decisive for predicting recreational use by pedestrians than it is in the case of cyclists. Therefore, the reclassification of pedestrian scores (Fig. 16. A.) presents a strong influence of accessibility (i.e. stretches having only a "rather high" accessibility but a "very high" landscape suitability are already assigned to the second resulting class) while the reclassification of cyclist scores (Fig. 16. B.) moderates this influence (i.e. stretches presenting only a "rather low" accessibility but a "very high" landscape suitability are assigned to the first resulting class).

		Accessibility					
		Very high 60	High 50	Rather high 40	Rather low 30	Low 20	Very low 10
Landscape suitability	Very high 4	64	54	44	34	24	14
	High 3	63	53	43	33	23	13
	Rather low 2	62	52	42	32	22	12
A	Low 1	61	51	41	31	21	11

		Accessibility					
		Very high 60	High 50	Rather high 40	Rather low 30	Low 20	Very low 10
Landscape suitability	Very high 4	64	54	44	34	24	14
	High 3	63	53	43	33	23	13
	Rather low 2	62	52	42	32	22	12
B	Low 1	61	51	41	31	21	11

Fig. 16. Pivot tables used for the combination of parameters "Accessibility" and "Landscape suitability" for pedestrians (A) and cyclists (B). Final scores were reclassified into the four resulting combined scores of accessibility and landscape suitability: "high" (orange), "rather high" (yellow), "rather low" (pale blue) and "low" (dark blue). The reclassification of pedestrian scores presents a stronger influence of accessibility than the reclassification of cyclist scores.

In a second step, the "infrastructures" model was used to balance the resulting scores of the combined "accessibility and landscape suitability" model. At that stage, this combined model was differentiated into four classes whose scores ranged from 4,000 to 1,000 (Table 9), while the "infrastructures" model consisted of three classes whose scores ranged from 200 to 0.

Table 9. Resulting classes after the combination of the models "accessibility" and "landscape suitability"

Accessibility + Landscape suitability	
Class	Score
High	4000
Rather high	3000
Rather low	2000
Low	1000

The reclassification of the resulting scores was performed in the same way for pedestrians and cyclists. A fifth category (displayed in red in Fig. 17) was added to the four existing categories after combining the "accessibility" and "landscape suitability" models.

River stretches without infrastructures were assigned to the same category as in step 1 (right column in Fig. 17). River stretches with few infrastructures were assigned a higher category than after step 1 and stretches with many infrastructures were assigned to two categories higher than after step 1.

		Infrastructures		
		Many 200	Few 100	None 0
Accessibility + Landscape suitability	Very high 4000	4200	4100	4000
	High 3000	3200	3100	3000
	Low 2000	2200	2100	2000
	Very low 1000	1200	1100	1000

Fig. 17. Pivot table used for determining the recreational use of river stretches according to the balancing of the combined model "accessibility and landscape suitability" by the model "infrastructures". Resulting scores were reclassified into the following modelled recreational use categories: "very high" (red), "high" (orange), "rather high" (yellow), "rather low" (pale blue) and "low" (dark blue). For example, stretches assigned to the lowest category (dark blue) after the first step (lower-right cell in Fig. 15) were assigned to the 4th category (pale blue) when they had only a few infrastructures and to the 3rd category (yellow) when they had many infrastructures.

II. 4. People count

II. 4. 1. Sampling procedure

To quantify the number of people observed along rivers, 88 sampling points were selected in the vicinity of the source population area. Although no interviews were conducted to assess the place of residence of observed individuals, it was assumed that they originated from the communities included in the study. River stretches situated further away from the source population area were excluded from the sampling procedure as the above-mentioned assumption had a higher probability of being violated.

The selection of sampling points took place in two steps. First, a preferential sampling influenced by river accessibility and quality allowed for the selection of 88 points. This number was chosen because it represented a reasonable objective given the resources available, the most limiting of which was the time spent in the field.

In the second selection step, the exact position of the preferentially selected points was manually adjusted on a 1:25'000 topographic map of Aarau (© 2012 Swisstopo) in order to correspond to map features easily identifiable in the field. On this map, they were displayed as areas of 50 x 10 m (Fig. 18). The repartition of the final sampling sites is available in appendix A 2, p. 107. For practical reasons, the study area was divided into three sectors and the sampling points were named according to them. All maps displaying the sectors, together with the sampling point labels can be viewed in appendix A 3 – A 5, pp. 108 - 110.

Fig. 18. Manual placement of sampling points on the 1:25000 topographic map. The point C2 was manually positioned at the intersection of two roads in order to be easily identifiable in the field.

II. 4. 2. Field recording of people's presence

The people count along rivers took place on two weekdays (Monday and Friday) of the same week, respectively on June the 18^{th} and June the 22^{nd}, 2012. The recording was conducted between 4 pm and 8 pm, in order to target people doing recreational activities or relaxing after work. On the first day, the temperature reached about 25°C and the weather was mostly sunny, punctuated by a short shower by the end of the afternoon. On the second day, the weather was very sunny with a few clouds and a warm temperature (25°C).

Field assistants counted all people passing by each sampling point during a time step of 10 minutes. Pedestrians and cyclists were recorded separately by means of mechanical Tally counters. A distinction was made between static and dynamic sampling sites (Fig. 19). In the former, both the people staying at the site (i.e. sitting on a bench) and those passing by were recorded, while in the latter, only those people passing by were accounted for.

Fig. 19. Distinction between static and dynamic sampling sites during people count. When the sampling point was situated in a static site (i.e. public place) (A), both people remaining at the specific site and those passing by were recorded. When the sampling point was situated in a dynamic site (i.e. along a street) (B), only those people passing by were recorded. Sources: Pictures taken by Sophie Rudolf, 2012.

II. 4. 3. Determination of river visitation levels

The results of the people count were analysed separately for cyclists and pedestrians. For both, the sampling points were first classified in ascending order according to the number of recorded people. The data were then divided into categories of people abundance according to the location of breaks in the progression of the histogram values. Finally, an analysis of variance was performed between each category of people abundance to test whether they actually presented a significantly different number of observed people.

The choice of the test was driven by the nature of the data distributions. For that reason, a diagram of their distribution frequencies was drawn to assess their normality. It resulted in the choice of the Kruskal-Wallis test, a non-parametric method designed for a one-way analysis of variance. It tested whether the variation of observed number of people was random or if different categories of river visitation level actually existed. The null hypothesis of random distribution was rejected when the p-value was smaller or equal to 0.05.

The test was performed with the "kruskal.test" function in the "stats" package of the R programming software (R Development Core Team, 2011). The R code is available for consultation in the enclosed CD.

II. 5. Local knowledge analysis

Questionnaires were sent to employees of Aarau's tourism office and municipality in order to assess the most visited river stretches around Aarau for recreation. Regional tourism employees were chosen because of their potentially good knowledge of the area and their awareness concerning the population's habits and recreational behaviours. The questionnaire consisted of some background information about recreation and the aim of the study, some short questions about a respondent's personal details (gender, place of residence, professional link to rivers) and a support material for the report of rivers' recreational use.

This support material consisted of a map depicting Aarau and its surroundings, as well as its main rivers delimited by 1 km^2 quadrants (Fig. 20). It was inspired from the original work of Benkler (2011). Respondents were asked to cross all quadrants that they thought were most frequented by people for recreational purposes along rivers. The maximal number of quadrants they were allowed to cross was fixed to 10. The complete questionnaire is available for consultation in appendix B, p. 111. After completion of the questionnaires, each quadrant was classified according to the percentage of times it was selected by respondents. Four classes were defined (i.e. "selected by more than 75%; 50%; 25%; 0% of the respondents").

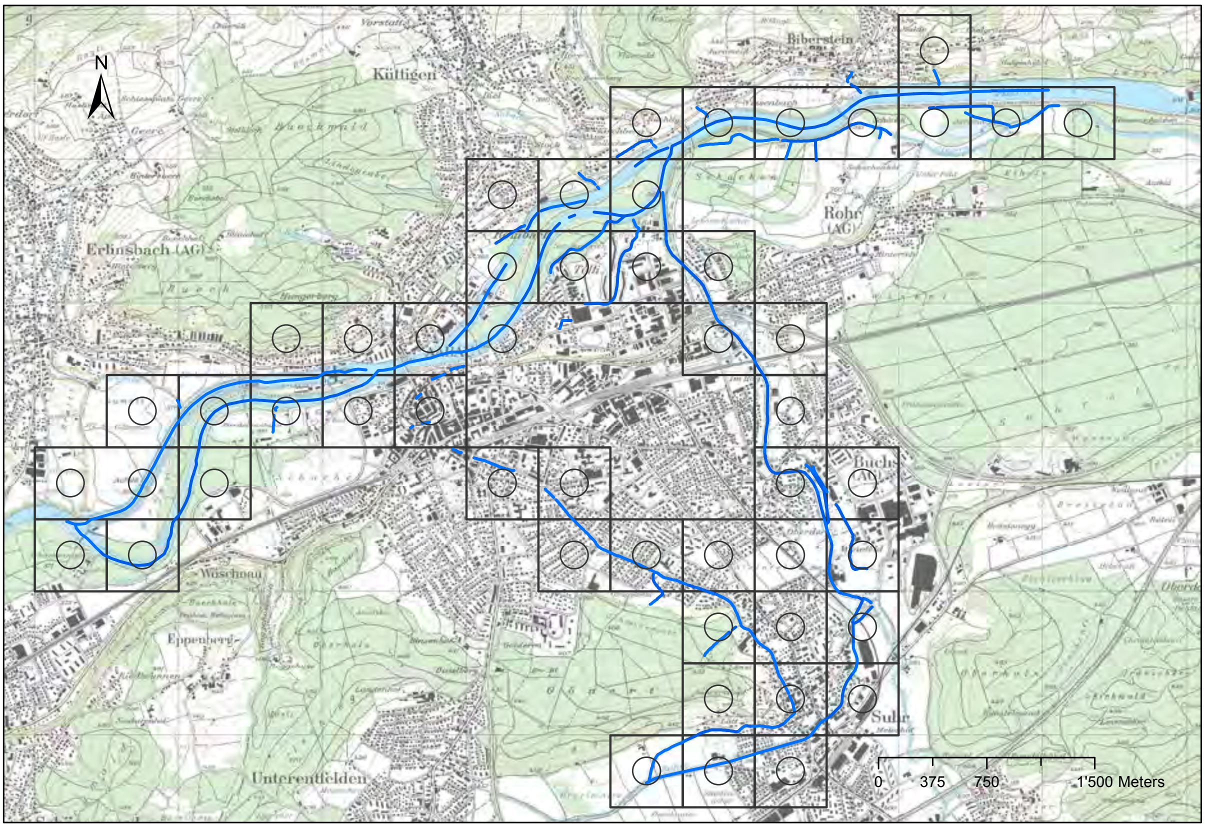

Fig. 20. Map support for the report of rivers' recreational use. Rivers are delimited by 1km² quadrants. Inspired from the original work of Benkler (2011). Sources: © 2008 FOEN (Eco-morphological state of Swiss rivers), © Swisstopo 2012 (Topographical map).

II. 6. Hotspot analysis

The results of the people count and of the local knowledge analysis were visually compared in order to gain insight about the use of rivers in the region of Aarau. Both approaches yielded complementary results. While the people count did not indicate if the individuals observed along the rivers where actually doing recreational activities, the local knowledge analysis was precisely designed to answer this question.

By comparing both analyses, it was possible to identify stretches characterized by a high recreational use - presenting both a high visitation level and a high reported recreational use – as well as river stretches that remained unused by people. Moreover, it provided further information on which river stretches were widely visited by people, but not necessarily for recreation (Table 10). In other words, the results of this analysis helped to reveal a) the empirical recreational use of rivers and b) their functional use.

Table 10. Comparison framework of the hotspot analysis.

		Visitation level	
		High	Low
Reported recreational use	High	**Recreational use**: Rivers' stretches most used for recreation	**Moderate recreational use:** Rivers' stretches whose recreational use was assessed as being high by locals, without that assessment being verified by field observations
	Low	**Functional use**: Rivers' stretches highly used by people, but not necessarily for recreation	**No recreational or functional use:** Rivers' stretches not used at all by people

II. 7. Comparison between modelled and empirical recreational use of rivers

Based on the determination of the empirical recreational use of rivers, an evaluation of the modelled recreational use could be made. To do so, a statistical analysis was first performed to test whether the modelled recreational use of rivers matched with the results of the people count. The model was then visually compared to the reported recreational use of rivers.

By superimposing the sampling points on the modelled recreational use of rivers, each was assigned to the modelled recreational category they belonged to according to the model. This way, they were distributed among the five categories ranging from "very high" modelled recreational use to "low" modelled recreational use. Again, a Kruskal-Wallis test with the same parameters as described in paragraph II.4.3. p.37 was performed to test the categories in pairs and assess whether their medians were significantly different. The goal of the analysis was to test whether the recreational patterns defined by the model could be observed in reality. The R code is available for consultation in the enclosed CD.

II. 8. Historical analysis

A short literature review was performed to get insight into the historical development and the importance of the rivers considered in the analysis. The use of primary sources – such as archive materials – was impossible due to time constraints. Instead, several different and complementary secondary sources were employed in the course of the research: a book (Lüthi, Boner, Edlin, & Pestalozzi, 1978), articles from Wikipedia (Aare, 2012; Aarau, 2012; Suhre, 2012), and relevant websites (Aarauer Bachverein, n.d.; Heinrich Wirri-Zunft, n.d.; WWF, n.d).

II. 9. Local context analysis

A semi-structured interview was conducted with Mr. R. Strebel, project manager of the division "Roads and Water bodies" in the city of Aarau's administration since the beginning of 2012. The main goals of this interview were to understand how rivers are managed in the city of Aarau, which river restoration efforts were already made and what the potential is for new restoration measures. In addition, the interview also tackled the topic of recreation in the context of river restoration projects. The detailed questions asked during the interview are available for consultation in appendix C 2, p. 115.

II. 10. Combined analysis for the determination of the improvement potential

The last goal of the master thesis was to determine which river stretches in Aarau present an improvement potential regarding their capacity to provide recreational or restorative opportunities. Such stretches must have a high accessibility, but a rather low landscape suitability and/or few infrastructures. This is because planning measures can influence these last two factors in the context of short nearby recreation and psychological restoration, whereas river stretches situated far away from populated areas require a costly time investment. Conversely, highly accessible river stretches with good quality and/or many infrastructures do not have much improvement potential, as they already meet people's needs.

To determine those river stretches having a good improvement potential, a conceptual decision tree was set up (Fig. 23). First, the GIS-base model developed for the recreational use mapping was used to select river stretches with an improvement potential, according to their physical landscape properties. In a subsequent step, the type of use characterizing the selected stretches was established based on the conclusions of the hotspot analysis. Finally, the proposed improvement measures were moderated and adapted according to the findings of the complementary analyses (historical and local context analyses).

The first river stretches to be selected were those with good accessibility but a low landscape suitability, corresponding to the lower-left corner on the pivot table used for the combination of parameters "accessibility" and "landscape suitability" (Fig. 21). All stretches falling within this category where selected according to their score numbers. They represent river stretches whose quality could potentially be improved by planning measures in order to enhance their recreational and/or restorative use.

		Accessibility					
		Very high 60	High 50	Rather high 40	Rather low 30	Low 20	Very low 10
Landscape suitability	Very high 4	64	54	44	34	24	14
	High 3	63	53	43	33	23	13
	Rather low 2	62	52	42	32	22	12
	Low 1	61	51	41	31	21	11

Fig. 21. Selection of river stretches presenting an improvement potential of their landscape suitability. The selected stretches are situated in the lower-left corner (dark red outline), have a "rather high" to "very high" accessibility and a ""rather low" to "low" landscape suitability. They include the score numbers 62, 52, 42, 61, 51 and 41.

Subsequently, river stretches presenting a rather good combination of accessibility and landscape suitability, but with no or few infrastructures, were also selected. They correspond to the upper-right corner on the pivot table used for the combination of the parameters “accessibility + landscape suitability” and “infrastructures” (Fig. 22). They represent river stretches whose infrastructure level could potentially be improved in order to enhance their recreational use.

		Infrastructures		
		Many 200	Few 100	None 0
Accessibility + Landscape suitability	Very high 4000	4200	4100	4000
	High 3000	3200	3100	3000
	Low 2000	2200	2100	2000
	Very low 1000	1200	1100	1000

Fig. 22. Selection of river stretches presenting an improvement potential regarding to the amount and the quality of their recreational infrastructures. The selected stretches are situated in the upper-right corner (dark red outline), have a “high” to “very high” combined “accessibility + landscape suitability” and “no” or “few” infrastructures. They include the score numbers 4100, 4000, 3100 and 3000.

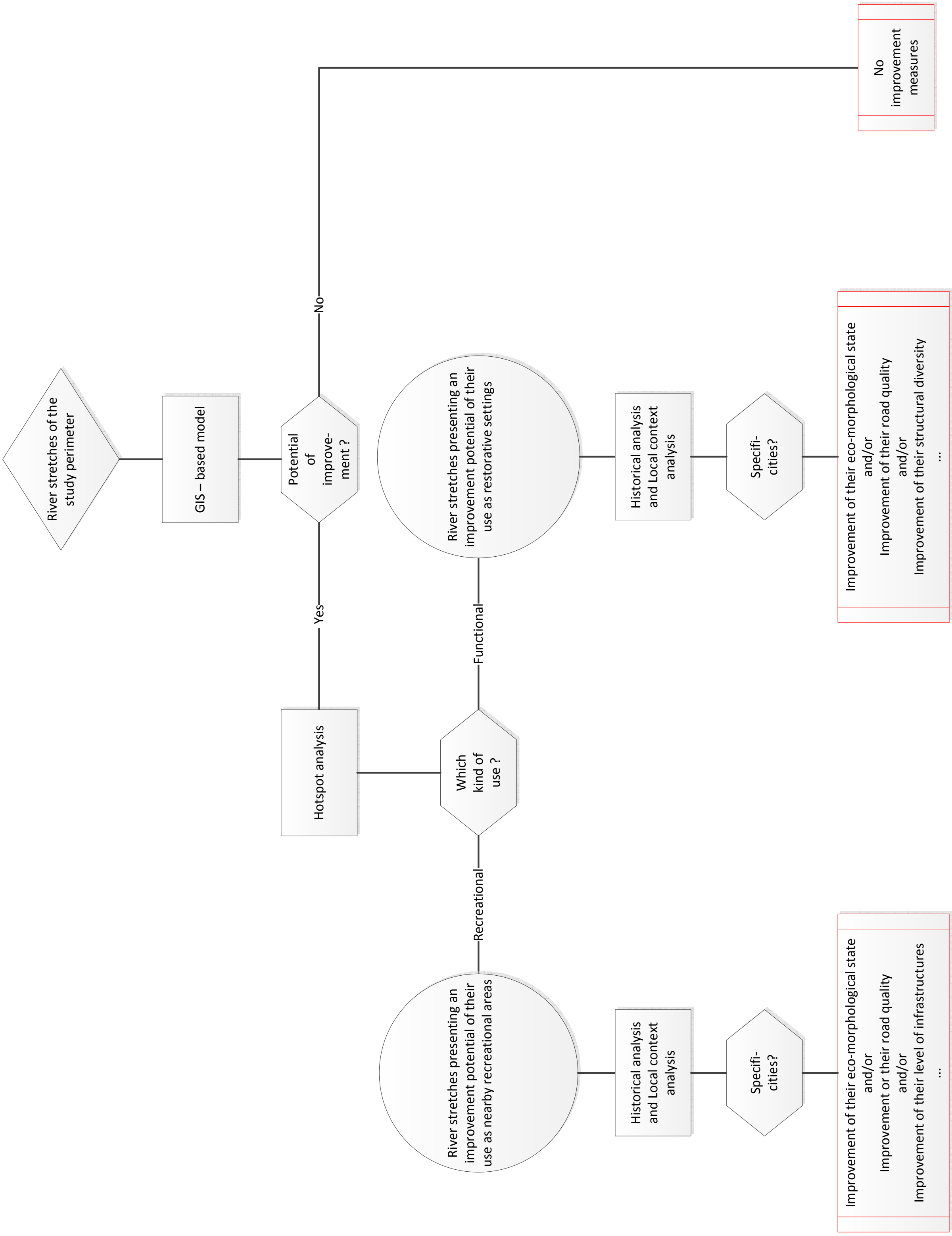

Fig. 23. Decision tree for the definition of rivers improvement potential. Diamonds represent input data, squares represent analysis methods, hexagons represent dichotomous decisions, circles represent decision's results, and red squares represent practical improvement measures.

III. Results and interpretation

III. 1. GIS-based model

III.1.1. Accessibility to river access points

III. 1. 1. 1. Potential amount of people able to reach a river within 15 minutes

The accessibility to river access points corresponds to the proportion of people able to reach a river within 15 minutes from their place of residence. This proportion varies depending on the means of transport (Table 11).

Table 11. Absolute number and proportion of people able to reach river access points within 15 minutes, according to their means of transport.

User type	Total number of people able to reach the access points	Proportion of the overall population (%)
Pedestrians	36644	98
Cyclists	36710	98
Car drivers	36444	97
Users of public transport	23285	62

Almost all inhabitants of the source population area (37,582 inhabitants) can reach a river's access point within 15 minutes: 98% of the population by foot, 98% by bicycle, 97% using their personal car, and 62% by public transport. These results indicate that people in Aarau have a very good access to rivers by foot, bicycle and cars, but a reduced accessibility when using public transport. This might be due to the planning of the public transport system, offering less flexibility than alternative transport means. In addition, this network is by far less developed than the road network used by pedestrians, cyclists and car drivers.

This conclusion must, however, be considered with caution. Only rivers larger than eight meters were accounted for in the model calculation in the case of cars and public transport. This restriction might partly lower the calculated accessibility to their access points.

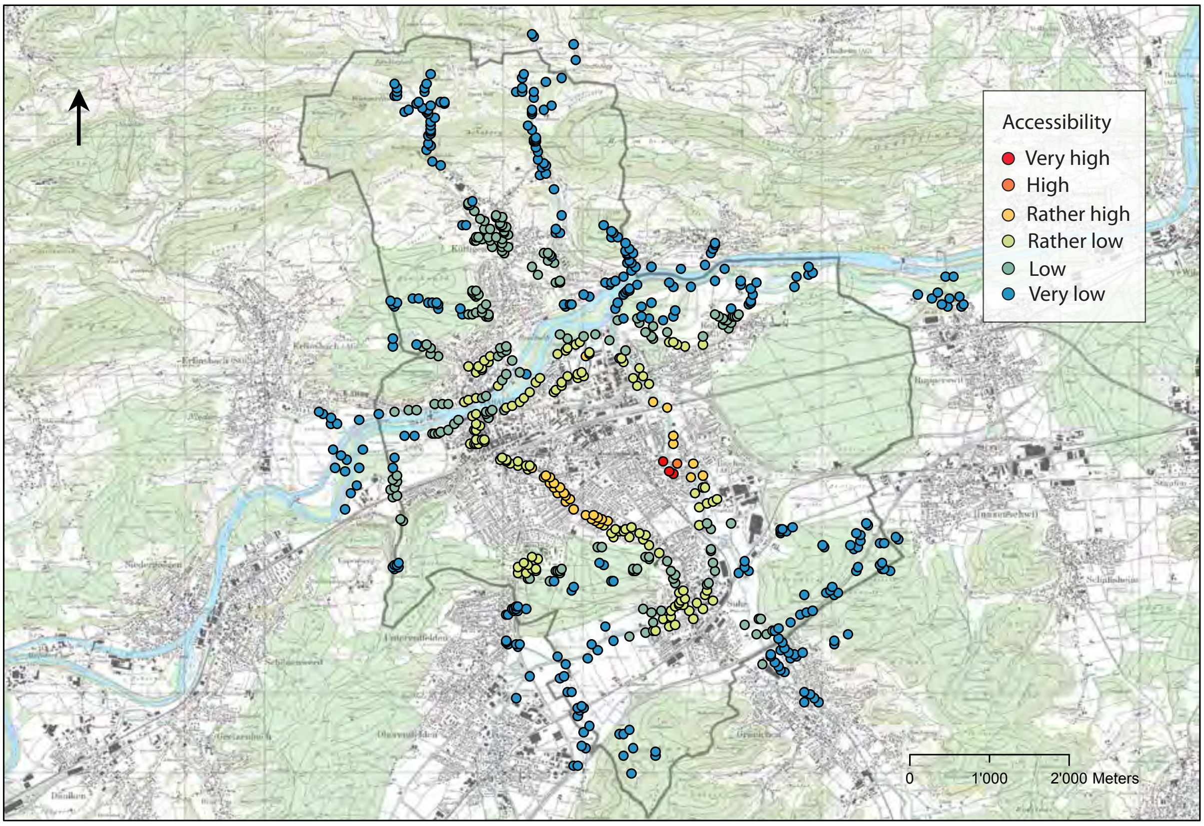

Fig. 24. Accessibility of river access points for pedestrians. It represents the potential amount of pedestrians (classified absolute values) that are able to reach each given access point within 15 minutes by foot. Inaccessible access points are not displayed on the map. Source: © 2012 Swisstopo (Topographical map).

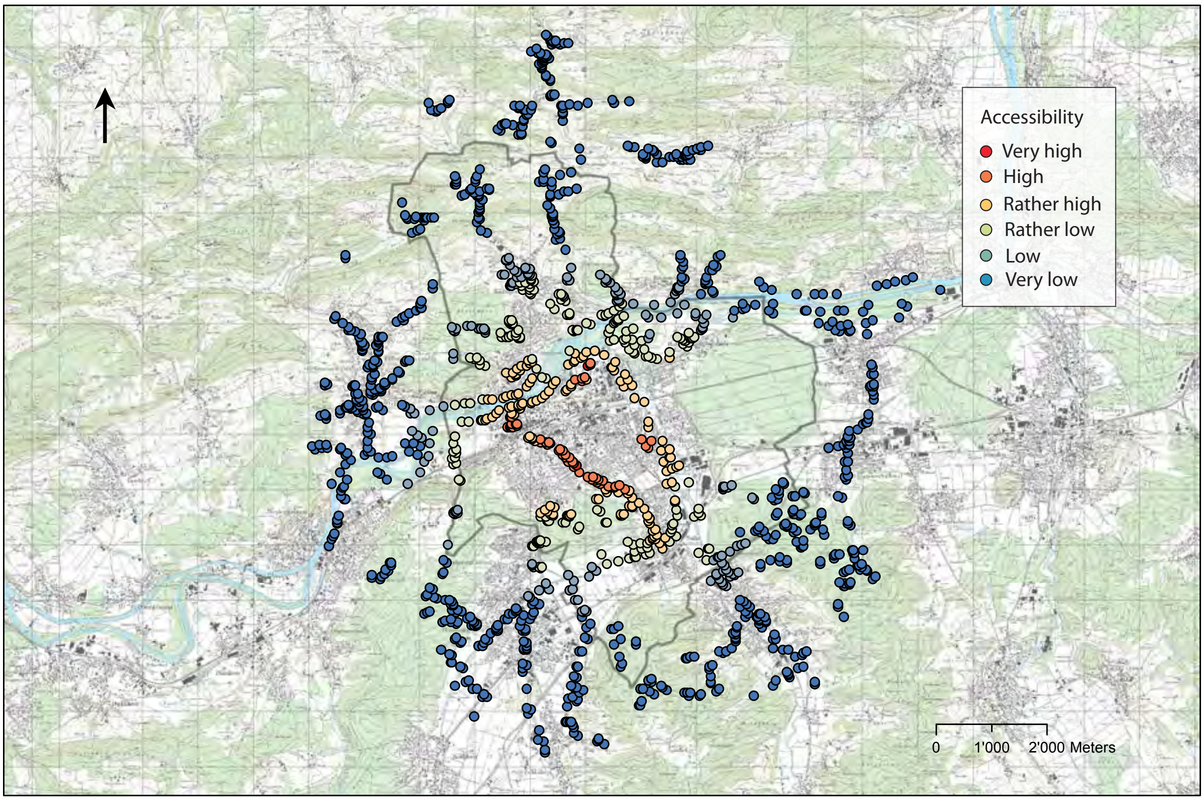

Fig. 25. Accessibility of river access points for cyclists. It represents the potential amount of cyclists (classified absolute values) that are able to reach each given access point within 15 minutes by bicycle. Inaccessible access points are not displayed on the map. Source: © 2012 Swisstopo (Topographical map).

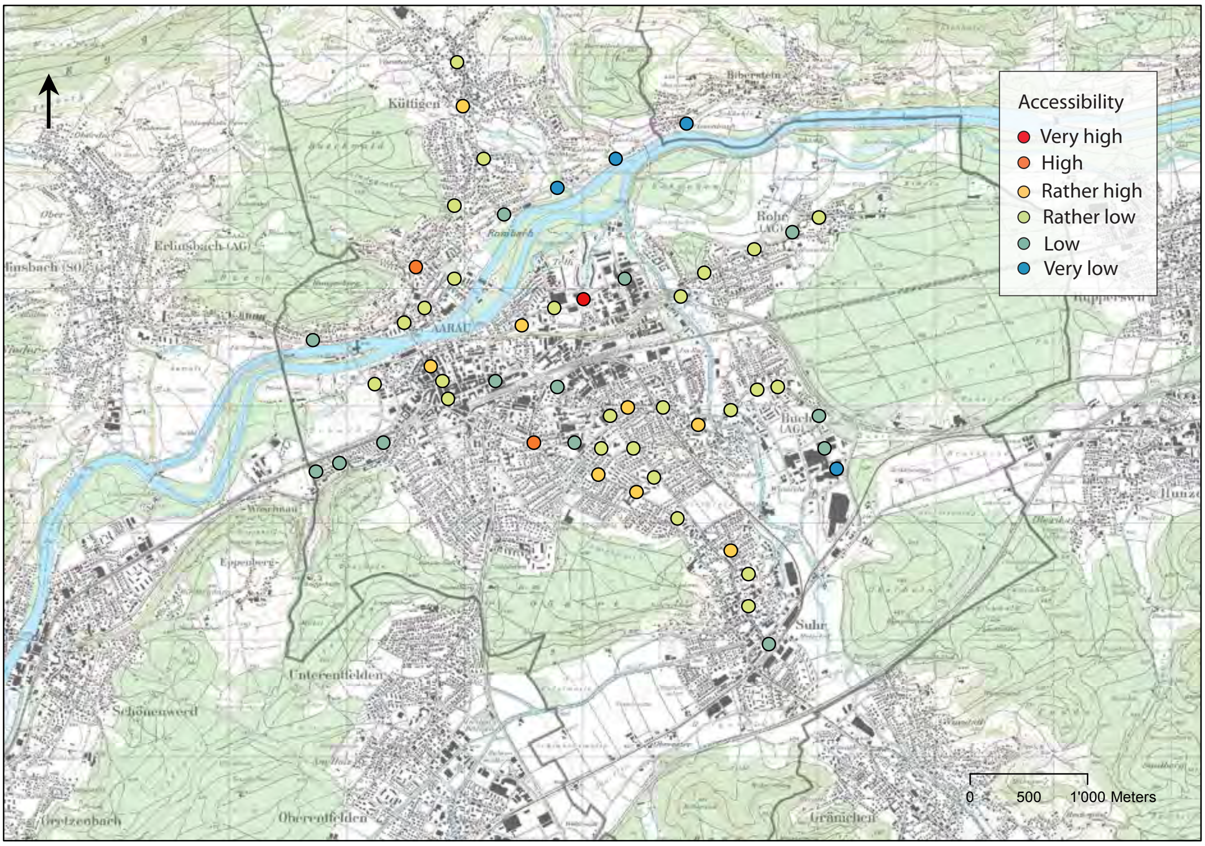

Fig. 26. Accessibility of river access points for users of public transport. It represents the potential amount of users of public transport (classified absolute values) that are able to reach each given access point within 15 minutes by public bus. Inaccessible access points are not displayed on the map. Source: © 2012 Swisstopo (Topographical map).

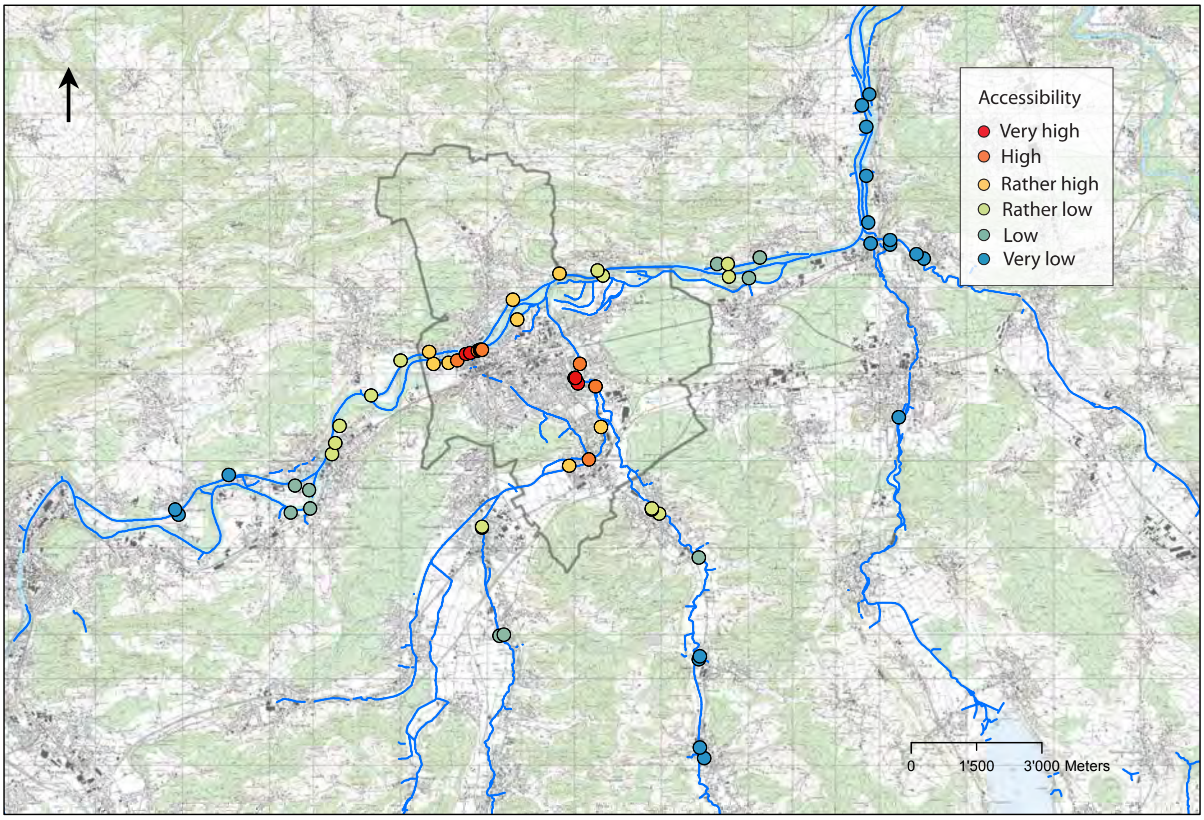

Fig. 27. Accessibility of river access points for car drivers. It represents the potential amount of car drivers (classified absolute values) that are able to reach each given access point within 15 minutes with their personal car. Inaccessible access points are not displayed on the map. Source: © 2008 FOEN (Eco-morphological state of Swiss rivers), © 2012 Swisstopo (Topographical map).

For pedestrians (Fig. 24), the potential amount of people able to reach river access points within 15 minutes varied between 0.007 and 360.38 people (the fractions arise from people's distribution among alternative access points according to the distance). It ranged from 0.001 to 154.51 people for cyclists (Fig. 25), from 0.2 to about 3,269 people for car drivers (Fig. 26) and from about 30 to 3,269 people in the case of public transport users (Fig. 27). These numbers are much larger in the case of car drivers and users of public transport because their reduced number of access points limited their distribution among alternative reachable access points.

The results of this analysis indicate that rivers situated within populated areas are by far the most accessible for recreation to pedestrians, cyclists and users of public transport. Access points situated outside of these areas have either a low accessibility or no accessibility at all because people can only cover a limited distance within 15 minutes. In the particular case of people travelling by car, all access points situated in a 3 km radius around populated areas showed a fairly high accessibility, due to the higher mobility of these users.

III.1.1.2. Influence of the geographical repartition of the population on the accessibility of river access points

The results of the accessibility calculation produced the following pieces of information for each river access point (sink point) (Fig. 28):

- Number of source points whose population reaches the given sink point (Nb_access_pts).
- Mean number of people reaching the given sink point per accessing source point (Mean_peop).
- Total number of people potentially able to reach the given sink point (Tot_peop)

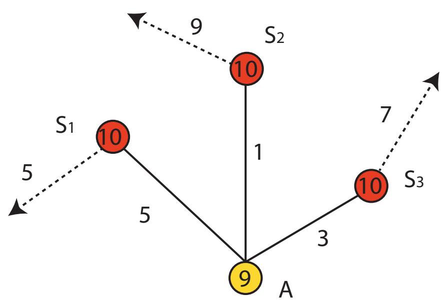

Fig. 28. Parameters influencing the potential number of people able to reach river access points. The sink point (access point) is displayed as a yellow circle (labelled A) and contains the number of people potentially able to reach it. The source points are displayed as red circles (labelled S_i) and contain their resident population. For each source point, the number of people reaching the displayed sink point are represented by solid lines, while the number of people reaching alternative sink points are displayed as dashed arrows. In this example, Nb_access_pts would be equal to 3, while Mean_peop would also be equal to 3 ((5+1+3)/3) and Tot_peop would be equal to 9.

The distributions of Nb_access_pts and Mean_peop for pedestrians are displayed in figures 29 and 30. Their values were classified into six classes, according to the 10, 25, 50, 75, 90, 100 percentile method, in order to enhance the comparability of the data. Tot_peop was already displayed in figure 24 (p. 45).

The parameter Nb_access_pts is “very high” along the Stadtbach (Fig. 29). It is also “high” in the city centre and in the vicinity of the village of Buchs. In Küttigen and Suhr, the value of this parameter is a bit lower, reaching a “rather low” value near the estate of Telli (see Fig. 4 p. 13) and “low” to “very low” values in peripheral areas. Conversely, the distribution of Mean_peop shows completely different patterns (Fig. 30). It is “very high” to “rather high” in the vicinity of Telli and along the Suhre in Buchs, decreasing to “rather low” along the Stadtbach and “rather low” to “low” in the city centre.

All in all, these two parameters indicate that only a few source points can reach the sink points situated near Telli, but that these source points contain a very high number of people. In contrast, many source points can reach the sink points situated along the Stadtbach, but the number of people they contain is comparatively much smaller. These patterns reflect the geographical repartition of Aarau’s population (See paragraph II.1.2, p. 12). The estate of Telli is actually highly populated; however, it is also rather isolated from the other districts of the city, bordered on the north side by the Aare, on the east side by the Suhre and on the south side by an industrial area. In contrast, the Stadtbach flows into the middle of a large residential area containing a very large number of residential buildings, although far less populated than the complex of Telli.

Interestingly, Tot_peop is higher along the Stadtbach than in the proximity of Telli (Fig. 24 p. 45). This indicates that Nb_access_pts might sometimes be more decisive than Mean_peop for rivers accessibility. Thus, the size and the connectivity of residential areas are as important as the strict population density when considering accessibility in peri-urban areas.

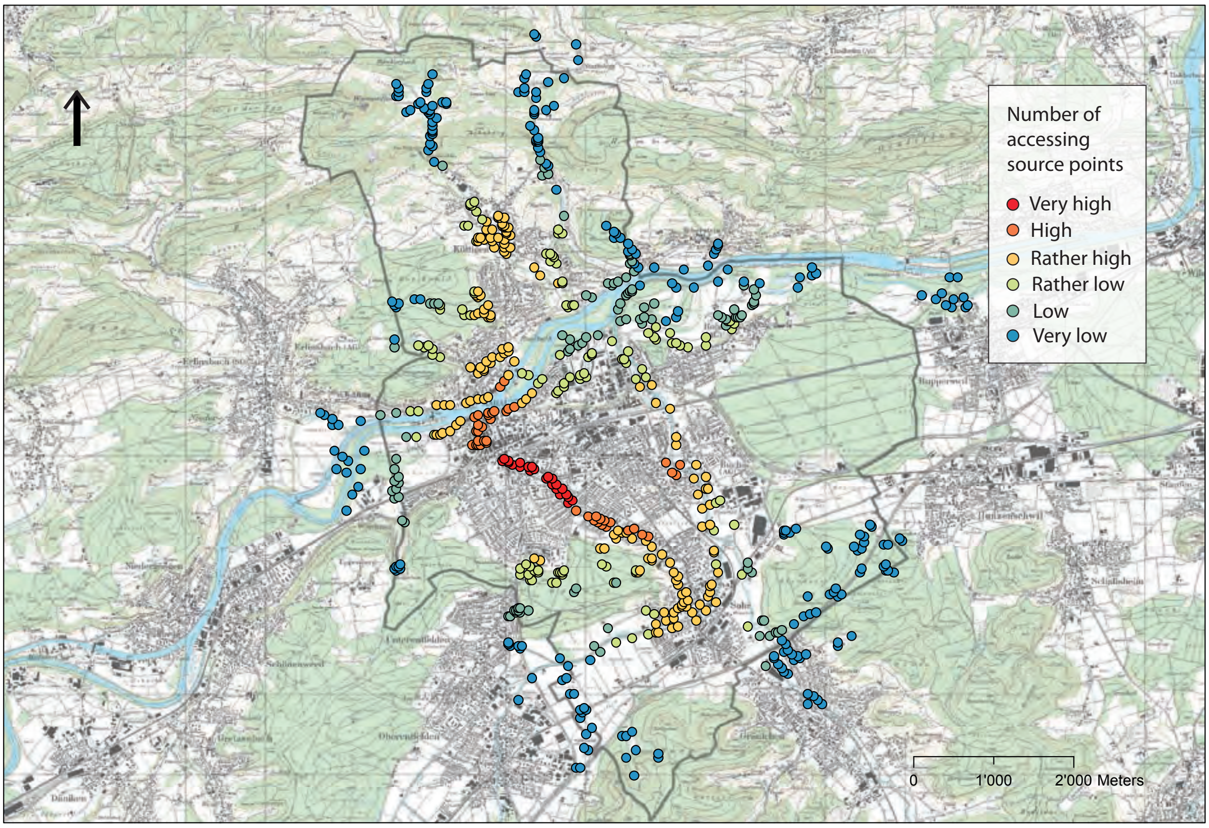

Fig. 29. Number of accessing source points (Nb_access_pts) per sink point. Source: © 2012 Swisstopo (Topographical map).

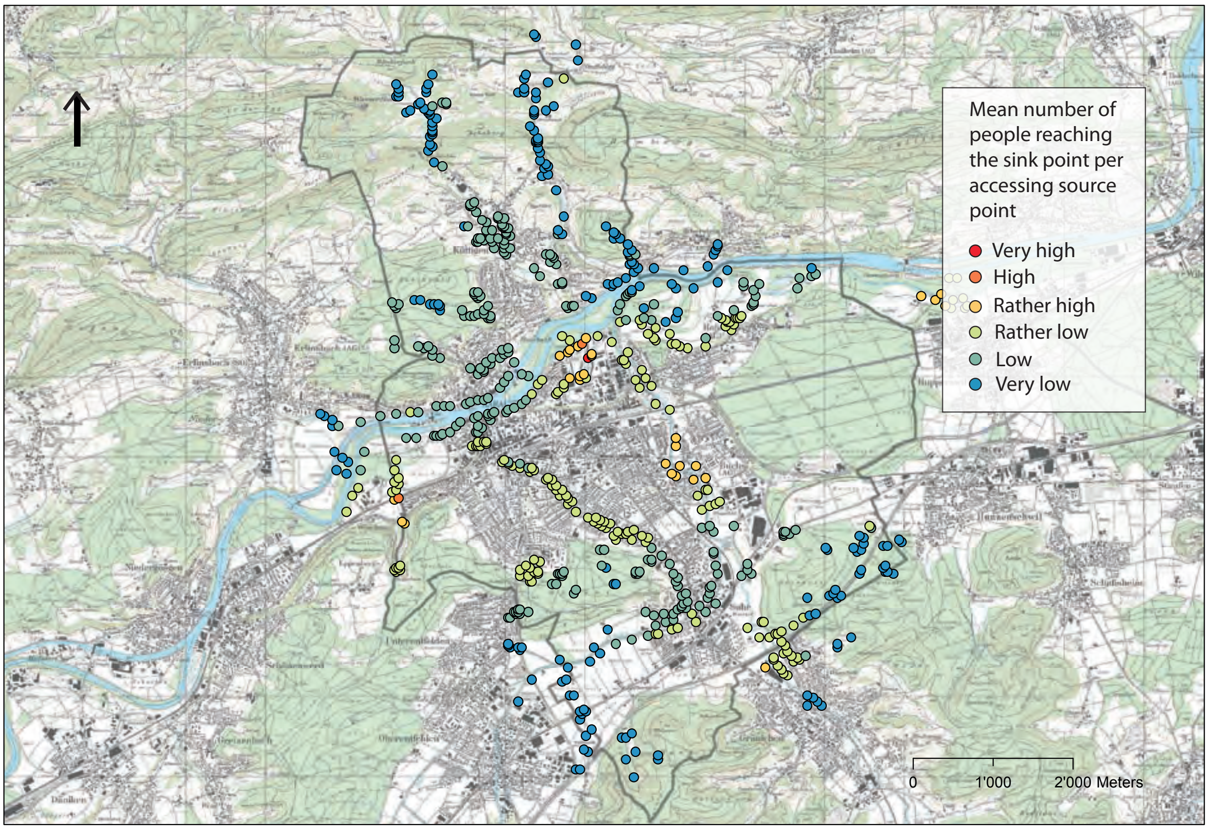

Fig. 30. Mean number of people reaching the sink point per accessing source point (Mean_peop). Source: © 2012 Swisstopo (Topographical map).

III. 1. 2. River stretches accessibility

III. 1. 2. 1. Reclassification of accessibility values

The accessibility value distributions resulting from the calculation performed with the aml script are displayed in Fig. 31, where high values indicate a high accessibility. For pedestrians and car drivers, the distributions are skewed to the left by a high frequency of small values, resulting in a smaller value of the distributions' means (18,890 for pedestrians, 16,762 for car drivers) compared to their medians (30,036 for pedestrians, 30,378 for car drivers). In contrast, the accessibility value distributions for cyclists and users of public transport are rather symmetrical, with only a light skew to the left, resulting in relatively close values for the means (45,222 for cyclists, 18,913 for users of public transport) and medians (50,197 for cyclists and 22,600 for users of public transport).

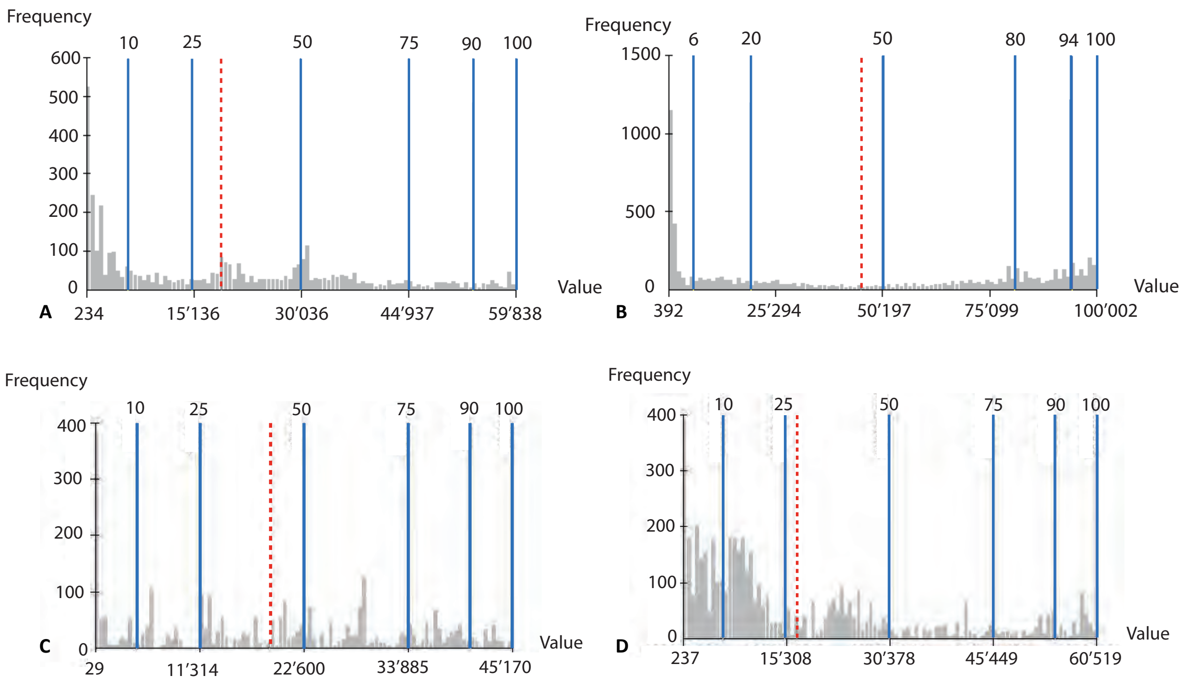

Fig. 31. Distribution of accessibility values along rivers for pedestrians (A), cyclists (B), users of public transport (C), and car drivers (D). The accessibility values attributed to the raster cells are displayed on the histogram as grey bars according to their frequency of occurrence. The dashed red bars represent the distributions means, while the blue bars represent the break values chosen as class boundaries for their reclassification. Their absolute values are written below the x-axis, while their percentile ranks in the distribution are expressed as percentages and written above the respective blue bars.

To divide these continuous distributions into six classes, three classification methods available in ArcGIS 10.0 were applied to the datasets, as well as a manual classification in percentiles 10, 25, 50, 75, 90 and 100. The resulting break values defined by the different methods are presented in table 12 and expressed as percentile ranks.

Table 12. Percentile ranks attributed to the accessibility distributions according to different classification methods. The percentile ranks are expressed in percentages (%).

	Percentile ranks (%)			
Classification method	Pedestrians	Cyclists	Users of public transport	Car drivers
Quantile	2/8/30/46/61/ 100	1/12/41/76/90/ 100	3/26/44/61/80/ 100	4/11/16/35/56/ 100
Manual	10/25/50/75/90/ 100	10/25/50/75/90/ 100	10/25/50/75/90/ 100	10/25/50/75/90/ 100
Natural Jenks	9/24/42/59/79/ 100	10/30/50/71/87/ 100	12/31/46/59/76/ 100	10/25/40/56/80/ 100
Geometrical interval	4/9/18/34/59/ 100	6/20/50/80/94/ 100	13/26/42/59/79/ 100	3/7/14/27/53/ 100

As the main goal of the classification was to identify river stretches presenting a particularly high accessibility, the most appropriate classification method to identify large values was chosen for each user type. It resulted in the choice of the manual classification for pedestrians, users of public transport and car drivers and of the geometrical interval for cyclists.

The quantile method attributed an equal number of features to each class, resulting in very narrow classes for the smaller values of the distribution, and a coarse differentiation for the highest values, especially in the case of pedestrians (large break between percentiles 61 and 100) and car drivers.

The manual classification according to specific percentiles provided a different number of features in each class and allowed for a precise identification of very large values (class limited by percentiles 90 and 100).

The natural Jenks method identified classes based on the inherent structure of the distributions. Break values were defined where big jumps in data values could be identified. It resulted in a classification aggregating large values into single classes (classes limited by percentiles 79 and 100 for pedestrians, and percentiles 87 and 100 for cyclists) and not allowing for a distinction among them.

Finally, the geometrical classification method produced very different results for cyclists and users of public transport than for the other types of users. In the first case, this method resulted in a precise classification of small and large values with an aggregation of medium values into larger classes. In the second case, the skewedness of the data induced a precise classification of small values (classes delimited by percentiles 4, 9, 18, 34, 59 in the case of pedestrians), at the expense of large values, which were all classified in a single class (delimited by percentiles 59 and 100 in the case of pedestrians).

III. 1. 2. 2. Accessibility maps

According to the classification methods described above, the resulting proportions of raster cells attributed to each accessibility class are displayed in Table 13. The proportion of cells attributed to the two highest accessibility classes (accessibility hotspots) is much larger for cyclists (18 and 19%) than for the other types of users. Even if this might by partly due to the different classification methods employed, it probably mostly reflects the higher mobility of cyclists comparing to pedestrians, and their higher flexibility comparing to users of public transport and car drivers. In fact, cyclists do not have to stick to the main roads as car drivers do. The resulting accessibility maps are presented in figures 32 to 35.

Table 13. Proportion of raster cells attributed to each accessibility class. Proportions are expressed as percentage (%) of the total number of raster cells and are rounded up to whole numbers.

Type of user	Very high accessibility (%)	High accessibility (%)	Rather high accessibility (%)	Rather low accessibility (%)	Low accessibility (%)	Very low accessibility (%)
Pedestrians	4	5	20	23	11	36
Cyclists	18	19	16	12	9	26
Users of public transport	6	14	22	29	10	19
Car drivers	5	5	7	20	31	32

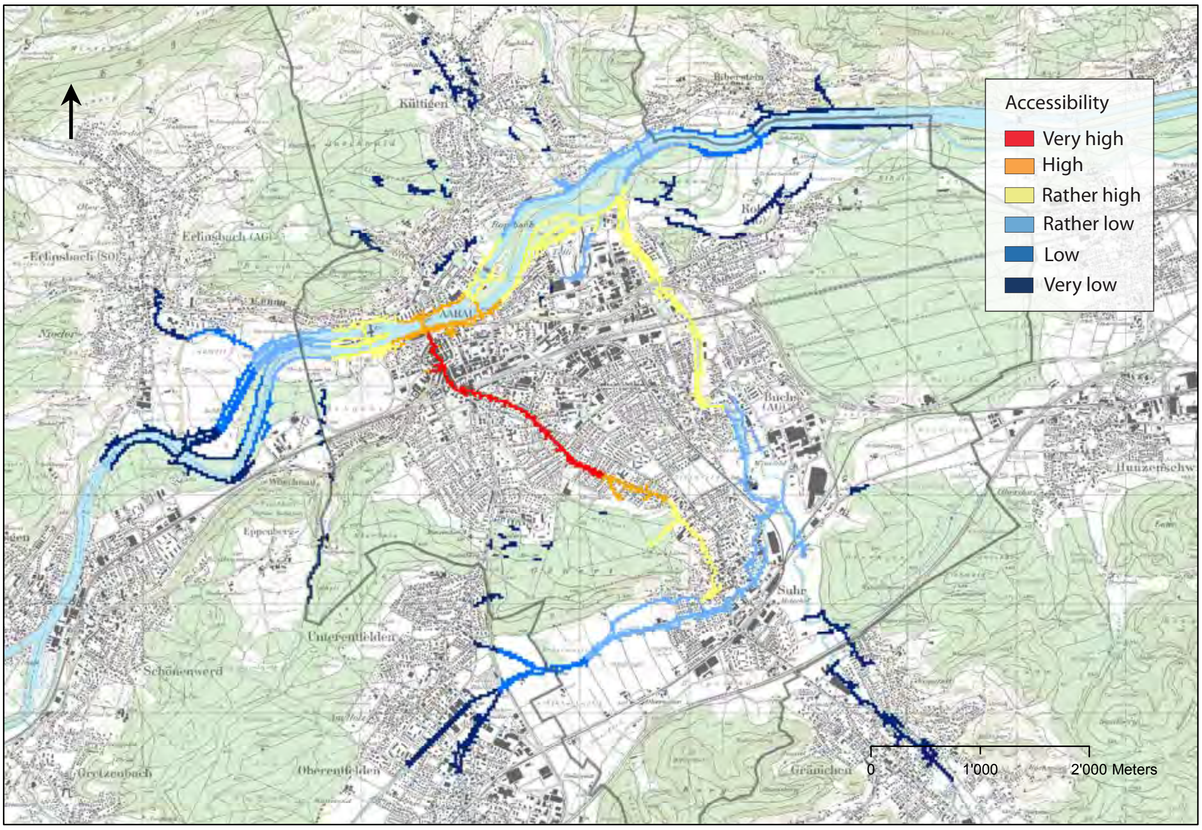

Fig. 32. Accessibility of river stretches for pedestrians. It represents the potential amount of pedestrians (classified relative values) that are able to reach each river stretch in the course of a recreational activity lasting less than 90 minutes in total, by foot. The source population area is displayed as a grey line, while roads along rivers are displayed in different colours depending on their accessibility. Source: © 2012 Swisstopo (Topographical map).

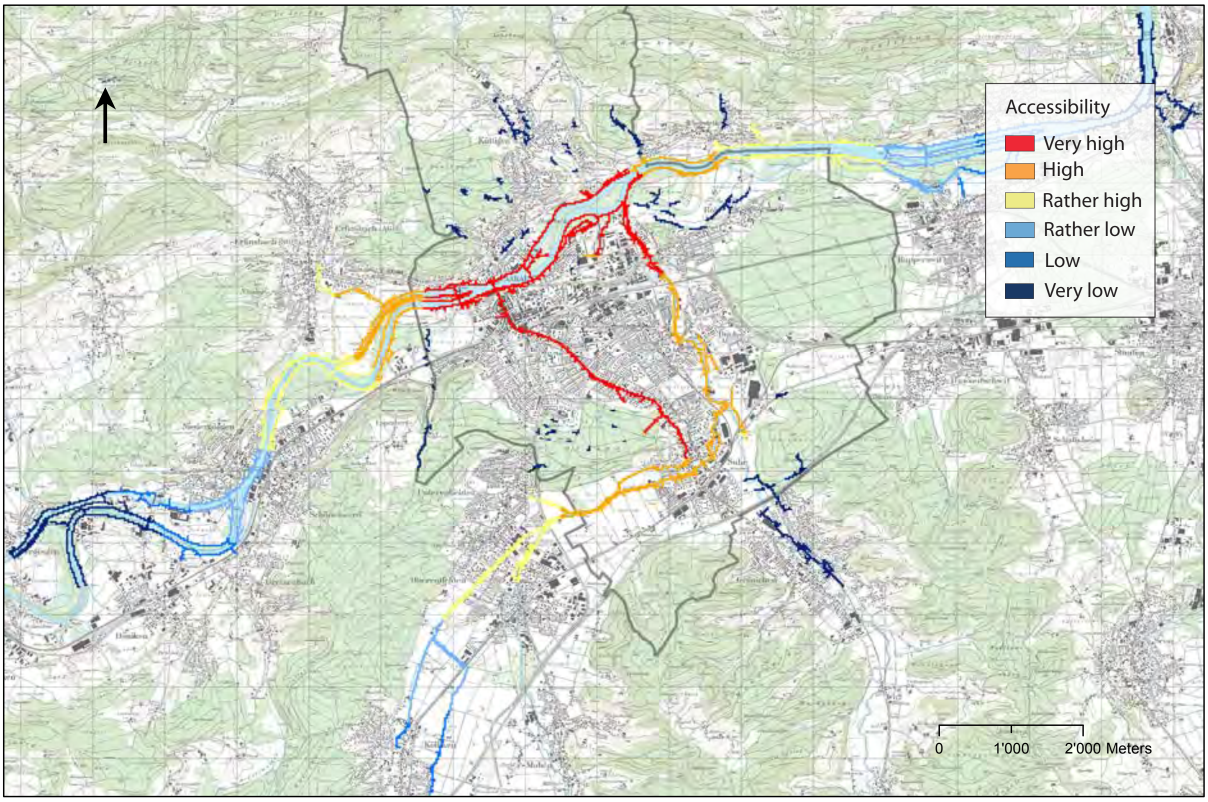

Fig. 33. Accessibility of river stretches for cyclists. It represents the potential amount of cyclists (classified relative values) that are able to reach each river stretch in the course of a recreational activity lasting less than 90 minutes in total, by bicycle. The source population area is displayed as a grey line, while roads along rivers are displayed in different colours depending on their accessibility. Source: © 2012 Swisstopo (Topographical map).

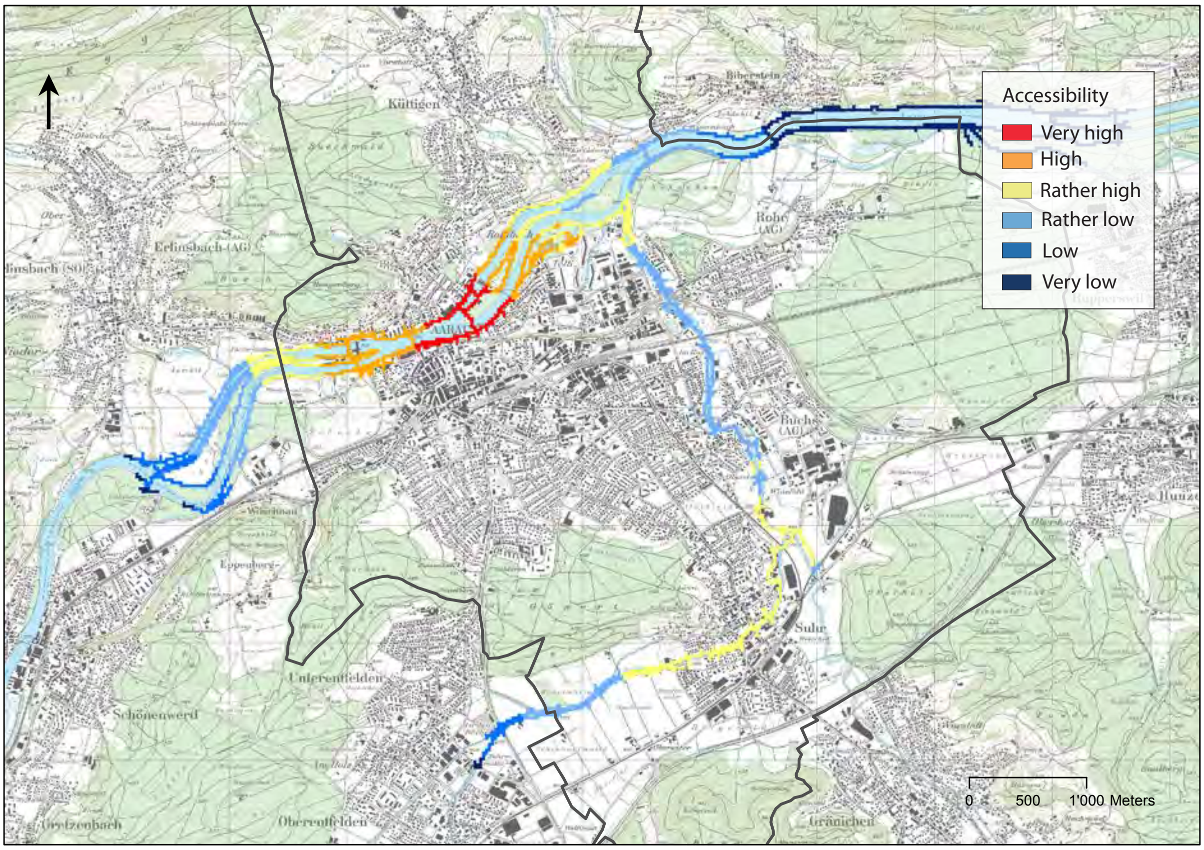

Fig. 34. Accessibility of river stretches for users of public transport. It represents the potential amount of users of public transport (classified relative values) that are able to reach each river stretch in the course of a recreational activity lasting less than 90 minutes in total, by public bus until the river access point, and then by foot. The source population area is displayed as a grey line, while roads along rivers are displayed in different colours depending on their accessibility. Source: © 2012 Swisstopo (Topographical map).

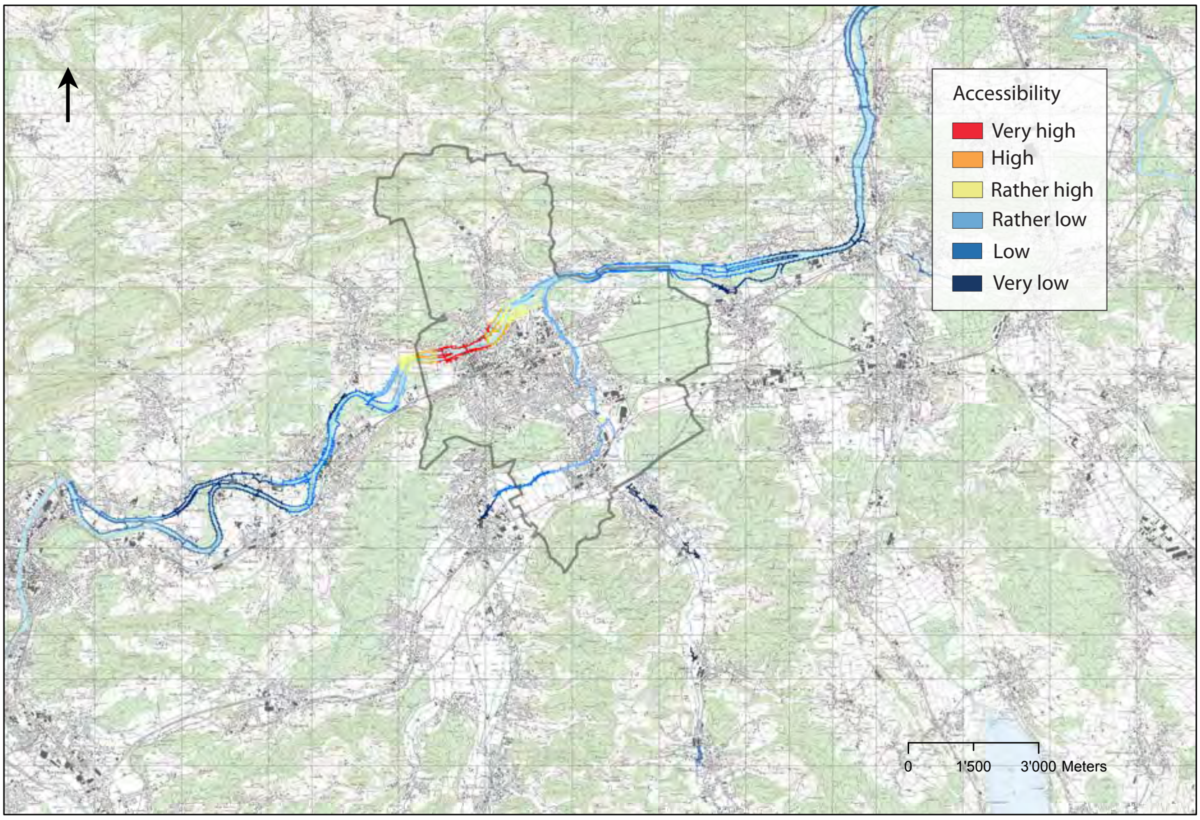

Fig. 35. Accessibility of river stretches for car drivers. It represents the potential amount of car drivers (classified relative values) that are able to reach each river stretch in the course of a recreational activity lasting less than 90 minutes in total, by private car until the river access point, and then by foot. The source population area is displayed as a grey line, while roads along rivers are displayed in different colours depending on their accessibility. Source: © 2012 Swisstopo (Topographical map).

The accessibility of river stretches is represented by a relative measure of the potential amount of people able to reach them while doing recreational activities or relaxing. In the case of pedestrians, river stretches assigned to the category "very high" accessibility are situated along the Stadtbach, up until its confluence with the Aare. The central section of the Aare is characterized by a "high" accessibility, together with a small stretch of the Stadtbach situated north of the village of Suhr. A "rather high" accessibility is present along the northern section of the Suhre as well as along the Aare - west and east of its central section - until its confluence with the Suhre. The other river stretches are assigned a "rather low" to "very low" accessibility as a result of their remoteness from populated areas.

For cyclists, almost all river stretches situated in populated sectors within the source population area get a "very high" accessibility, except for the southern section of the Suhre. This last stretch is assigned to the category "high" accessibility, together with the portion of the Aare situated west of its central section and north of the village of Rohr. All remaining stretches get a "rather high" to "very low" accessibility, depending on their remoteness from the populated areas.

For users of public transport and car drivers, the most accessible river stretches are situated in the central section of the Aare. The accessibility then decreases towards the east and the west. For users of public transport, the section of the Suhre situated near the village of Suhr also has a "rather high" accessibility. However, the results of the accessibility calculation for car drivers are likely more biased than for the other user types by the linear equation used to distribute people among alternative access points. In fact, larger distances separate the access points from the places of residence in their case. In consequence, the concentration of highly accessible river stretches only in the central section of the Aare is probably not representative of the reality.

In conclusion, the most accessible river stretches (i.e. river stretches characterized by a "rather high" to "very high" accessibility) are situated within the most populated areas for pedestrians and users of public transport. For cyclists, the accessible stretches are situated within a three kilometres perimeter around the most populated areas. For the reasons highlighted in the above paragraph, the perimeter including river stretches accessible to car drivers is more difficult to establish.

It is important to point out one of the limitations of the model clearly apparent at this stage of the analysis: this model is inaccurate for small river stretches not connected to the main watercourses considered (Aare, Suhre and Stadtbach). All of these peripheral streams are classified as having a "very low" accessibility and are therefore displayed in dark blue. This is due to their separation from the main rivers, which does not allow them to benefit from the contribution of people accessing alternative access points in the second step of the accessibility calculation.

III. 1. 2. 3. Influence of access points distribution on river accessibility

The distribution of access points influences the calculations of accessibility, as represented in figure 36. This figure represents two particular cases of a fictional situation where a source point contains 10 people. In the first case (A) only one access point is accessible to these 10 people, while in the second case (B) two alternative access points - situated at equal distances - are accessible to them.

In case (A), the 10 people reach the access point and all raster cells accessible within 30 minutes from this access point will get a value of 10 (orange line). In case (B), 5 people will reach each access point, because the 10 original people are distributed among them. Consequently, all raster cells accessible within 30 minutes from each access point will get a value of 5 (plain and dashed yellow line for the left access point, plain and dashed red line for the right access point).

In this case, the river stretch accessible to both access points will get a value of 10 (orange line). Compared to case (A), a smaller portion of the river gets a value of 10, while two peripheral stretches (yellow and red dashed lines) get a value of 5 each.

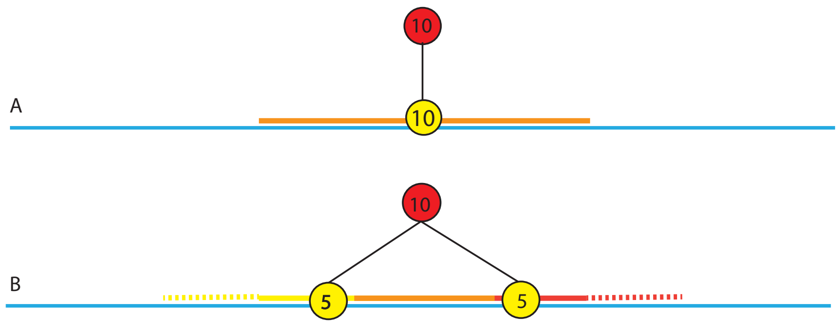

Fig. 36. Influence of access point distribution on calculated accessibility. The red circles represent source points and the numbers inscribed in their centres represent the number of people they contain. The yellow circles represent river access points and the numbers inscribed in their centre represent the number of people accessing them. The blue line represents a river. In case (A), the orange line represents the river stretch accessible from the access point. In case (B), the orange line represents the river stretch accessible by both access points. The yellow line represents the river stretch accessible to the left access point, while the red line represents the river stretch accessible by the right access point.

This very simplified situation clearly shows that the accessibility values attributed to river stretches partly depend on the number of access points distributed along them. This phenomenon might slightly bias the calculated accessibility.

III.1.3. Landscape suitability

The landscape suitability analysis was performed separately for pedestrians and cyclists because the road selection was conducted differently according to their mobility characteristics (e.g. park footpaths were assigned to the highest quality class for pedestrians while they were assigned to the lowest for cyclists). However, as only about 768 m of park footpaths are present in the study perimeter, this difference in classification does not induce a significant change in the final landscape suitability results.

Table 14. Proportion of raster cells attributed to each landscape suitability class. Proportions are expressed as the percentage (%) of the total number of raster cells and are rounded up to whole numbers. The resulting landscape suitability is displayed according to different colours: dark green (very high), pale green (high), pale blue (rather low) and dark blue (low).

		Road quality for recreation		
		Very high	High	Low
River quality for recreation	Very high	8	18	1
	High	13	24	2
	Rather low	6	13	2
	Low	3	8	2

Consequently, the next paragraphs will treat landscape suitability both for pedestrians and cyclists, without differentiation. After reclassifying the landscape suitability scores into four resulting classes, the majority of the raster cells (39%) were assigned to the class "very high" landscape suitability (Table 14). Slightly fewer were assigned to a "high" landscape suitability (33%), while only 21% and 7% of the cells were assigned to the categories "rather low" and "low" landscape suitability, respectively.

In conclusion, most river stretches in and around Aarau already have a "high" to "very high" landscape suitability to support recreation when considering only road and river eco-morphological quality as indicators. The resulting map is presented in figure 37.

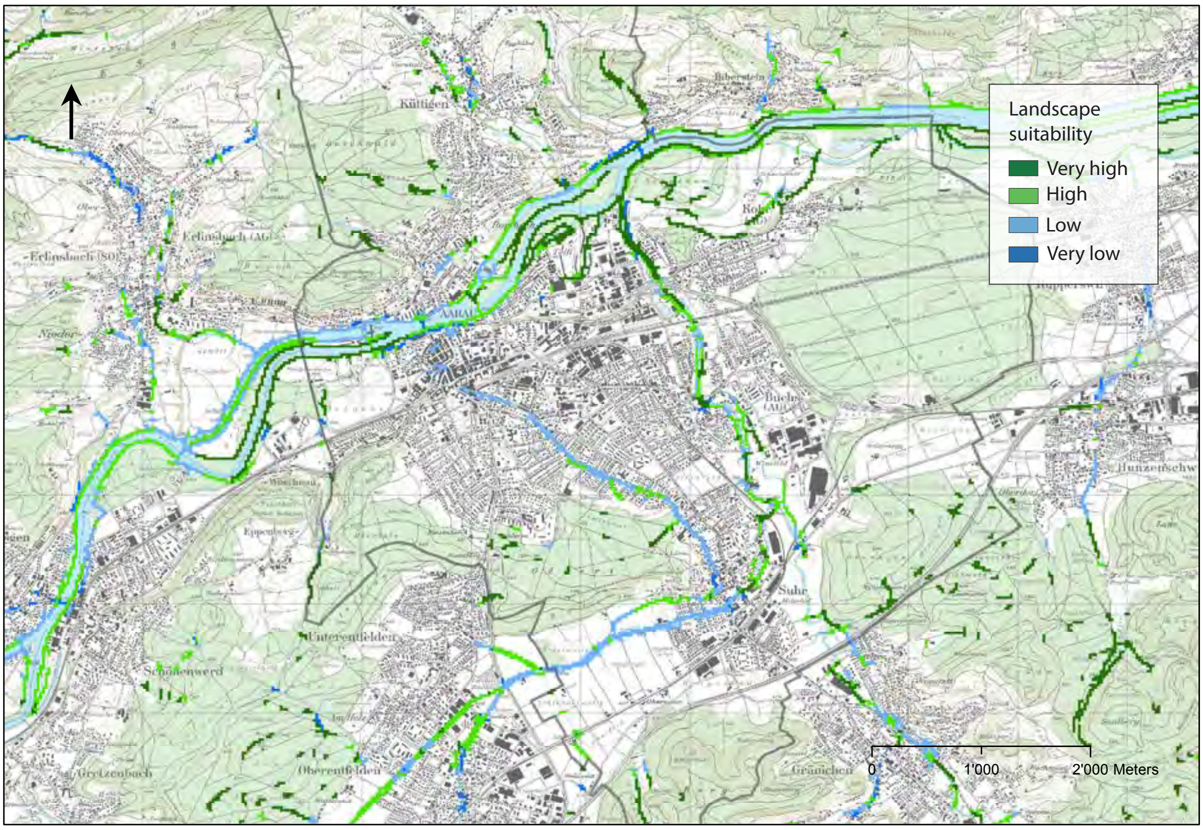

Fig. 37. Landscape suitability of rivers to provide recreation. The source population area is displayed as a grey line. Source: © 2012 Swisstopo (Topographical map).

River stretches with a “very high” landscape suitability are situated along the lower branches of the Aare – both west and east of its central section – as well as on the northern section of the Suhre. Those belonging to the “high” landscape suitability class are located mainly in the central section of the Aare, along one of its upstream branches, and along the Suhre. The Stadtbach and the left bank of the Aare’s upper branch – west of its central section – have a “low” landscape suitability. Only a few stretches, situated near dams along the course of the Aare, have a “very low” landscape suitability.

III. 1. 4. Amount of recreational infrastructures along rivers

The amount of infrastructures along rivers was calculated exactly the same way for pedestrians and cyclists. Hence, the next paragraphs refer to both users. The GPS records of small recreational infrastructures are not presented in this manuscript, but their complete datasets are included in the enclosed CD. The distribution of density values for infrastructures along rivers is displayed in figure 38.

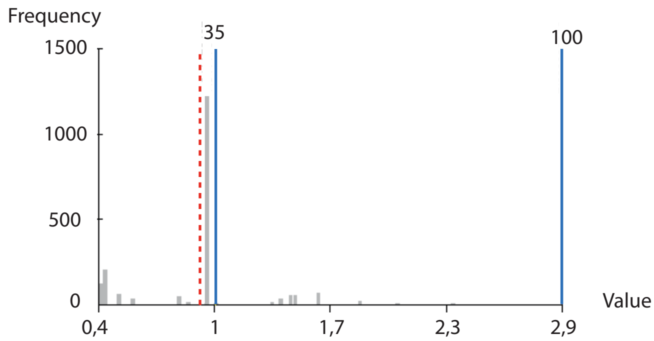

Fig. 38. Distribution of infrastructures density values along rivers. The infrastructures density values are displayed on the histogram as grey bars according to their frequency of occurrence. The dashed red bar represents the distribution mean, while the blue bars represent the break values chosen as class boundaries. Their absolute values are written below the x-axis, while their percentile ranks in the distribution are expressed as percentages (%) and written above the corresponding blue bars.

Very few raster cells presented high infrastructure density values and the distribution was classified into only two classes by the Natural breaks (Jenks) classification method. The data were separated according to their intrinsic structure, which in this case was perfectly suitable to identify raster cells having a particularly high number of infrastructures. The break values were defined as the 35 and 100 percentile ranks. According to this classification, 86% of cells presenting infrastructures were classified as having “few” infrastructures, while 13% were classified as having “many” infrastructures.

The resulting map is presented in figure 39. Recorded infrastructures are present along all rivers except the Stadtbach and the lower branch of the Aare, west of its central section. Also, stretches presenting many infrastructures are often situated in direct proximity to urban or peri-urban centres (Aarau, Niedergösgen).

In the case of the Aare's lower branch, the absence of infrastructures reflects its status as a natural protected area (R. Strebel, personal communication, June 22, 2012). The amount of recreational infrastructures thus seems to reflect planning decisions: many infrastructures are placed in areas dedicated to recreation, while protected areas are kept free from them in order to prevent the population from putting pressure on their ecological functioning.

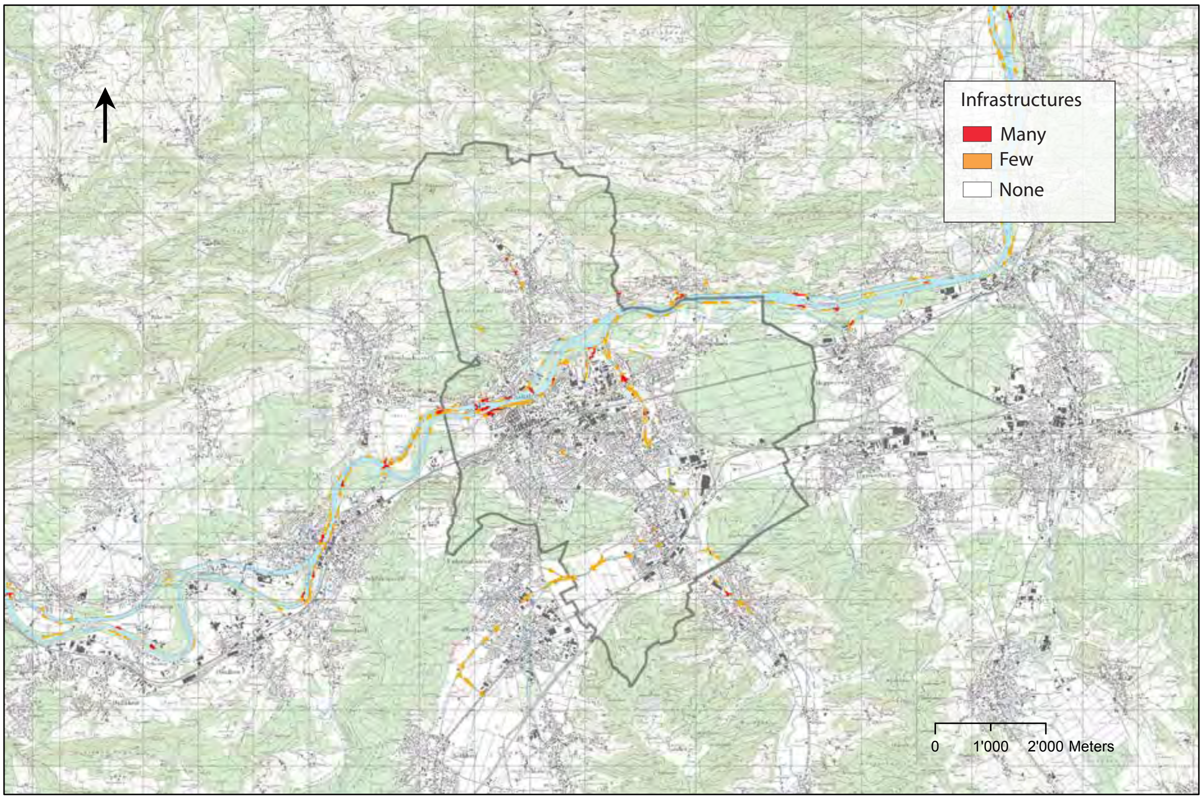

Fig. 39. Amount of recreational infrastructures along rivers. The source population area is displayed as a grey line. Source: © 2012 Swisstopo (Topographical map).

III. 1. 5. Modelled recreational use of rivers

For pedestrians, most of the cells were attributed to a “low” (32%) or “rather low” (31%) recreational use, while most of them were attributed a “rather high” (34%) or “high” (27%) modelled recreational use for cyclists (Table 15).

Table 15. Proportion of raster cells attributed to each class of modelled recreational use. They are expressed as percentages (%) of the total number of raster cells and are rounded up to whole numbers.

Modelled recreational use	Pedestrians (%)	Cyclists (%)
Very high	4	11
High	13	27
Rather high	20	34
Rather low	31	17
Low	32	11

These important disparities are mainly attributable to two factors. First, cyclists have a globally higher accessibility than pedestrians, as already emphasized in paragraph III.1.2.2. p. 52. Second, the reclassification of cyclist scores was performed by giving more importance to the landscape suitability factor than in the case of pedestrians (see material and methods, p. 34). As most river stretches have a “high” to “very high” landscape suitability (see Table 14 p. 57), classification in the two higher classes of recreational use was favoured in the case of cyclists, even if their accessibility was not very high.

The final maps displaying the modelled recreational use are presented in figures 40 and 41. River stretches are represented as plain lines instead of raster cells for visual comfort. For pedestrians, modelled recreational “hotspots” (i.e. stretches presenting a “very high” modelled recreational use) are situated in the central section of the Aare, at the foot of the old town, while the northern part of the Stadtbach and the northern stretch of the Suhre are classified as having a “high” modelled recreational use. The southern section of the Stadtbach, together with the right bank of the Aare (i.e. near the estate of Telli, see Fig. 4 p.13) and a small segment of the Aare situated upstream from the city centre, have a “rather high” modelled recreational use. All other stretches are classified as having either a “rather low” or a “low” recreational use, depending on their remoteness from the populated areas.

In the case of cyclists, many more stretches are classified as “hotspots”, including the central section of the Aare, its right bank until the confluence with the Suhre and the northern segment of the Suhre. The southern part of the Suhre situated between the villages of Buchs and Suhr, the two branches of the Aare upstream from the old city, as well as the right bank of the Aare downstream from its confluence with the Suhre are assigned to the class “high” modelled recreational use. Finally, the Stadtbach, the southern stretch of the Suhre and some stretches of the Aare upstream from the city are classified as having a “rather high” recreational use, while the remaining river stretches are assigned to the “rather low” to “low” categories.

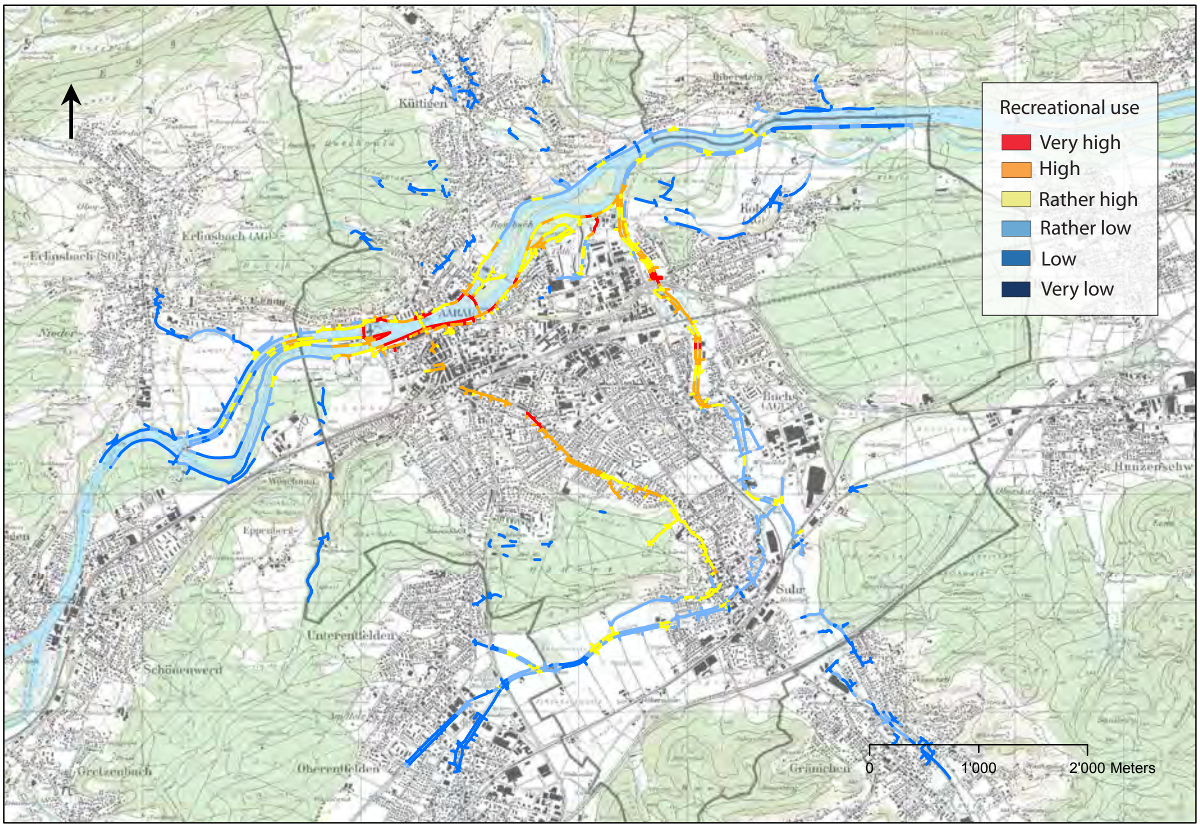

Fig. 40. Modelled recreational use of rivers by pedestrians. The source population area is displayed as a grey line. Source: © 2012 Swisstopo (Topographical map).

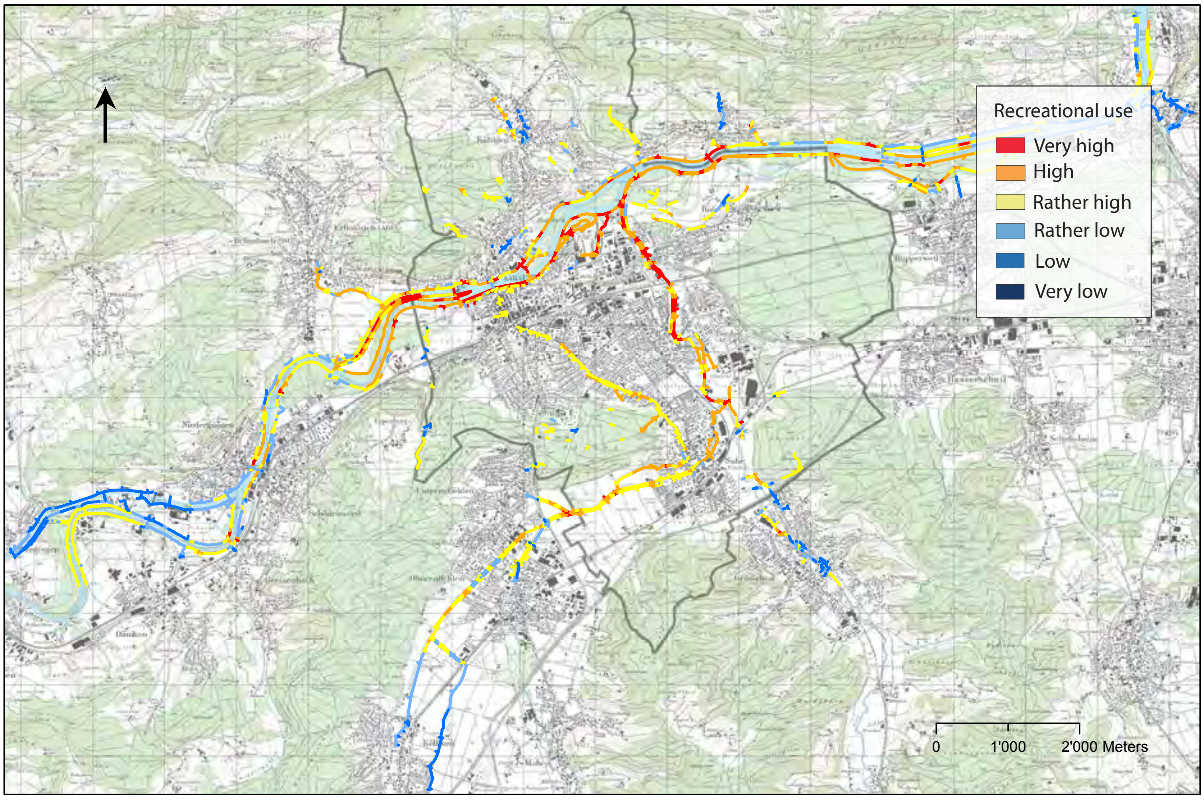

Fig. 41. Modelled recreational use of rivers by cyclists. The source population area is displayed as a grey line. Source: © 2012 Swisstopo (Topographical map).

III. 2. Visitation level

III.2.1. Frequency distribution of observed people

The number of recorded pedestrians varied between 0 and 118, depending on the sampling points, and between 0 and 61 in the case of cyclists (Fig. 42). In both cases, very few sampling points presented a high number of recorded individuals. In contrast, the frequency distributions show a high concentration of sampling points where few people were recorded.

On the whole, the absolute number of recorded cyclists (759) was higher than the number of recorded pedestrians (448). This general overrepresentation of cyclists is probably due to the time step of 10 minutes employed when performing the people count. During this short period of time, cyclists can cover a much greater distance than pedestrians and the probability of observing them is therefore higher.

In contrast, more sampling points showed a total absence of cyclists (N=24 sampling points) than a total absence of pedestrians (N=20 sampling points). This might be because a few sampling points were situated on footpaths which are officially forbidden to cyclists.

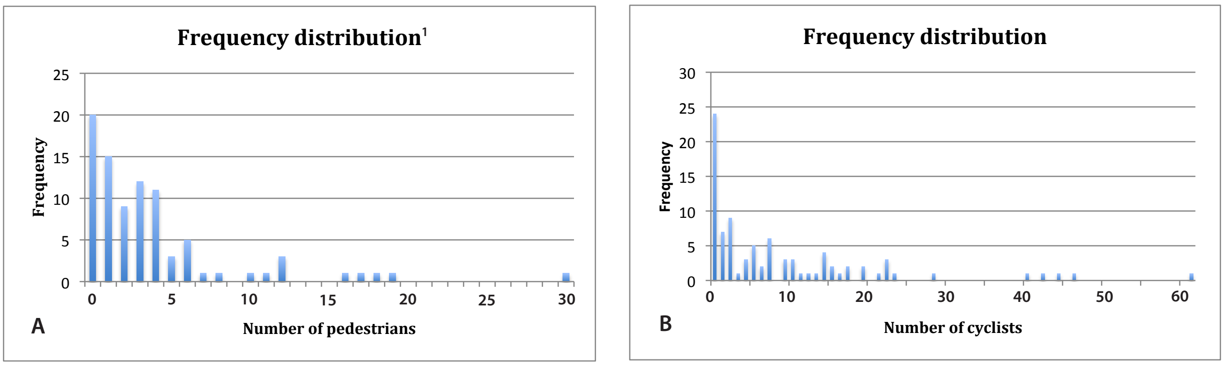

Fig. 42. Frequency distribution of the number of recorded pedestrians (A) and cyclists (B) at the 88 sampling points. The x-axis represents the number of recorded individuals, while the y-axis represents the number of sampling points presenting a given number of recorded individuals. [1]The sampling point recording 118 pedestrians was too large to be displayed.

In the case of pedestrians, two possible outliers corresponding to the sampling points A 26 (118 pedestrians recorded) and A 30 (30 pedestrians recorded) (see appendix A 3, p. 108 to view their location) were identified as having an exceptionally high number of recorded people. These outliers are both situated in public places with open bars that attract many people. They were not included in the statistical analysis in order to avoid biasing the results; however, they were displayed in the final visitation level map as “hotspots” because they represent areas of very high visitation rate.

Finally, the frequency distribution histograms indicates that none of the distributions are normally distributed, which confirms the relevance of performing a Kruskal-Wallis test instead of an ANOVA in the next step of the analysis.

III.2.2. Definition of visitation level classes

Figure 43 presents the division of pedestrian and cyclist distributions into different groups of visitation level according to the location of breaks in the progression of their histogram values. Only two groups were defined for pedestrians, while three different groups were defined for cyclists. This reflects the higher number of cyclists observed during the 10 minutes time step, which resulted in the definition of more robust classes.

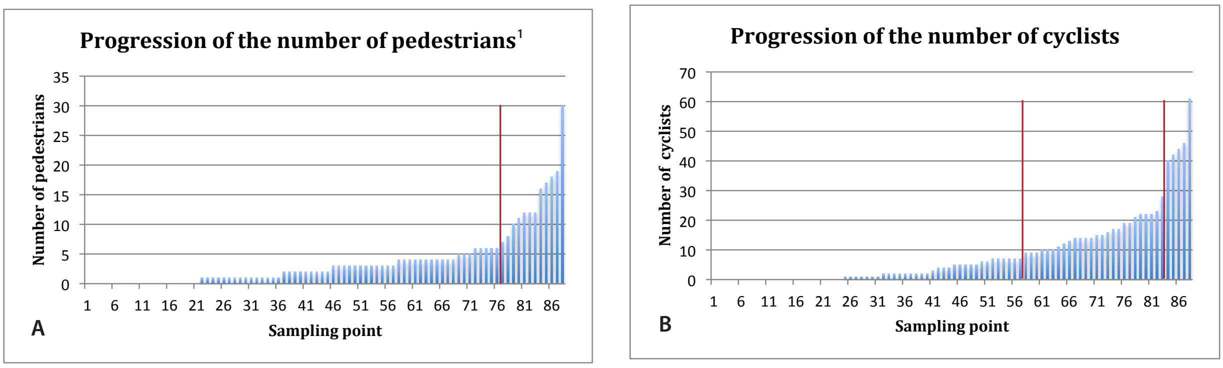

Fig. 43. Definition of break values in the distribution of the number of recorded pedestrians (A) and cyclists (B). The red bars represent the break values separating the distributions into groups. [1]The sampling point recording 118 pedestrians was too large to be displayed.

In both cases, most of the observations are included in the group presenting the lowest number of recorded individuals – i.e. group 1 – and only a small number of observations are included in the highest visitation level group (Table 16). The chosen classification resulted in relatively homogenous groups in most cases, as shown by their mostly small coefficients of variation. The first group of cyclists represents an exception because of its larger coefficient of variation (CV = 1.2). In spite of this rather large intra-specific variation, the statistical analysis could still be performed.

Table 16. Statistical characteristics of the different groups of visitation level defined for pedestrians (A) and cyclists (B). Group 1 represents sampling points with the lowest number of observed people, while group 3 represents sampling points with the highest number of observed people.

A	Group 1	Group 2
N[1]	75	11
Mean[2]	2,1	12,9
Sd[3]	1,9	4
CV[4]	0,9	0,3

B	Group 1	Group 2	Group 3
N[1]	56	26	5
Mean[2]	2,09	15,6	46
Sd[3]	2,5	5,2	8,4
CV[4]	1,2	0,3	0,2

[1]Number of observations per group [2]Mean [3]Standard deviation [4]Coefficient of variation

III.2.3. Statistical test

The results of the Kruskal-Wallis test indicated that a significantly different number of people were observed between the defined groups for pedestrians ($p<0.05$ for groups 1 and 2; Fig. 44. A.) and for cyclists ($p<0.05$ for all group comparisons; Fig. 44. B.). In practical terms, this means that the differences noticed among the groups are probably not happening simply by chance, but that some river stretches are significantly more visited than others.

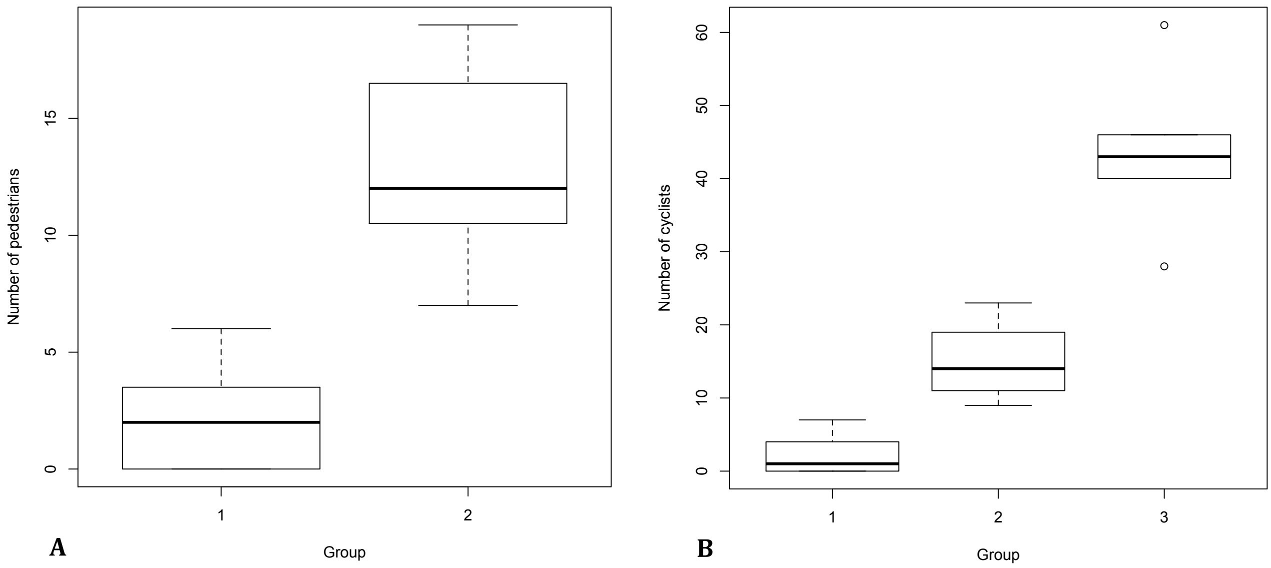

Fig.44. Boxplots of the different visitation level groups for pedestrians (A) and cyclists (B).

III.2.4. Maps of visitation “hotspots”

On the visitation level maps, sampling points were represented according to which group they belong (i.e. group 1, 2 or 3). For a better understanding, the map legends do not refer to these groups, but instead indicate if the visitation level recorded at each sampling point was “high” (group 2 for pedestrians, group 3 for cyclists), “medium” (group 2 for cyclists) or “low” (group 1).

Sampling points presenting a “high” visitation level are described as visitation “hotspots”.

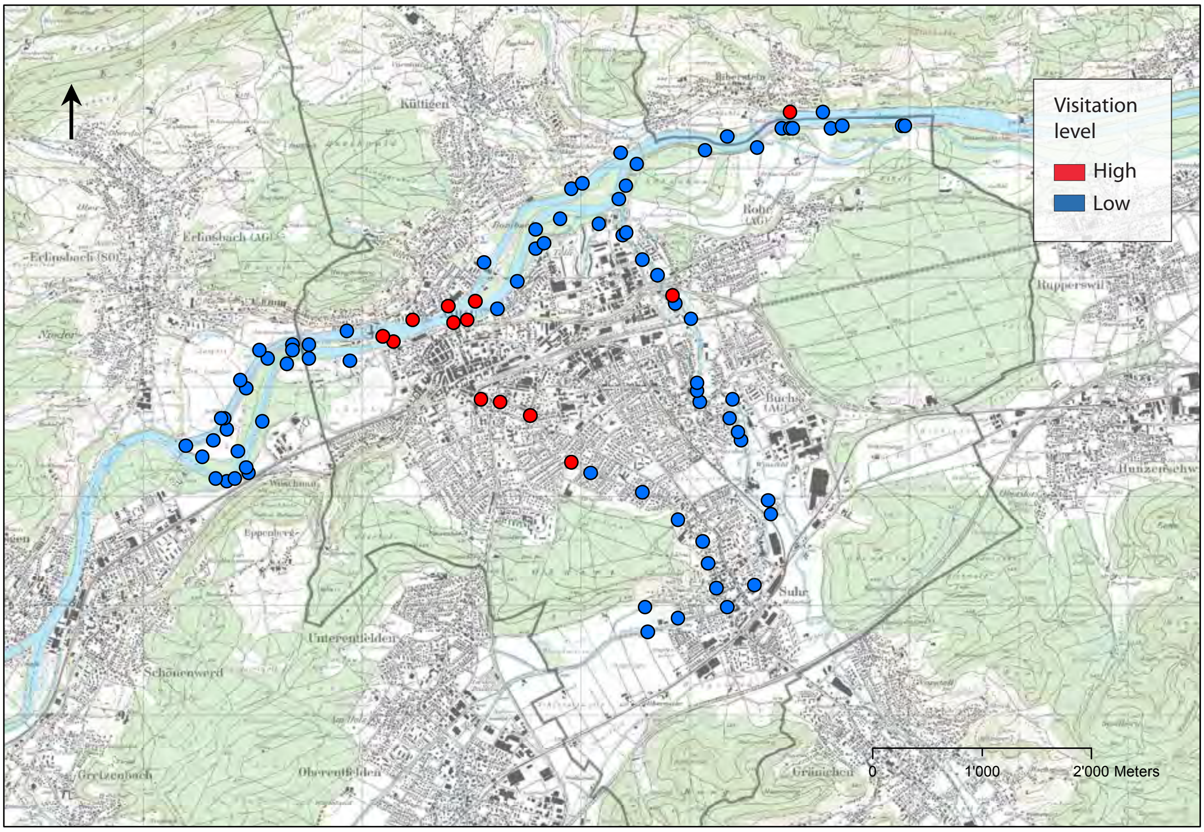

Fig. 45. River visitation level for pedestrians. Source: © 2012 Swisstopo (Topographical map).

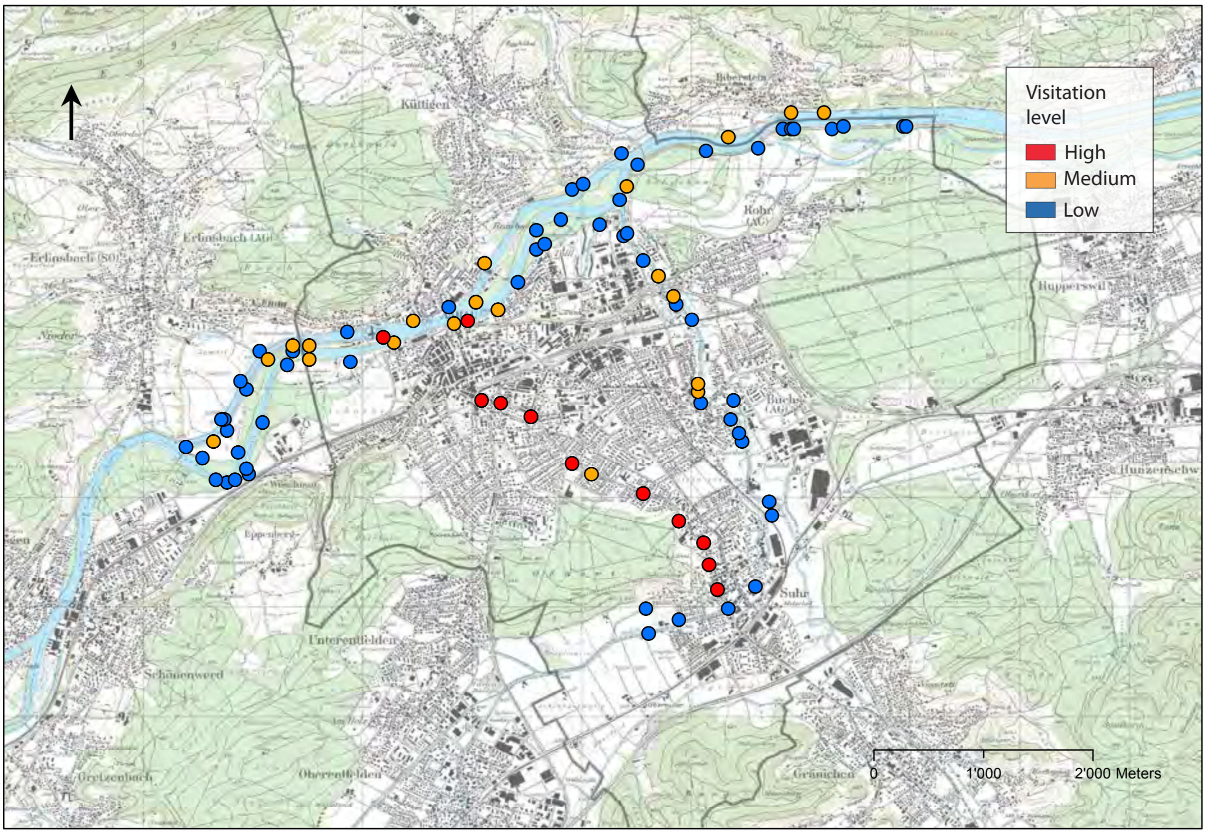

Fig. 46. River visitation level for cyclists. Source: © 2012 Swisstopo (Topographical map).

For pedestrians, river visitation “hotspots” are situated in the central section of the Aare at the foot of the old town and along the northern stretch of the Stadtbach (Fig. 45). Two additional “hotspots” are located in proximity to the village of Biberstein and along the Suhre. However, these two last “hotspots” are very isolated and their high level of visitation are more likely due to stochastic events, such as the recording of very large families.

Cyclists show a similar pattern of visitation level, as many people were observed in the central section of the Aare and along the northern stretch of the Stadtbach (Fig. 46). Further, some punctuated stretches presenting a medium number of people were observed along the Suhre and the Aare, upstream from the city centre. However, there is a noticeable difference between cyclists and pedestrians in regards to the southern section of the Stadtbach, where a very high number of cyclists were recorded. This can probably be attributed to the important bicycle track built along this section of the river, which allows people working in Aarau, but living in the southern neighbouring communities, to reach their working place by bike.

III.3. Declared recreational use

Seventeen people replied to the questionnaire and provided information from their own experiences about where the population of Aarau and its neighbouring communities usually go for short nearby recreation along rivers. Five respondents worked at the city tourism office, while the other 12 worked for other sectors of the municipality. Slightly more women (N=10) than men (N=7) returned the questionnaire and almost all respondents (N=15) were from one of the communities of the source population area (i.e. Aarau, Küttigen, Buchs and Suhr). Only a few respondents (N=4) declared having to deal with rivers in their profession.

The river stretches most often designated as being used for recreation (identified by more than 75% of the respondents) are situated in the central section of the Aare at the foot of the old tow and slightly to the east (Fig. 47). Several other quadrants of this perimeter were also identified by more than 50% of the respondents. Other stretches of the Aare were also identified, but by fewer people (from 50 to 0% of the respondents). Few people designated the extreme south sections of the Suhre and the Stadtbach as being used for recreation, and only one person indicated that the northern and central stretches of these streams were used as recreational areas.

In conclusion, it appears that people recognised the Aare as being used for recreation, especially in its central section, but very few considered the Stadtbach and the Suhre as recreational areas.

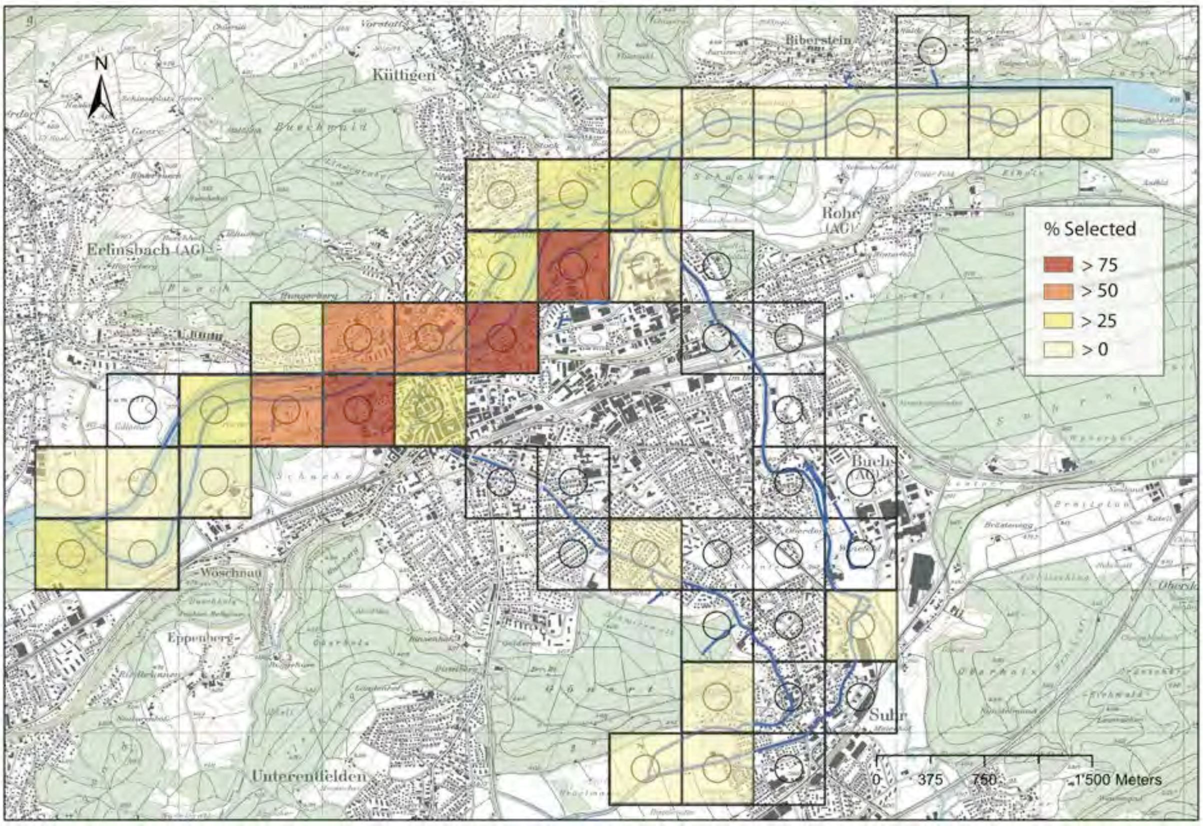

Fig. 47. Reported recreational use of the rivers. The colour of the quadrants indicate the percentage of time they were selected by respondents as being used for short nearby recreation. Source: © 2012 Swisstopo (Topographical map).

III. 4. Empirical recreational use and functional use of rivers

The comparison between river visitation levels and declared recreational use is presented in Table 17. Each of the river stretches are classified according to their recorded visitation level and their reported recreational use, which determines their empirical recreational use or their functional use.

Table 17. Empirical recreational use and functional use of rivers around the city of Aarau

		Visitation level	
		High	Low
Reported recreational use	High	**Recreational use:** Central section of the Aare (at the foot of the old town), two branches of the Aare upstream from the central section (cyclists only)	**Moderate recreational use:** Stretch of the Aare situated between its central section and its confluence with the Suhre
	Low	**Functional use:** Stadtbach	**No recreational or functional use:** Aare at the eastern and western extremities of the study perimeter, Suhre

The central section of the Aare was identified as having the highest empirical recreational use around Aarau, both for pedestrians and cyclists. In the specific case of cyclists, the two river branches situated directly upstream from the central section seem to be also widely used for recreation.

In contrast, the eastern and western extremities of the river, as well as the Suhre in its entirety, have an apparently low recreational use, as indicated by both analyses.

More surprisingly, the stretch of the Aare situated between its central section and its confluence with the Suhre was determined as having a low visitation level by the field measurements, even though it was actually designated as being widely used for recreation by respondents to the questionnaires. This special situation might be explained by two different factors depending on the users being considered. For pedestrians, it is possible that the 10 minutes threshold fixed for recording the number of people did not allow for the observation of enough individuals to conclude a significantly higher number of users in this area. Concerning cyclists, this specific stretch of the river is actually situated in a forested area where access is theoretically forbidden to all categories of persons except pedestrians. This might explain why the number of cyclists recorded in this section of the river was low.

Finally, the most interesting aspect revealed by the comparison of actual visitation levels and reported recreational use concerns the Stadtbach. Although this watercourse has a high visitation level, it was almost never mentioned as a river stretch used for recreation by respondents to the questionnaire. This probably means that many people walk or cycle near this watercourse without having the conscious goal of recreational use. It is also possible that the road bordering the Stadtbach is used as a commuting route between home and work – especially by cyclists – or as a pleasant path to get around the city. This suggests that the Stadtbach does indeed have an important functional use, even if it is not used specifically for recreation.

III. 5. Model evaluation

III.5.1. Statistical test

According to the results of the modelled recreational use, sampling points were assigned to groups ranging from group 1 ("low" modelled recreational use) to group 5 ("very high" modelled recreational use). For pedestrians, the five categories of modelled recreational use were present within the perimeter of the people count, while only categories 3 to 5 ("rather high" to "very high" modelled recreational use) were identifiable for cyclists. In this case, stretches in categories 1 and 2 ("low" to "rather low" modelled recreational use) were actually situated further away from the source population area and were therefore not accounted for during the fieldwork. The complete distribution of points among the different groups is available for consultation in the appendix D 1-D 2, pp. 116-117.

Table 18. Statistical characteristics of the different groups defined according to the results of the modelling approach for pedestrians (A) and cyclists (B). Group 1 represents sampling points with a "low" modelled recreational use, while group 5 represents sampling points with a "very high" modelled recreational use.

A	Group 1	Group 2	Group 3	Group 4	Group 5
N[1]	18	26	15	18	11
Mean[2]	1,94	2,46	3,13	4	20,9
Sd[3]	2,21	1,86	3,14	5,83	33,25
CV[4]	1,14	0,76	1	1,5	1,6

B	Group 3	Group 4	Group 5
N[1]	29	34	25
Mean[2]	11,86	6,56	7,6
Sd[3]	13,42	12,32	8,31
CV[4]	1,13	1,88	1,09

[1]Number of observations per group [2]Mean [3]Standard deviation [4]Coefficient of variation

For pedestrians, the groups were heterogeneous – as indicated by their large coefficients of variation – and group 5 included fewer sampling points than the other groups. The group means increased from group 1 to group 5 (Table 18. A.). In the case of cyclists, the groups also had large coefficients of variation; however, their means did not increase from group 3 to group 5 and instead showed a decreasing trend (Table 18. B.).

Even though the defined groups showed high intra-group variations, the results of the Kruskal-Wallis test revealed some significant results for pedestrians (Table 19).

Table 19. Results of the Kruskal-Wallis test between groups for pedestrians.

	Group 4	Group 3	Group 2	Group1
Group 5	0,004606*	0,003541*	0,0003487*	0,0002402*
Group 4		0,5938	0,6447	0,6139
Group 3			0,6807	0,225
Group 2				0,2024

*Statistically significant results (p-value < 0,05)

The median value for modelled recreational use of group 5 was significantly higher than that of all other groups, indicating that the highest number of observed people at sampling points belonging to group 5 was not observed by chance alone. In practical terms, this signifies that the model of river recreational use was a good predictor of which river stretches were most visited by people (i.e. recreational "hotspots"). Alternatively, no significant differences were observed among the groups representing other intensities of modelled recreational use. This does not necessarily mean that the model was unable to predict the recreational use of these categories with precision. It is also possible that the short time step of 10 minutes employed for the people count was insufficient for capturing these differences of recreational use intensity. The boxplot of the modelled recreational use of the different groups helps to better represent these results (Fig. 48 A).

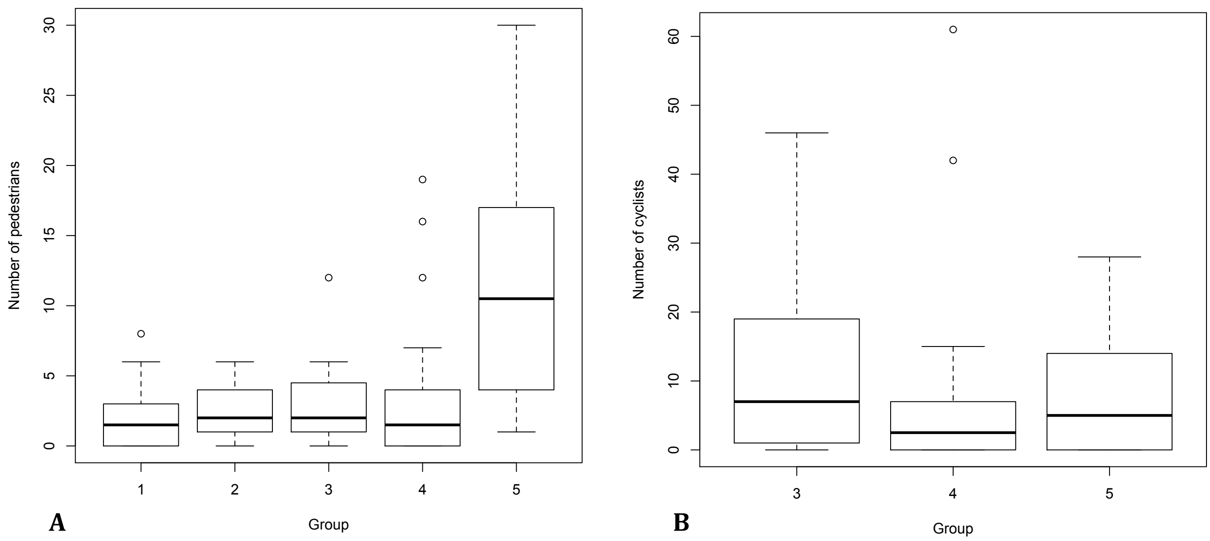

Fig. 48. Boxplots of the different groups defined according to the results of the modelled recreational use for pedestrians (A) and cyclists (B). For pedestrians, an outlier (Nb peop=118) was not accounted for in the drawing of the boxplot, because it induced a poor quality graphic. However, this outlier was taken into account in the statistical analysis.

In contrast, the results of the Kruskal-Wallis test for cyclists did not show any significant trend among the different groups (Table 20), which can be further visualised from their boxplots (Fig. 48 B).

Table 20. Results of the Kruskal-Wallis test between groups for cyclists.

	Group 4	Group 3
Group 5	0,3754	0,3577
Group 4		0,0657

*Statistically significant results (p-value < 0,05)

III.5.2. Visual comparison

However, the Kruskal-Wallis test can only be used to compare the results of the GIS-based model to the visitation level determined by the people count. In order to make a complete and robust evaluation of the modelling output, it is also necessary to compare it to the empirical recreational use of rivers defined in Table 17 (p. 67). The following paragraphs make this comparison for each river separately.

Aare: The recreational use of the Aare by pedestrian was generally well represented by the model. In fact, it predicted a "very high" recreational use in its central section, which corresponds to the empirical use defined based on the hotspot analysis. It also indicated a "rather high" use of the river's stretch situated between its central section and the confluence of the Suhre. This was further confirmed by the hotspot analysis, even if the determined visitation level of this area was not very high. The model designed for cyclists, on the other hand, did not correspond very well with the empirical data gathered on river use. It predicted a "high" to "very high" recreational use of the Aare along most of its length, a prediction that was not confirmed by the empirical analysis.

Suhre: Both models overestimated the recreational use of the Suhre in its northern section, from its confluence with the Aare to the village of Buchs. The empirical analysis indicated a very low usage of this river by people, whereas the modelled recreational use for pedestrians was found to be "high". Alternatively, the recreational use of the Suhre's southern stretch was well represented by the modelling approach for pedestrians.

Stadtbach: For pedestrians, the model predicted a "high" recreational use along the Stadtbach. This is in accordance with the observed visitation level, but contradicts what respondents declared in the questionnaire. This could indicate that the model was able to predict not only the recreational use, but also the functional use of rivers. In the case of cyclists, the model failed to represent the actual use of the Stadtbach. It only predicted a "rather high" use of the river, while it was the most visited river stretch according to the people count.

In conclusion, the model showed different capabilities in identifying river use. It seems to be a good predictor of the empirical river use for pedestrians, while it was often unable to deliver accurate results for cyclists.

III. 6. Historical background

The amount of historical information available on Aarau's rivers varies depending on the watercourse considered. The results of the short historical analysis are therefore presented below for each river separately, and with various levels of details.

III.6.1. Aare

In ancient times and during the Middle Ages, the Aare was an important trading route (Aare, 2012) and served as a natural border between different peoples for a long period of time. The city of Aarau further constituted an important passage route between the Jura range and the Swiss Plateau, signified by a wooden bridge built early on to cross the Aare (Aarau, 2012). At that time, the river's landscape in proximity to the city was far from its current state. Unlike today, the course of the river meandered and formed several branches. Several islands existed at the foot of Aarau's old city making the crossing of the Aare much easier than at other stretches (Aarau, 2012). Floods regularly occurred, inundating the fields and sweeping away the bridges.

The situation changed radically in the middle of the 19th century, as the industrialisation of the area increased (Lüthi et al., 1978, p.231). The river landscape became highly impacted by human influence. A modern stone bridge called "Kettenbrücke" was built and the course of the river was corrected both upstream and downstream from the city (Lüthi et al., 1978, p.231). In the beginning of the 1870s, a canal was dug in parallel to the natural course of the river upstream from the city and was subsequently enlarged in the early 1900s in order to install a hydroelectric power plant for electricity. A second hydroelectric installation was built in the 1920s a few hundred meters downstream, just at the foot of the old town (Lüthi et al., 1978, p.231).

In the last years, many efforts were made to restore the course of the river in several places, especially for ecological reasons. Some of these restoration projects were conducted as compensation measures for the hydroelectric exploitation of the river (R. Strebel, personal communication, June 22, 2012). The whole stretch of the Aare situated near Aarau is part of a cantonal protected alluvial landscape and is included in a European conservation network (WWF, n.d.,).

III.6.2. Suhre

Comparatively few pieces of evidence exist on the evolution of the Suhre. Lüthi et al. (1978, p.237) emphasized the importance of the river for agriculture and found indications of conflicts between the population of Aarau and Suhr about the use of the river for the watering of their fields. The course of the river was corrected in the 19th and 20th centuries (Suhre, 2012) and many industries were installed along the river between Buchs and its confluence with the Aare (R. Strebel, personal communication, June 22, 2012).

Many efforts were recently made to restore the last stretch of the river before its confluence, as this section is an important spawning habitat for some endangered fish species (Aarauer Bachverein, n.d.). In addition, a project conducted in 1995 helped increase the ecological state of the river upstream from the village of Suhr (Heinrich Wirri-Zunft, n.d.). Several new small hydroelectric plants are planned along the river in the vicinity of Aarau in the next years (R. Strebel, personal communication, June 22, 2012).

III.6.3. Stadtbach

There is a lot of information available on the history of the Stadtbach, regardless of its small size. Unlike the other watercourses analysed in this master thesis, the Stadtbach is actually completely artificial.

The Stadtbach was vital for the population of the city of Aarau, with an origin that probably dates back to the early development of the medieval town in the 13th century (Heinrich Wirri-Zunft, n.d.). The Stadtbach originated both from springs arising south of the city – upstream of the village of Suhr – and from an artificial diversion of the Suhre (Lüthi et al., 1978, p.238). A canal was dug from Suhr to Aarau in order to deliver the water to the city. In the old town, the river separated into three branches (Fig. 49) and supplied the town's wells (Lüthi et al., 1978, p.238). For a very long time, Aarau's population was almost completely dependent on this river for its water consumption, since the water from the Aare was often unsafe for drinking. In addition, the stream was also used by industries for the energy provided by the many watermills installed along its course (Lüthi et al., 1978, p.241).

Fig. 49. Aarau around 1612, viewed from the north. At the forefront is the Aare and the wooden bridge used to cross it. In the background, the Stadtbach can be seen entering the city next to the tower and, in the centre of the image, the river flowing into three branches through the old town. Source: Heinrich Wirr-Zunft, n.d.

The riverbed had to be cleaned up once a year in order to prevent it from being filled up with waste material and to guarantee high quality water. During four consecutive days in September, the watercourse was completely dried and its bed was cleared of branches, stones and other filling material (Heinrich Wirri-Zunft, n.d.). On this occasion, it was also allowed to catch fish trapped by the low water level (Heinrich Wirri-Zunft, n.d.). However, the city was deprived of its most precious water source during this cleaning ritual and the reopening of the Stadtbach at the end of the fourth day was met with a popular feast, which continues to take place every year in Aarau under the name of "Bachfischet" (R. Strebel, personal communication, June 22, 2012).

After the river is reopened, people from Suhr launch paper boats decorated with lit candles in the course of the newly cleaned river. Children from Aarau then make a procession with lanterns along the river course through the city in order to celebrate the return of the stream (R. Strebel, personal communication, June 22, 2012). Today, the Stadtbach is no longer used for water consumption and its annual drying out was given up in 2000 for ecological reasons, but restoration and improvement measures are still undertaken during the week preceding the "Bachfischet" (Heinrich Wirri-Zunft, n.d.).

Through historical inheritance, the Stadtbach is now owned by the city of Aarau – and not by the Canton of Aargau – which makes it a very particular case in Switzerland (Lüthi et al., 1978, p. 241). For these reasons, the Stadtbach is a well-known element of the city landscape in spite of its small size. Most people from Aarau know about its existence, even if they are not necessarily aware of its historical relevance (R. Strebel, personal communication, June 22, 2012).

In fact, the Stadtbach lost its importance for the city around 1860, when a modern water system supply was installed in Aarau because of public health issues (Heinrich Wirri-Zunft, n.d.). Its water was still used for a while by firemen and industries, but these uses were also given up – by firemen in 1900 and industry in the early 20th century – because of widespread electrification (Heinrich Wirri-Zunft, n.d.). Moreover, the three branches of the river flowing within the old city were rerouted underground to allow for the passage of cars (Heinrich Wirri-Zunft, n.d.). The sources from which the Stadtbach was partly dependant were eventually drained in the course of land meliorations from 1942 to 1945 and a new junction was built, where the Stadtbach is now directly diverted from the Suhre (Heinrich Wirri-Zunft, n.d.). Over the last few years, several measures were taken to improve the ecological state of the stream and to give people easier access to its water. The city centre was declared a "traffic free area" and several water channels with fountains were installed to indicate the former location of the Stadtbach (R. Strebel, personal communication, June 22, 2012).

III. 7. Local context and possible future developments

The interview conducted with Mr. Strebel – project manager for the division "Roads and Water bodies" in Aarau – provided additional insight into the local context and the way rivers and recreation are considered by the authorities of the city. All information presented in this chapter comes from this interview, except if specified.

III.7.1. River management in Aarau

In general, rivers are under the responsibility of the Canton of Aargau and the municipalities have to apply cantonal decisions. Restoration programs exist at the cantonal level that are especially aimed at the enhancement of rivers' ecological state and at the linking of water ecosystems. The Stadtbach represents an exception to this general organisation, because it is property of the city for historical reasons (see paragraph III.6.3. p. 72) and is managed directly by its authorities in collaboration with the village of Suhr.

One of the issues regarding the Stadtbach concerns its location in the middle of a densely built residential area. Even if its water level can be partly regulated in case of heavy precipitation – e.g. by closing the system that diverts it from the Suhre – the risk of flooding cannot be completely eliminated. In reality, some of the water falling in the forest situated south of Aarau flows downhill to the Stadtbach and can foster the occurrence of floods. In order to prevent such events, the construction of water retention basins in the forest is planned.

III.7.2. Restoration or enhancement measures already undertaken

In addition to flood protection measures, several restoration and development projects were already conducted around the city in order to enhance the biological state of the rivers and their recreational appeal. Along the Aare, several alluvial landscapes were restructured in order for them to reach an improved ecological functioning.

> In the proximity of Aarau, this is especially the case for the woodland area located on the right bank of the river, between its central section and the confluence of the Suhre. There, a former industrial canal designed for electricity production – called Frey-Kanal because it was used by the Frey chocolate factory – was restructured and its underground stretches were reopened in order to improve the ecological diversity of the area. Also, a section of the Stadtbach flowing through the estate of Telli (see Fig. 4 p.13) and named "Sengelbach" was redeveloped to foster its functions of natural habitat and nearby recreation area for the inhabitants of the district. The "Aarauer Bachverein" - an association involved in the conservation of near-natural watercourses in proximity to Aarau - conducted both projects (Aarauer Bachverein, n.d.).

As already mentioned, projects also took place to increase the ecological and the recreational function of the Stadtbach, e.g. by planting more plants and placing big stones in the stream's watercourse in order to allow people to access it. Finally, the opening of water channels in the city centre also enhanced the historical value of the stream.

III.7.3. Planned restoration or enhancement measures

In the coming years, further improvement measures are being planned, like the creation of new sitting facilities and the planting of trees in the central section of the Aare. At a larger scale, it is very likely that new restoration projects will take place along the Aare as compensation for the exploitation of the river's waterpower by electric companies. In fact, the exploitation concession of the AXPO hydroelectric power plant had to be renewed in 2011, while that of the IBA power plant will have to be renewed by 2014. These concessions usually go along with ecological compensation measures. Additionally, the "Aarauer Bachverein" will probably also conduct some smaller projects in the area.

III.7.4. Consideration of recreation in urban planning

As already illustrated by some of the above examples, nearby recreation is being taken into account in river development planning in Aarau. However, conflicts of interest may occur which complicate river management.

> For example, some people are opposed to the opening of water channels in the city centre because they consider them to be dangerous for children. Also, the ecological and the recreational functions of the rivers are sometimes difficult to combine, as illustrated by people's habit to make fires on the gravel banks bordering the Aare. This practice is theoretically forbidden for ecological reasons, but no efficient controlling system is set up to stop this practice for economical reasons. Likewise, some river stretches are voluntarily lacking in recreational infrastructures and are forbidden to cyclists in order to preserve their quietness. This is the case for the lower branch of the Aare situated upstream from the city centre. However, cyclists do not always respect these restrictions, which in turn often leads to conflicts with pedestrians or dog walkers.

Finally, it is interesting to note that some river sections attract more people than others. For example, the central section of the Aare attracts a high number of people, especially in summer around the two summer bars set up along the river. This section is also situated directly east of "Schachen", a popular area bordering the river, where many cultural and sporting events take place (e.g. football games, athletics, horse races, swimming pool, open air cinema, circus, etc.). In comparison, very few events are organized along the Suhre or the Stadtbach. Instead, people prefer to go to these rivers on their way to work or to walk their dogs.

III. 8. Improving the potential of rivers regarding their use as nearby recreational areas or restorative settings

The results of the combined analysis reveal river stretches that have a potential for improvement. The conclusions of the analysis are presented separately for pedestrians and cyclists. In a first step, river stretches identified by the GIS-based model as having an improvement potential are designated. Those presenting no improvement potential at this stage are not considered further, as they either fall within the categories (a) river stretches that already meet people's needs or (b) river stretches situated too far away from populated areas to be used as nearby recreational areas and/or restorative settings. In a second step, possible improvement measures are presented, depending on the outcome of the decision tree.

Before proceeding further, it is important to emphasize that these results are not to be interpreted as criticisms of the actual restoration or recreation policy in Aarau. Also, not all stretches presenting an improvement potential should necessarily be enhanced, because there is no need of reaching an excellent landscape suitability or level of infrastructure along all rivers. Instead, the results of this analysis should be understood as guidelines to define priorities when planning new measures to improve the recreational or restorative use of rivers.

The results of the model's selection concerning the improvement potential of rivers are presented in figures 50-53 and are summarized in Table 21.

Table 21. Improvement potential of river stretches according to the type of user and the type of improvement

<table>
<tr><td colspan="2" rowspan="2"></td><td colspan="2">User type</td></tr>
<tr><td>Pedestrians</td><td>Cyclists</td></tr>
<tr><td rowspan="2">Improvement potential</td><td>Landscape suitability</td><td>• Stadtbach
• Left bank of the Aare in its central section
• Some stretches of the Suhre at proximity of installations (highway)</td><td>• Stadtbach
• Stretch of the Suhre between Suhr and Oberentfelden
• Upper branch of the Aare, upstream from its central section
• Some stretches of the Suhre at proximity of installations (highway)</td></tr>
<tr><td>Level of infrastructures</td><td>• Stadtbach
• Suhre between Buchs and its confluence with the Aare
• Aare between its central section and the confluence of the Suhre
• Central section of the Aare</td><td>• Almost the whole perimeter</td></tr>
</table>

III.8.1. Improvement potential for pedestrians

For pedestrians, the Stadtbach shows a high level of improvement potential regarding its landscape suitability, as both its eco-morphological state and its bordering roads quality could be enhanced to encourage its use. Apart from this river, some stretches of the Suhre, together with the left bank of the Aare in its central section, also show an improvement potential.

When it comes to the infrastructure level, the Stadtbach again shows the highest potential for improvement, as only a few infrastructures are present along its course. The Suhre, the central section of the Aare and its stretch situated before the confluence of the Suhre could also receive more infrastructures.

The Stadtbach has a clear functional use, which implies that improvement measures should focus on its eco-morphological and structural state or on its road quality rather than on its amount of recreational infrastructures. According to the historical analysis, the Stadtbach has an additionally important cultural value and issues regarding its location in the middle of a densely populated area were emphasized by the local context analysis. Under these conditions, small enhancement measures aimed at increasing its restorative potential – such as the planting of colourful endemic plant species or the general greening of its banks – seem suitable. More comprehensive measures should be avoided as they may in fact conflict with flood protection problems or the historical status of the stream.

The Suhre also has a mostly functional use, limiting the relevance of increasing its amount of recreational infrastructures. The stretches presenting an improvement potential for landscape suitability are dispersed and situated near large installations, such as a highway bridge. It is indeed possible that an enhancement of their eco-morphological state could potentially affect the stability of these installations, making such operations dangerous. In addition, the Suhre already has a good quality bordering path, which further limits its landscape suitability enhancement. According to these findings, it appears that the Suhre does not show a high improvement potential regarding to its use as recreational area or restorative setting.

On the contrary, the sections situated along the Aare clearly have a recreational use. Its central section – and especially its left bank – is very much constrained by the hydroelectric exploitation of the river, which probably restricts the enhancement of its landscape suitability. By contrast, new recreational infrastructures could be installed along this highly visited river stretch. The local context analysis did in fact indicate that such measures are already planned for this section. Finally, the implementation of more infrastructures in the forested area situated along the Aare between its central section and the confluence of the Suhre is likely unsuitable, even if it presents a good improvement potential. In fact, this area includes alluvial woodlands whose fauna and flora are to be preserved from too much visitation pressure.

III.8.2. Improvement potential for cyclists

In the case of cyclists, several stretches present the same landscape suitability improvement potential as for pedestrians, particularly for the Stadtbach and the Suhre. Additionally, some river sections situated further away from populated areas could also be enhanced, like the upper branch of the Aare located upstream from its central section. However, the eco-morphological state of this section might be rather difficult to improve because it consists of an artificial canal built in the early 20th century for the electrical exploitation of the river's waterpower.

On the one hand, it is possible that simple measures could greatly enhance its ecological and structural state, while on the other hand, such actions might hinder the functional and economical use of the river.

In the south of the study perimeter, the Suhre also revealed an improvement potential for cyclist recreation between the villages of Suhr and Oberentfelden. As already mentioned in paragraph III.6.2. p. 72, some restoration measures were undertaken starting in 1995 in this area to enhance its ecological state. Alternatively, some measures could be taken to completely prohibit car traffic along this section.

The GIS-based model does not allow for prioritising where the amount of recreational infrastructures could be enhanced for cyclists, since the overall high accessibility results in a homogenous distribution of the potential of improvement.

In conclusion, it appears that the Stadtbach has the highest improvement potential regarding its use as restorative setting because of its central situation in the city of Aarau and the suburban roads bordering it. Additionally, the central section of the Aare and its upper branch situated upstream from the old city both have an improvement potential regarding their recreational use.

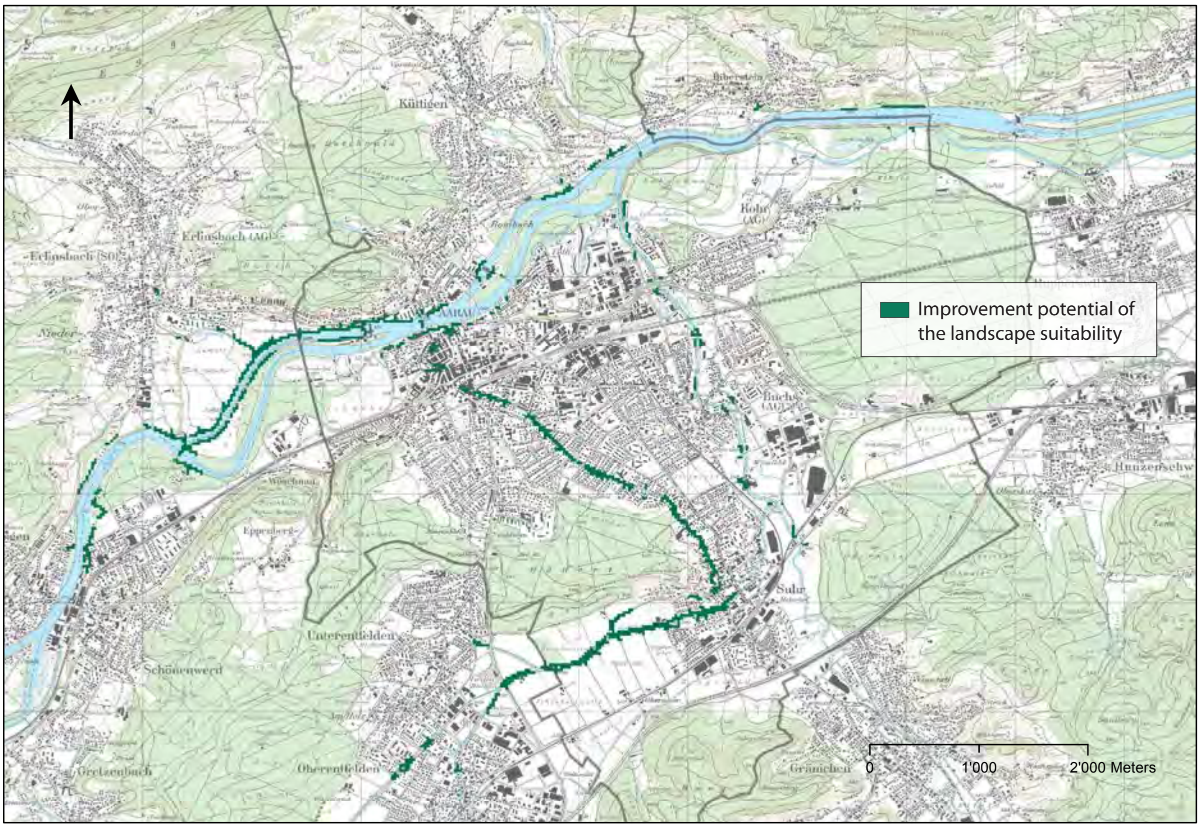

Fig. 50. Improvement potential of river landscape suitability, for pedestrians. Represents river stretches for which the eco-morphological quality or the quality of the bordering path could be improved in order to encourage recreational or restorative opportunities. Results from the GIS-based model. Source: © 2012 Swisstopo (Topographical map).

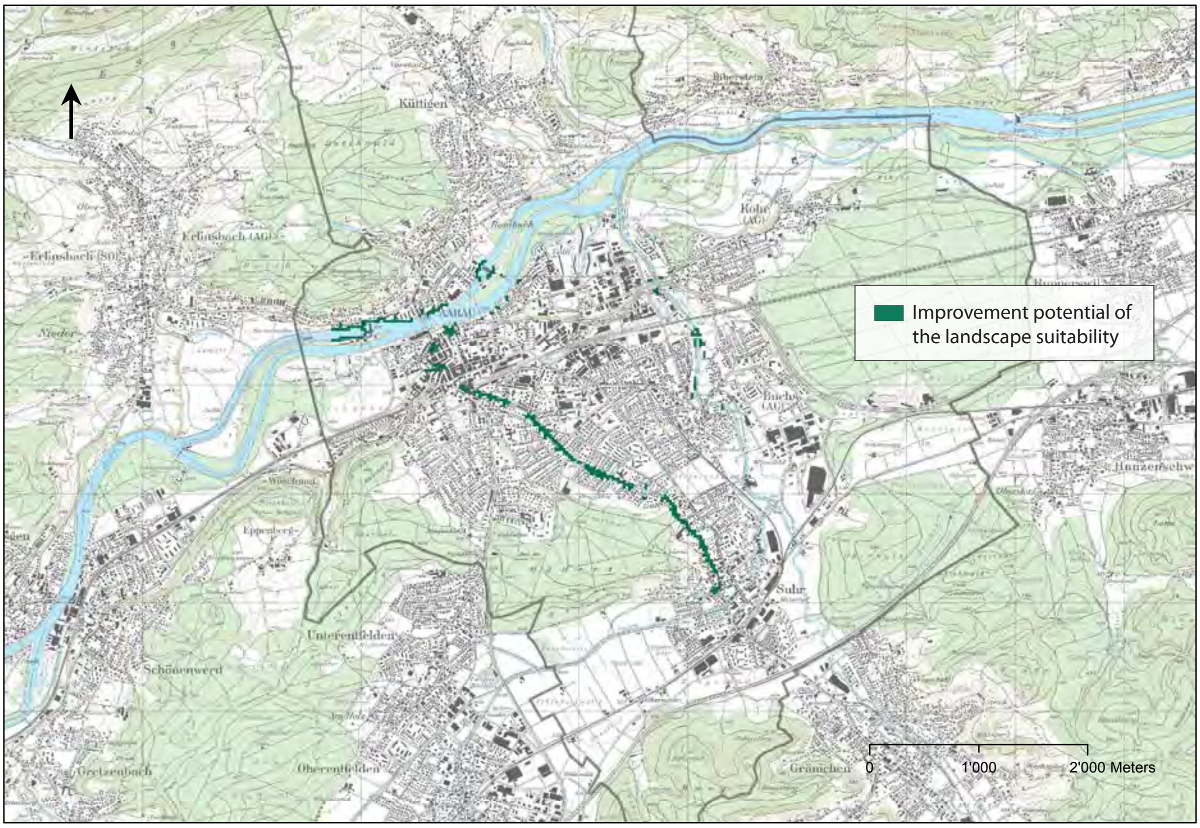

Fig. 51. Improvement potential of river landscape suitability, for cyclists. Represents river stretches for which the eco-morphological quality or the quality of the bordering path could be improved in order to encourage recreational or restorative opportunities. Results from the GIS-based model. Source: © 2012 Swisstopo (Topographical map).

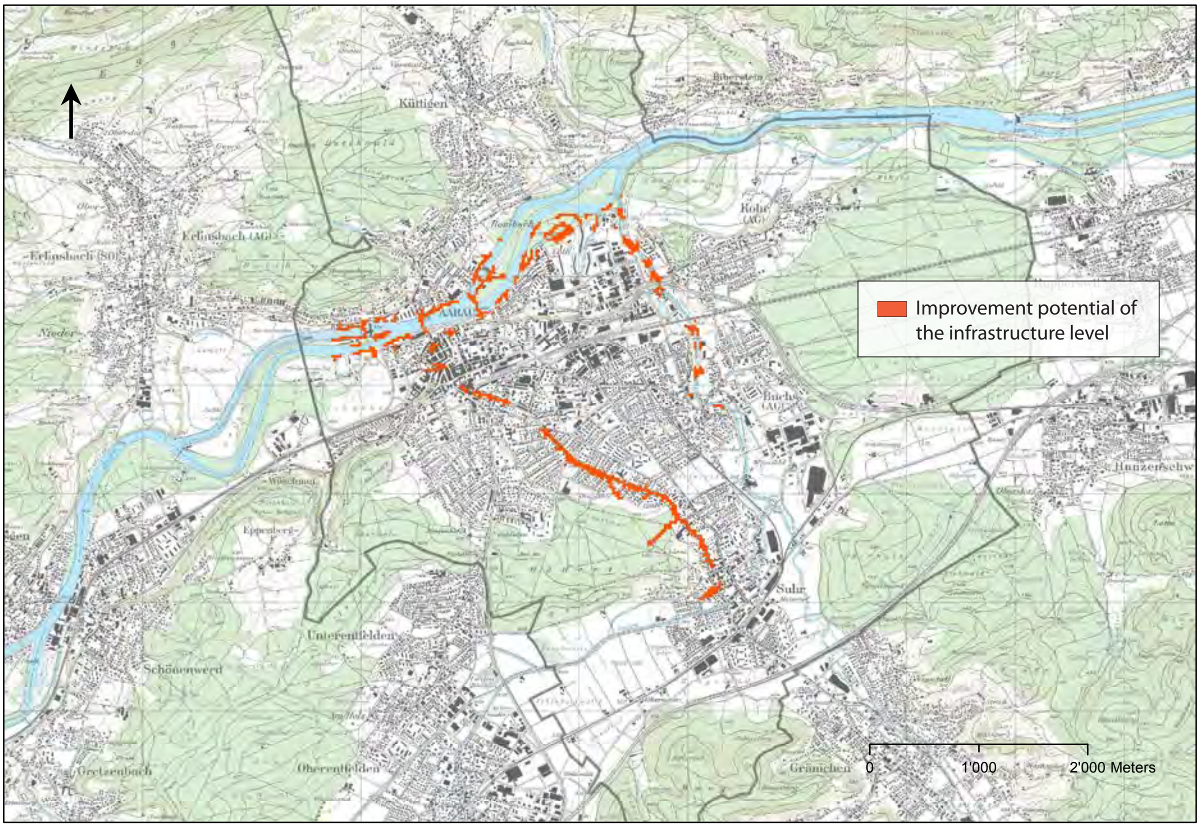

Fig. 52. Improvement potential of river infrastructure level, for pedestrians. Represents river stretches for which the amount and the quality of small recreational infrastructures could be improved in order to encourage recreational or restorative opportunities. Results from the GIS-based model. Source: © 2012 Swisstopo (Topographical map).

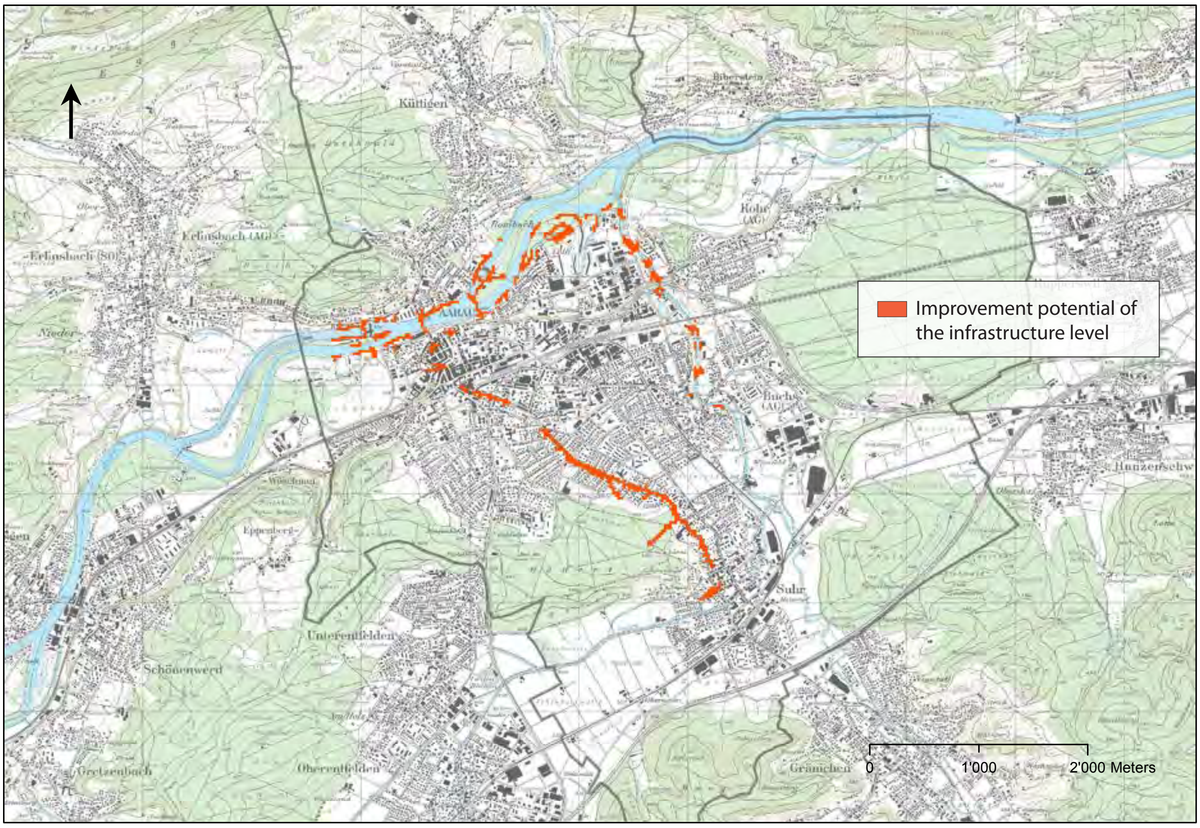

Fig. 53. Improvement potential of river infrastructure level, for cyclists. Represents river stretches for which the amount and the quality of small recreational infrastructures could be improved in order to encourage recreational or restorative opportunities. Results from the GIS-based model. Source: © 2012 Swisstopo (Topographical map).

IV. Discussion

IV. 1. Accounting for accessibility in urban planning

The developed accessibility model helps determine the potential amount of people able to reach each river's access points to start a recreational activity, depending on four different means of transport. Interestingly, it also provides information on the actual accessibility of each river stretch in the course of short nearby recreation.

Using this model, it was possible to determine that almost all inhabitants of Aarau can potentially reach a river within 15 minutes from their places of residence, which confirms the widespread presence of watercourses around the city. Also, most of the rivers situated within the main populated areas are well accessible to pedestrians and users of public transport in the context of short nearby recreation. For cyclists, the accessible stretches are situated within a three kilometres perimeter around the main populated areas.

IV. 1. 1. River access points accessibility: a discrete choice problem

The fundamental idea of the accessibility method developed in the context of this master thesis consists of transforming river characters from continuous to discrete. River access points were defined specifically for each user type and the potential amount of people able to reach them from their place of residence by travelling along the road network was calculated. As individuals living at a given location had the possibility to reach alternative access points, the accessibility calculation can be described as a discrete choice problem, in the sense of De Vries & Goossen (2002).

The use of Federal population census records as source points for the accessibility calculation is in accordance with findings of Swiss empirical studies on recreational behaviour (Irngartinger et al., 2010; Kienast et al., 2012) emphasizing that most of individuals access their recreational areas from home. It also represents a good compromise between data availability and precision because (a) these data are easily available at the Swiss level and (b) their level of aggregation is well adapted to the small scale of the study and precisely reflects the geographical repartition of the population. For the same reasons, it avoids the pitfalls noted in other studies, where data are aggregated to large centroid areas often delimited by political borders, which leads to data smoothing and truncates reality (Brainard, 1999). In spite of these many advantages, a few limitations must be acknowledged in the use of population census records. First, the Swiss Federal Statistical Office (FSO) does not indicate records containing only one individual as such, but register them as counting three people in order to guarantee privacy protection. Second, some population census records do not intersect with the road network and could not be accounted for in the accessibility calculation. Nonetheless, these limitations probably do not significantly influence the results of the analysis, as few records contain one individual in Aarau, and only about 5% of the total records were ignored in the calculation.

The definition of access points was performed differently for pedestrians and cyclists than for car drivers and users of public transport. For pedestrians and cyclists, the method was rather simple and transparent, as the access points were defined by intersecting roads bordering rivers with roads not bordering them. It is a cost-efficient approach because it uses available data from the Swiss road network. For car drivers and users of public transport, access points were recorded manually and were likely incomplete because of the absence of precise recordings of public parking places. This process was very time-consuming and the lack of reliable data considerably limits the representativeness of the results.

The use of road distance was preferred to Euclidean distance in order to calculate accessibility, in contrast to the approaches developed by Huber (2012) and Spiess et al. (2008). In fact, even if Euclidean distance is easier to calculate, it cannot represent the effects of potential barriers such as rivers or highways, which can considerably increase travelling time (De Vries & Goossen, 2002). Ideally, it would have been even better to use actual travel time instead of travelling distance because the former is thought to influence travel costs more strongly (Brainard, 1999). Unfortunately, no data about average travel speed per road segment was available to conduct such an analysis.

A linear function was used to distribute people among alternative accessible access points. This implies that the probability of a given access point to be chosen as the starting point for a recreational activity is linearly decreasing with its remoteness from the population census records. This is a very simplified representation of the reality; humans are not completely rational and do not always choose the shortest way to access a recreational area. Moreover, previous studies suggest that a distance-decay function would be more appropriate to represent the influence of distance on visitor behaviour (Ode & Fry, 2006). Distance-decay functions are characterized by parameters that have to be empirically defined. In the future, empirical studies could be conducted in order to determine these parameters in the context of short nearby recreation along rivers. Alternatively, parameters already defined in previous studies on woodland recreation could be used (Ode & Fry, 2006).

Before concluding, it has to be acknowledged that, even if the good availability of population census data and road network datasets could allow for a country-wide application, the computation-intensive characteristic of the model might limit its reproducibility.

In addition, the approach is not completely automated, because some operations have to be done manually (e.g. the selection of roads bordering the rivers sometimes has to be completed by hand). Also, it should be emphasized that the calculations were performed with the ArcMacroLanguage (aml) available in ArcInfo. This macro language is not widely used anymore and the aml script could possibly be updated by translating it into a modern programing language in order to foster its use in the longer term.

IV. 1. 2. River stretch accessibility: a conceptual linear trip

For the calculation of river accessibility from the access points to each river stretch, it was assumed that people would exclusively follow the rivers once reaching them, taking the exact same path both on their way to and from the river. This is again a simplified representation of the reality, as people might follow a river for a while and then opt for another path – or they might even prefer to make a loop instead of a linear recreational trip. A better way to represent people's actual recreational behaviour might be to use agent-based models, but their practical implementation would be far beyond the scope of this master thesis.

The following important element that biased the results in this study should be accounted for in future studies. Access points should be aggregated along the rivers according to a constant distance after the first step of the accessibility calculation. Otherwise, their spatial repartition induces biases in the final outcome, as reported in paragraph III.1.2.3. p. 56.

The reclassification of stretched accessibility values into discrete classes allows for the increase of the results' readability and for the simplification of their interpretation. However, it also induces an important loss of information, as the inherent structure of the data is often lost during the reclassification process. In order to limit this negative impact and to present transparent results, the choice of the classification method should always be carefully adapted to the data distribution and to the objectives of the analysis.

IV. 2. Modelling the use of rivers as nearby recreational areas and restorative settings

The modelling approach presented in this master thesis uses raster data and suggests a GIS-based combination of rivers' "accessibility", "landscape suitability" and "infrastructures" in order to define their potential use as nearby recreational areas or restorative settings. The parameters used to create the two intermediate models "landscape suitability" and "infrastructures" refer to preference studies on recreational behaviour. Their number is restricted and they are combined using pivot tables in order to present a simple and transparent model. After evaluation of the outcome of this study, it is apparent that the developed model is able to represent fairly well the use of rivers by pedestrians, but fails to accurately represent river use by cyclists.

IV. 2. 1. Model characteristics

When developing GIS-based models, two alternative ways of representing spatial information – vector versus raster format – are conceivable. Both have advantages and disadvantages and were used alternatively in different studies. In the context of mapping river recreational use, Spiess et al. (2008) employed a vector representation.

> Spiess et al. (2008) developed a selection model in which factors influencing recreation along rivers are defined together with buffering distances representing their spatial influence. In a first step, all river stretches falling within the perimeter of influence of a selection of factors are retained for further analysis. In subsequent steps, other factors are integrated into the model, which narrows river selection and produces different categories of recreational potential. Their model is comprehensive and simple to put into practice, but it does not provide much flexibility.

On the contrary, the present model is based on raster data because they allow for different layers of spatial information among which calculations can be made. As the layers can be created independently from each other, this type of spatial representation leaves more room for flexibility and is better adapted to this kind of analysis. Furthermore, a 25 m spatial resolution was employed because it is a good compromise between the precision necessary at such a small local scale and the computation intensity necessary to process the data and perform the calculations.

The process of weighting and adding different layers of spatial information in a raster format has been widely used for suitability mapping and analyses in a broad range of research fields. In fact, geographic information systems have been employed for at least 20 years to develop habitat suitability models for endangered animal species (Donovan et al., 1987, as cited in Kliskey, 2000) or, more recently, to map ecosystem services for planning and management (Egoh et al., 2008; Nelson et al., 2009). In the context of the recreational suitability analysis, the same principle has already been used on several occasions.

> De Aranzabal, Schmitz & Pineda (2009) studied the potential of specific landscapes to meet visitor's recreational needs, Ode & Fry (2006) predicted and quantified urban pressure on woodlands, and Kliskey (2000) determined the potential of a landscape to host a specific recreational activity. Even more specifically, Huber (2012) also applied the same kind of approach to define the recreational potential of rivers in a portion of the Canton of Zürich.

But unlike these previous approaches, the model developed in the present master thesis does not simply weight and add the raster layers, but combines them with the use of pivot tables. This process results in more transparent and robust outputs, because the traceability of each step in the analysis is guaranteed. In fact, the simple addition of raster layers has the tendency of making the results vague because of the impossibility of keeping track of the subsequent operations performed. In addition, the weighting of the different parameters must rely on solid empirical findings, which were not available in the present case.

IV.2.2. Selection of model parameters

IV.2.2.1. Amount of recreational infrastructures – a relevant indicator?

Many different authors used models of "accessibility" and "landscape suitability" to represent the recreational use of landscape elements (Colson et al., 2010; de Vries & Goossen, 2002; Ode & Fry, 2006), but few also included a model of the "infrastructures" in their modelling approach. Huber (2012) and Spiess et al. (2008) are examples of this integration and their work served as a basis for the development of the present model. The inclusion of the "infrastructure level" in the modelling of river recreational potential raises interesting questions.

Although it is often assumed that the amount of recreational infrastructures has a positive impact on recreation, Junker (2008) demonstrated that this influence on people's satisfaction is more complex in the context of rivers. Her results show that a high amount of recreational infrastructures positively affects people's satisfaction only when the eco-morphological state of the river is low. She interpreted this finding as follows: if people do not perceive a river as being natural, they want to at least benefit from good infrastructures nearby. Conversely, people do not especially value infrastructures if the river already offers them a good near-natural environmental setting for recreation. Under these conditions, the use of the "infrastructure level" as an indicator of recreational suitability can be criticised. A high amount of infrastructures could indeed increase the recreational use of river stretches having a low eco-morphological state, but the absence of infrastructures might not necessarily limit the recreational use of stretches presenting high eco-morphological conditions.

It is nonetheless important to put Junker's findings into context: her study did not target urban watercourses, but rather large restoration projects undertaken outside of the cities. In the particular case of urban rivers, the importance of infrastructures might have a different significance. It seems that the amount of infrastructures reflects planning decisions; many infrastructures are present in areas suitable for recreation, while unsuitable areas – such as protected natural ecosystems – are kept free from them. From a conceptual point of view, however, planning is not only a steering mechanism; it often reflects needs. In this regard, the amount of infrastructures might be a very good indicator of a river's recreational use, as it reveals where people go most often for recreation. Consequently, it is relevant to include this parameter in the GIS-based modelling of river recreational use.

IV. 2. 2. 2. Eco-morphology – a reliable measure of rivers' ecological state?

The parameters used for the building of the models "landscape suitability" and "infrastructures" were selected according to preference studies available in the literature, but only a few of them were retained because of the absence of qualitative assessments.

In addition, many of these parameters have an ambiguous effect on recreational behaviour and people's preferences, making their interpretation difficult.

In order to obtain better quality indicators, future studies should design a preference study specifically aimed at developing a GIS-based model of river recreational use by means of targeted expert-interviews (Gul et al., 2006) or visitor survey questionnaires (de Aranzabal et al., 2009; Kliskey, 2000).

It might be argued that the eco-morphology is not appropriate to reflect a river's ecological state and even less appropriate to match with people's perception of naturalness. In reality, the eco-morphology only reflects the structural state of rivers, and not their ecological functioning, chemical composition or level of biodiversity (Hütte & Niederhauser, 1998). In spite of these limitations, the eco-morphology is one of the only measures of river quality widely available at the Swiss scale and easily adapted into a GIS model. Moreover, the module-step concept of the Federal Office for the Environment (FOEN) considers the visible eco-morphological state of rivers as a relevant indicator of their ecological quality (FOEN, 1998, as cited in Junker, 2008). Junker (2008) further found that "[...] aesthetic preferences [of people] relate more positively to eco-morphological quality than expected" (p. 141).

For these reasons, it seems relevant to use the eco-morphological state of rivers as an indicator of their suitability to offer recreational and restorative opportunities. Alternatively, it could be possible to use complementary indicators in order to get a better representation of the real appeal of watercourses to people at a smaller scale. In such a case, it would be recommended to record features like plant cover, for example. In fact, some small canals might be much more appreciated if they host diverse vegetation types, in spite of their artificial character.

IV. 2. 3. Modelling the recreational use of rivers by cyclists: reasons for discrepancies

After evaluation, it is clear that the model was unable to represent the recreational use of rivers by cyclists, unlike the use by pedestrians. Several reasons might explain this discrepancy.

First, the higher mobility of cyclists considerably decreases the influence of accessibility on river use (Degenhardt et al., 2010). This was obvious in the results of the accessibility model, where almost all river stretches situated within populated areas received the same "very high" level of accessibility. Under these conditions, the model does not manage to make a clear distinction between alternative stretches because the importance of the "accessibility" in contrast to the "landscape suitability" is overestimated. In reality, cyclists are probably seeking landscape elements with more distinct characteristics (Kienast et al., 2012). This implies that "landscape suitability" should be given more importance in the model combination. Similarly, the presence of recreational infrastructures might be less important to cyclists than to pedestrians. According to these findings, it would be important to find another way to balance the three models "accessibility", "landscape suitability" and "infrastructures" in future studies in order to better represent the recreational use of rivers by cyclists.

Second, although many road sections are forbidden to cyclists, the Swiss road network available as a GIS dataset is not detailed enough to distinguish them. In order to better understand cyclists' recreational behaviour, it would be advisable to use more precise records of these banned road stretches. Even if some cyclists have the tendency to disrespect these bans, it is likely that banned roads will significantly influence their recreational routes, since they will want to avoid conflicts with pedestrians.

A final aspect that may have an important influence on cyclists' travelling patterns is commuting. There are many individuals in Aarau that use bicycles to commute between their place of residence and their place of work (R. Strebel, personal communication, June 22, 2012). These routine trips might have a significant repercussion on the visitation level of some rivers, as for example the Stadtbach in Aarau.

IV. 3. Linking GIS modelling to local context analyses: bridging "space" and "place" approaches towards landscape perception

The local context analysis and the involvement of local knowledge in the combined analysis provides information on which river stretches are most often used for recreation, and gives insight on the reasons steering their preferential status. To reach these conclusions, the methodological framework developed in this master thesis combines the strengths of different approaches, while overcoming their respective weaknesses by making use of complementary analyses. In the next paragraph, the advantages and shortcomings of each method are detailed and critically assessed.

IV. 3. 1. Combining the strengths of different approaches

In planning for recreation and psychological restoration along rivers, GIS modelling can be used to simplify the problems, encourage knowledge generation and help in decision-making by making use of objective parameters and reducing the costs of the analysis in terms of time and budget. However, this method is often limited by the scarcity of good representative data and the many uncertainties concerning the choice of relevant parameters. It is also influenced by conscious and unconscious omissions and subjective choices that are made during its development process.

The hotspot analysis helps determine an empirical value for the use of rivers by combining a measure of their actual visitation level together with an analysis of their declared recreational use. On the one hand, the people count performed in the first step of this analysis is an objective way of determining which river stretches are most visited by people. But it unfortunately does not reveal whether people are going to the rivers specifically for recreational purposes or for other reasons. The local knowledge analysis, on the other hand, is more targeted and helps determine where people go especially for recreation by considering inputs from residents. These residents are individuals who actually live or work in the study area and thus have a good idea about the local situation and of its population's habits. However, although often considered as a necessary complement to more objective approaches (Raymond et al., 2009), this type of analysis also has some important shortcomings.

Among them is the fact that people's judgements are often biased by their personal values, perceptions and habits, making this kind of analysis rather subjective and difficult to interpret.

Ultimately, the combination of both methods – people count and reported recreational use – helps overcome their respective shortcomings and presents a more realistic assessment of the actual use of rivers for recreation.

The historical analysis is a good approach to define what rivers were used for in the past and, based on this information, which meanings and values they might still carry today. In addition, this analysis also identifies conflicts that might arise in river management due to their historical value. Nonetheless, such historical analyses can be limited by the existence of reliable sources to understand the phenomenon under consideration. In this study, only secondary sources were used due to the lack of time available to perform a comprehensive search of materials from the archive. This restricts the quality of the analysis, as secondary sources might be biased by the interpretation of their authors. Reporting historical facts is often dependent on subjectivity and induction because of socio-cultural influences (Swetnam, Allen, & Bentancourt, 1999).

In complement, the local context analysis is used to identify several potential conflicts that might arise when considering recreation along rivers today or in the future. It also gives insight into the possibility of future river restoration developments around Aarau and adds some aspects of place meaning in the analysis. Unfortunately, this approach relies on only a single interview, greatly limiting its representativeness and its completeness because of possible biases in the personal values, habits and interests of the interviewee.

In the final analysis, all of these different approaches are combined in order to make the most of their respective strengths and define the improvement potential of rivers for recreational or restorative purpose around Aarau.

Going beyond specific results, this master thesis presents a comprehensive framework aimed at representing and understanding river use. If this approach is applied in future studies, the following aspects could be improved in order to increase the reliability of the results: A larger time-step should be used for the people count, since the distance covered by pedestrians within 10 minutes is too small to observe subtle differences in their visitation level. Also, more local people should be included in the determination of the reported use of rivers for recreation and in the local context analysis. Finally, more time should be allocated to the historical analysis in order to assess the reliability of the consulted sources.

IV. 3. 2. Significance of people's values and habits for recreational behaviour

The framework designed for this master thesis to map and understand river use in peri-urban areas is unique in its way of combining both "space" and "place" approaches towards landscape perception. Unlike other studies that combine these two approaches in a single GIS-based model, "place" analyses are used in complement to the objective modelling of physical parameters considered as influencing recreation and restorative activities along rivers.

Consequently, the GIS-based model can be regarded as representing the "potential" recreational or restorative use of rivers that would be theoretically attained if people's preferences were only driven by the array of physical properties fulfilling their biological needs. Conversely, the differences noticed between the modelled and empirical use of rivers might partly reflect people's habits, as well as the values that they attribute to rivers.

IV. 3. 2. 1. The importance of values for rivers' use

Through the ages, rivers have played an important role in the development of societies by providing water and facilitating communication, and often hold a strong symbolic value (Postel & Richter, 2003, p. 5-8). At the Swiss scale, Junker (2008) noticed that people are very concerned about river restoration projects and often have the tendency of underestimating flood risks, in spite of the long history of flood protection engineering in the country. Moreover, she determined that river landscapes hold a highly personal value for people because they are part of their everyday environment and foster their self-identification. Junker also established that people assign a personal value to rivers because they provide a good recreational area and consist of a valuable ecological habitat for plants and animals. Conversely, she noticed that other river attributes – more functional – (i.e. provision of economical or flood protection services) are valued less by individuals.

This differentiation between the personal and functional values of rivers might partly explain some particularities that arose when comparing the modelled and empirical recreational use of rivers around Aarau. For example, it was found that the Suhre and the Stadtbach are globally less visited for recreation then the Aare, even if many of their stretches have a higher accessibility. In addition, it was observed that few people use the Stadtbach for recreation, while this river is actually highly visited. This might be explained by differences in the values assigned to each river by people. During the interview, Mr. Strebel emphasized that commuters and people walking their dogs predominantly used the Stadtbach and the Suhre. Conversely, he stated that many events and animations are taking place along the Aare, near its central section. This might indicate that people assign a rather functional value to the Suhre and the Stadtbach because they are mainly used as travelling routes, while the Aare would be assigned a more personal value because this river is exclusively visited for recreation.

IV. 3. 2. 2. The importance of habits and place knowledge for rivers' perception

In his study, Benkler (2011) acknowledged the importance of people's habits on a river's recreational use, because people have the tendency to go where they and their predecessors have already been. In fact, human habits often take root in self-concepts developed in situations where personal behaviour is conformed to social expectations (Hansman, 2011). These habits therefore allow us to perform routine actions without too much reflection, so that past habits are often the best predictors of future actions (Hansman, 2011). In consequence, those river stretches most visited in the past might have greater chances to be visited again in the future, since people have the tendency to visit places they already know and with which they are already personally bonded. In line with this hypothesis, Degenhardt et al., (2010)'s study on recreational behaviour found that the recreational areas visited most often are those already well-known by people.

IV. 4. Improving river quality in peri-urban areas: planning beyond recreation

The GIS-based model and the conceptual framework developed in the context of this master thesis can help to determine which river stretches have the potential to offer more recreational opportunities to urban populations. However, the use of the model and framework can go beyond this first objective and can help identify other watercourses whose general enhancement could improve life quality in urban areas in the context of the new health concerns arising from our modern urban lifestyle.

IV. 4. 1. Opportunities and limitations of the modelling approach when planning for recreation

Based on the few objective parameters included in the modelling approach, this report presents a GIS-based tool that can identify and display which urban river stretches could be enhanced in order to provide more room for recreation. Two main types of improvements are accounted for in the model: the enhancement of rivers' landscape suitability (e.g. eco-morphological quality and quality of the roads bordering the watercourse) and the enhancement of their recreational infrastructures. Once this first prioritisation step is completed – and the recreational use of the given river stretches is assessed – a suitability analysis can be performed. This includes both the historical and the local context analyses and identifies other factors that might limit the recreational potential of the selected river stretches. Several conflicts can arise when planning for the recreational use of rivers because of the many services they provide. First, watercourses are not harmless landscape features; they can be a danger to the population in case of flooding and, even in normal conditions, the current of large rivers can sweep people away. Thus, the recreational use of rivers should be considered only if it does not pose a threat to the security of the population. Second, rivers have an important economic value because their waterpower can be used to produce electricity. For this reason, their watercourse is locally heavily modified – in particular in direct proximity to hydroelectric installations – and cannot be improved for recreation without limiting their economic exploitation.

Third, the recreational use of rivers often conflicts with their ecological function and threatens their status as valuable natural habitats. It is not always desirable that people have access to rivers because they might disturb the ecosystems that the river's host. Alternatively, some simple ecological measures implemented in urban streams conflict with human use because they limit their access to the water. For example, the tolerance of nettles along the Stadtbach – aimed at favouring butterflies – does not meet the approval of the population because of their stinging properties (R. Strebel, personal communication, June 22, 2012).

An observed final consideration when planning for recreation along rivers concerns their historical and cultural status, as emphasized by Hobi (2008). The civil engineering works limiting rivers' natural functioning have an important historical value, in spite of their often negative influence on a river's ecological state. They reflect efforts of past populations to better control their natural environment and attain a higher living standard. This last aspect is particularly important to consider in the case of the Stadtbach, as it was artificially created and cannot therefore be "restored" in the ecological sense, as its functioning was never natural.

IV. 4. 2. Restorative settings: an alternative to recreation

Even more interestingly, the framework – and most particularly the decision tree – generated in this study permits the identification of small rivers highly visited by people, but not necessarily for recreational purposes. These watercourses are of no interest in the context of planning for recreation. In fact, their use is contradictory to the current definition of recreation:

> "Recreation is an activity, as contrasted with sheer idleness or complete rest", "The choice of activity is voluntary, free of compulsion or obligation", and "Recreation is prompted by internal motivation and the desire to achieve personal satisfaction, rather than by extrinsic goals or rewards" (McLean & Hurd, 2011, pp. 24-25).

Under these conditions, small rivers such as the Stadtbach – situated along commuting routes – cannot be considered as having a recreational function because people do not visit them for the purpose of recreation, but rather because they are part of their functional everyday environment.

However, recreation should not be considered as an end in itself but only as one of several ways necessary to combat the impacts of our modern and sedentary lifestyles. The World Health Organisation (WHO) recommends at least half an hour of daily moderately intensive physical activity in order to reduce the risks of many illnesses (e.g. heart attacks, colon cancer, diabetes 2, obesity, and depression) and increase the general psychological well- being (Hansman, 2011). But the WHO does not emphasize that this amount of physical activity should be reached specifically during recreation. In fact, it is very well possible to integrate physical activity into one's daily routine, like cycling to work, climbing the stairs by foot or getting off the bus one station before the desired destination.

The mechanisms aiding in the recovery from stress and increasing wellbeing were most notably studied by Kaplan & Kaplan (1989) who, over the course of their research, developed the "Attention Restoration Theory" (Hansman, 2011). According to them, it is important to make a distinction between directed and involuntary attention (Hansman, 2011). The first demands an effort to stay concentrated on a given task and can be depleted under continuous stress, leading to a decrease in well-being. The latter does not require any mental effort and develops under stimuli possessing a "directly fascinating quality" (Hansman, 2011). Today, our everyday life is full of many different stimuli, and a great mental effort is needed to keep concentrated, which depletes our directed attention and reduces our effectiveness and resistance to stress (Hartig, Mang, & Evans, 1991). Restorative settings are very important for the recovery of directed attention, but not all have the same efficiency in fostering this process (Hansman, 2011). Four different components determine the suitability of the surrounding environment for recovery: its ability to induce a feeling of "being away" from daily problems, its coherent and extended spatial extent, its fascinating quality, and its compatibility with an individual's current aspirations (Hansman, 2011).

In particular, natural settings are assumed to possess a very high fascinating quality, because they stimulate indirect attention and allow for the recovery of depleted directed attention (Hansman, 2011). A study revealed that even the simple view of a small park on the way to work could potentially have a positive impact on people's moods (Wythe, 1980, as cited in Nordh, Hartig, Hagerhall, & Fry, 2009). These findings support the idea that while the provision of actual recreational areas is not the only mean of improving life quality, planning should also account for elements of the urban landscape that have a limited recreational value, but could consist of micro-restorative settings. These elements are often little valued by urban planning managers as being beneficial, but they might have a significantly positive impact on urban lifestyle.

IV. 4. 3. Integrating *a priori* banal landscape features to urban planning

The Stadtbach is a very good example of such a functional urban landscape element because of its high accessibility and visitation level, but its apparently low recreational use. Measures to improve its vegetation diversity or enhance its visibility might have a positive influence on a large number of people because of its location in the centre of a residential area, even if some individuals might not even notice its presence.

The benefits of improving the state of urban rivers was already emphasized by Tunstall, Penning-Roswell, Tapsel & Eden (2000) in their study on public attitude towards river restoration. But, the massive improvement of a river's state is not necessarily essential for producing a significant increase in its perceived aesthetic quality (Junker & Buchecker, 2008). Often, a few small improvements of its structural diversity is sufficient enough to increase its appeal.

Additionally, it is worth enhancing the already existing urban elements instead of designing new psychological restorative settings. Making the most of city specific features is currently a well-developed trend (Nordh et al., 2009), as it promotes density in the context of increasing urbanization, while enhancing the quality of cities and preserving their historical heritage. The re-development of brownfields for industrial, commercial, residential and recreational purposes in western cities became popular in the last few decades, apparent in Switzerland by the complex of Sihlcity in Zurich, the estate of Le Flon in Lausanne or the industrial district of Vevey. Likewise, planners have realized that already existing urban landscape features can be used to provide new green areas and offer more room for psychological restoration within already densely populated cities (De Sousa, 2003). New York's High Line consists of one of the most striking examples of such an achievement.

> This former elevated rail line brought freight cars into factories in the estate of Manhattan from 1934 until 1980. It was then completely abandoned and eventually became colonised by wildflowers. In the course of the 1990s, the estate became a vivid neighbourhood full of restaurants, galleries and lofts, and the city's authorities were willing to tear down the old rail line, which was at that time not very aesthetic (Goldberg, 2011). However, the idea emerged to turn it into an elevated open green park providing room for the population of the densely populated Manhattan (Goldberger, 2011). Nowadays, it is not only a green area, but also a witness to the historical and industrial heritage of the city. Other examples of this type exist in the world, among them the "Promenade Plantée" established in Paris in 1988 along the route of a former railway (Goldberger, 2011).

At a smaller scale, many intensive roof gardens are also established on existing urban buildings in order to provide aesthetic and psychological benefits to urban populations, as acknowledged by Oberndorfer et al., (2007). These authors further noticed that the positive impact of roof gardens on people's restorative experiences was present even when they were accessible only as a visual relief.

These examples illustrate the importance of planning not only for already attractive recreational areas, but also for urban landscape elements that are not specifically used for recreation but whose enhancement can help the urban population to recover from stress and maintain regular physical activity.

IV. 5. Need for further research

In order to improve the model of river recreational use, it is advisable to focus on two main problem areas. First, the parameters driving river attractiveness in the case of mobile people – in particular of cyclists – should be better understood. It is essential to grasp the relative importance of "accessibility", "landscape suitability" and "infrastructures" to the user in order to better represent, understand and predict their recreational use of rivers. To do so, more empirical studies are needed, such as survey questionnaires, field observations or GPS real-time studies. Second, empirical studies are also needed to identify and quantify which landscape parameters affect river attractiveness or repulsion the most. Such studies should be designed in order to easily include the defined parameters into a GIS-based model.

In its actual state, the model could be further used for other purposes, such as the assessment of the recreational potential of rivers in peri-urban areas at the Swiss scale (on the condition that the model's computation intensity be reduced). Alternatively, the model could also be used to prioritise recreational areas as a function of specific user types. For example, the accessibility calculation could be adapted to the reduced mobility of elderly in order to define which river stretches are most accessible to them and could be equipped with more specific urban infrastructures, like benches or guardrails. Such specialised trails already exist in some countries, especially in Scandinavia (Bell, Tyrvaïnen, Sievänen, Pröbstl, & Simpson, 2007). In addition, the model could also be used – under the condition of a better understanding of cyclists' recreational behaviour – to identify possible areas of conflicts between pedestrians and cyclists, or between recreation and other types of river services.

On a larger scale, the general conceptual framework developed in the context of this master thesis could be applied to other kinds of urban features (e.g. woodlands, green parks, walls, etc.), or to alternative types of recreation, such as end-of-the-day recreation.

From a more conceptual point of view, a general reflection on the meaning of "recreation" in urban planning is needed in order to better define what exactly is meant when referring to this concept. Moreover, the space given to small urban landscapes in the context of psychological restoration should be further studied to get a better grasp of the potential of such urban features to improve the quality of life in cities.

Finally, an additional research topic could examine the better integration of a river's recreational use in decision-making processes concerning rivers and their restoration. In particular, the identification of potential conflicts arising between the different landscape services provided by rivers could help in a global integration of ecological, economic, social and flood protection issues, while fostering the acceptance of restoration projects by the population.

V. Conclusion

This master thesis presents a conceptual framework together with GIS-based tools designed for the mapping and the better understanding of river use in the context of short nearby recreation and psychological restoration in Swiss peri-urban areas.

The outcomes of the study result in different products and conclusions aimed at facilitating decision-making in the field of urban planning and river restoration. First, the study provides a method to calculate the accessibility of continuous landscape features such as rivers for different kinds of users by determining their access points and considering their accessibility as a discrete choice problem. Second, it delivers a simple and transparent raster-based model aimed at mapping the potential recreational use of rivers by combining the three parameters “accessibility”, “landscape suitability” and “infrastructures” through the use of pivot tables. The study further develops a robust conceptual framework combining both “space” and “place” approaches towards landscape perception in order to better understand the recreational or functional use patterns of rivers in peri-urban settings. Finally, this study provides a GIS-based tool that can be used to determine which river stretches have the highest improvement potential in terms of landscape suitability and infrastructure level for providing more recreational or restorative opportunities to urban populations.

By applying the methods developed in this study to the concrete case of the city of Aarau, several valuable conclusions can be drawn. First, all river stretches situated within a 3 km perimeter around the most populated areas should be taken into account when planning for short nearby recreation, because it is the maximal distance that average people are able to reach when undertaking this kind of recreation. It thus represents the perimeter where potential conflicts might arise between recreation and other services provided by watercourses (e.g. economical, ecological, protection services, etc.).

Second, the accessibility model emphasizes the importance of population structure and the structure of residential areas on river accessibility. This means that river enhancement measures for recreation or restorative opportunities should not only be undertaken in very densely populated areas, but also in large and well-connected residential districts. In fact, the potential number of people able to reach rivers within 15 minutes in such large areas can be very high, which signifies that many people can profit from river improvement measures.

Third, the evaluation of the raster-based model shows that it is well adapted to represent the recreational use of rivers by pedestrians, and that it can be used in practice for decision-making at small scales. On the contrary, more studies are needed in order to improve the representativeness and the accuracy of the cyclists’ model.

From a more global point of view, the conceptual framework combining the “space” and “place” perception of rivers is a good complement to the modelling approach. In particular, it allows for the identification of river stretches presenting (a) a high recreational use and (b) a rather functional use. These categories of river use can additionally help in defining practical enhancement measures.

In regards to the health problems induced by our modern urban lifestyle, the outcomes of the study emphasize the importance of enhancing functional urban landscape features that are highly accessible but little used for recreation. In fact, their visual or qualitative improvement can provide relief from stress and encourage the practice of a regular physical activity. In line with this, the analysis also recommends to improve the state of already existing urban landscape features such as rivers in order to make the most of them, make our cities denser and keep track of their historical heritage.

Finally, the GIS-based tool provides a simple and quickly available assessment of river improvement potential regarding recreational and restorative opportunities. When integrated into the general conceptual framework, it further allows for a better understanding of the values that people hold for the rivers, and helps identify potential conflicts between rivers’ recreational, ecological or economic services.

The array of tools and the conceptual framework developed in the context of this master thesis consist of a coherent and transparent approach towards planning for short nearby recreation and restorative opportunities in peri-urban areas. They further encourage reassessing the well-established paradigm of recreation in the context of physical and psychological well-being in urban centres.

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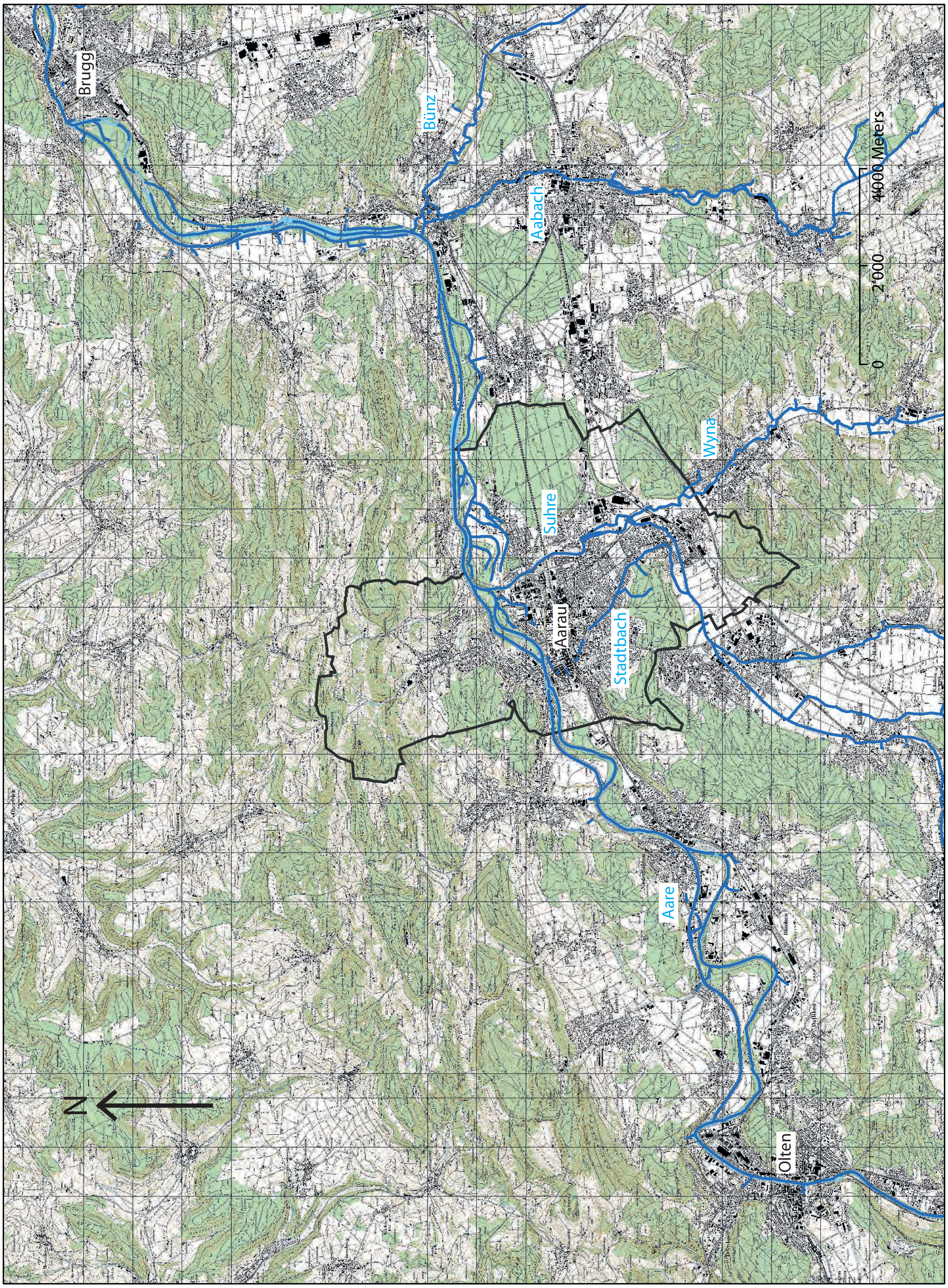
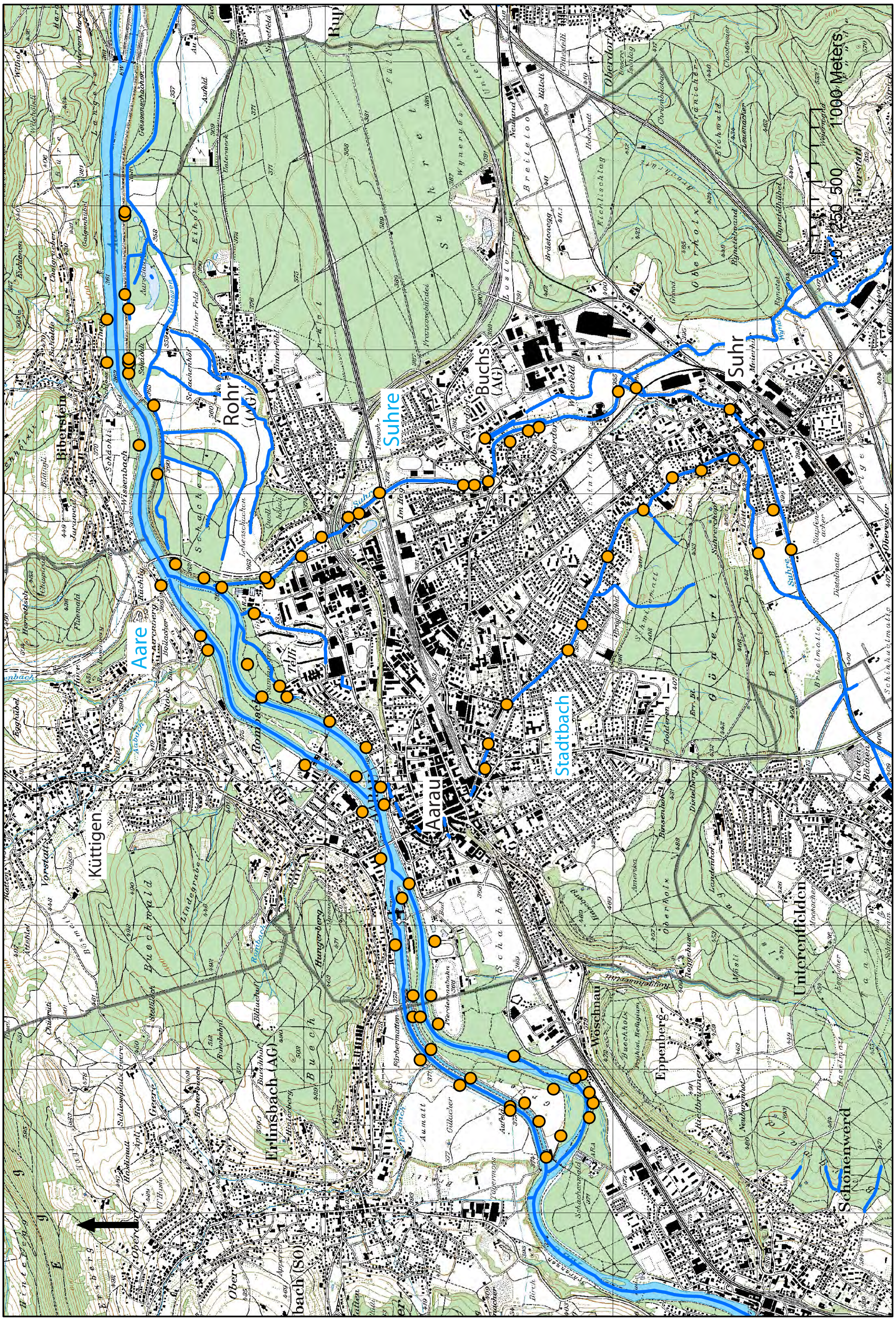
VII. Appendix

A 1: Complete study perimeter



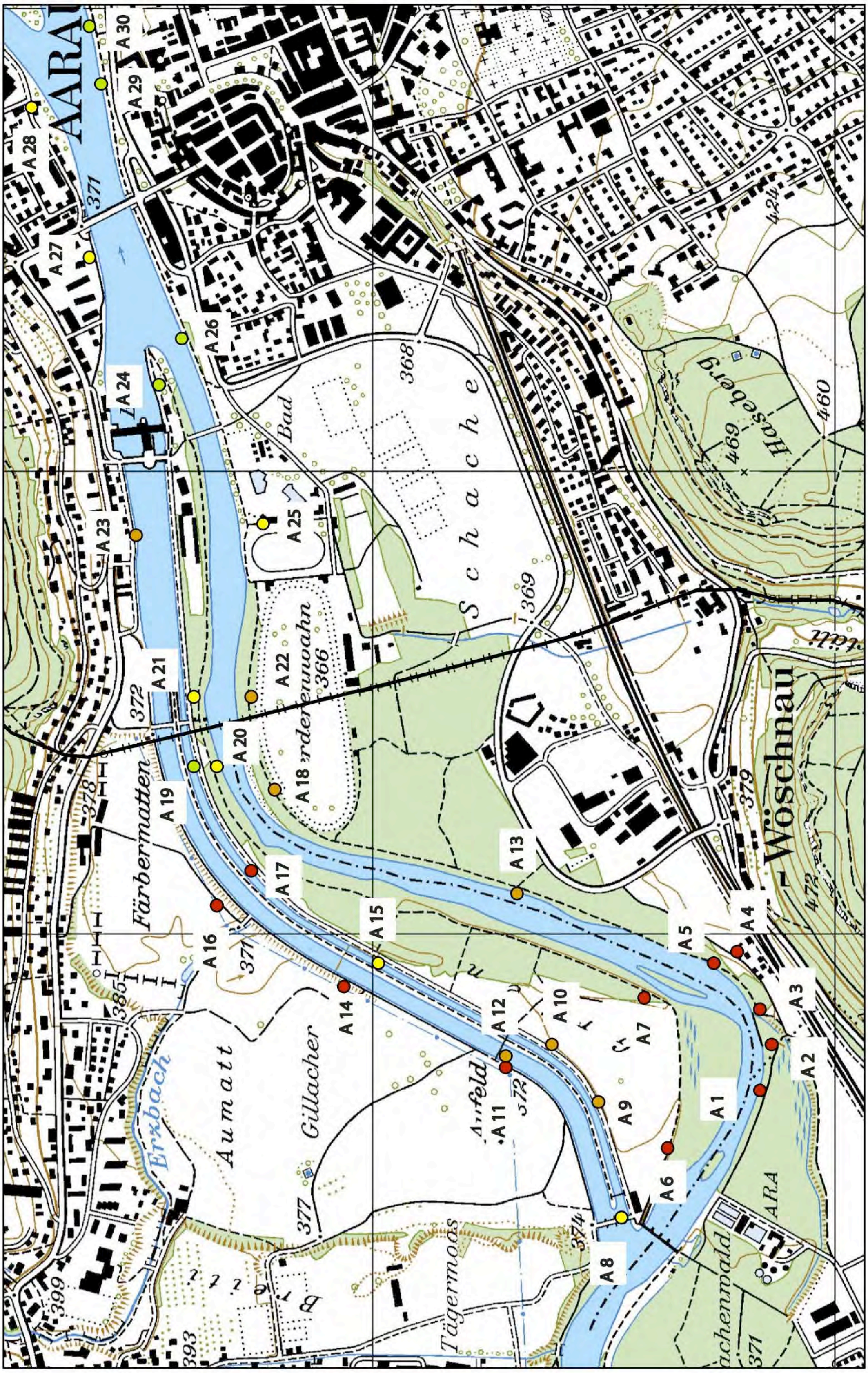
The black perimeter delimits the source population area and the main rivers are displayed in dark blue. Town names are written in black and river names in blue. Sources: © 2012 Swisstopo (Topographical map), © 2008 FOEN (Eco-morphological state of Swiss rivers).

A 2: Repartition of the sampling points along the main rivers of Aarau



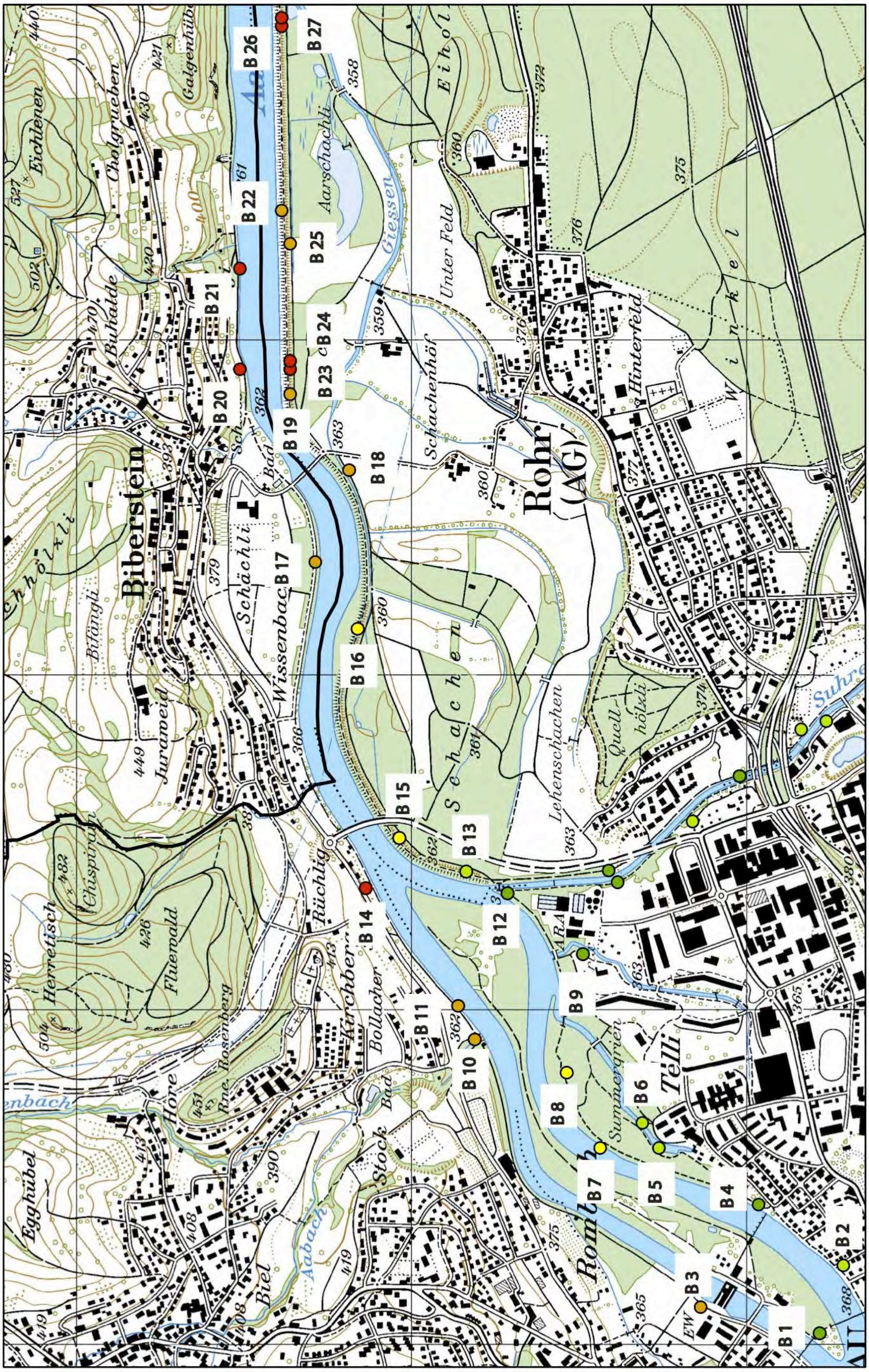
Sampling points are displayed as orange circles. The grey perimeter delimits the source population area and the main rivers are displayed in dark blue. Town names are written in black and river names in blue. Sources: © 2012 Swisstopo (Topographical map), © 2008 FOEN (Eco-morphological state of Swiss rivers).

A 3: Sampling points situated in sector A.



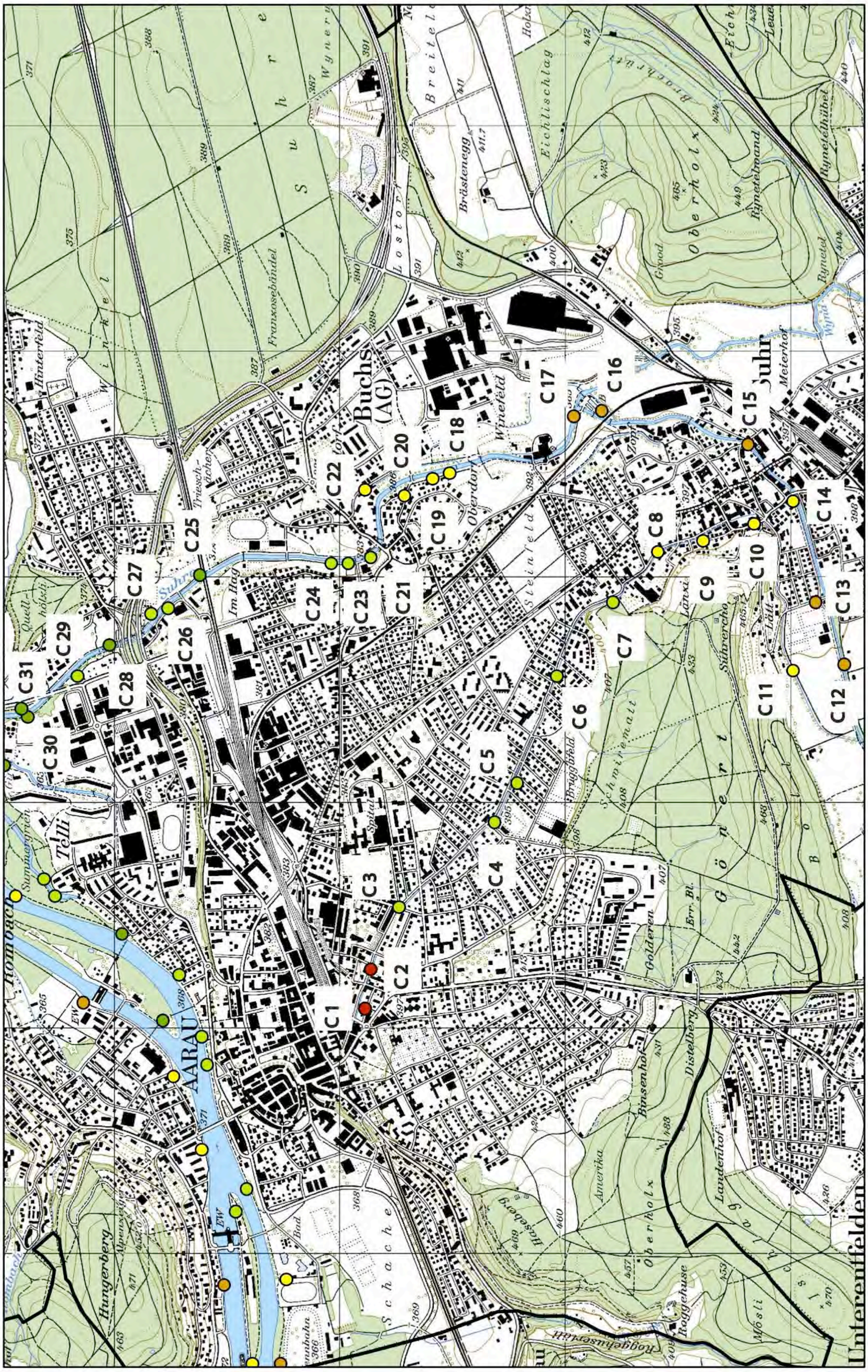
Sampling points are displayed as coloured circles. Source: © 2012 Swisstopo (Topographical map).

A 4: Sampling points situated in sector B



Sampling points are displayed as coloured circles. Source: © 2012 Swisstopo (Topographical map).

A 5: SAMPLING POINTS SITUATED IN SECTOR C



Sampling points are displayed as coloured circles. Source: © 2012 Swisstopo (Topographical map).

B: Questionnaire developed for the local knowledge analysis

Nutzung von Gewässern als Naherholungsgebiete

Eine WSL Befragung — Sophie Rudolf, unter Betreuung von Felix Kienast

Liebe Teilnehmerinnen, liebe Teilnehmer

Flüsse und Bäche sind wichtige landschaftliche Elemente in der Schweiz. Ihre Benutzung als Naherholungsgebiete in Ballungsräumen ist bisher jedoch erst wenig erforscht. Das Ziel dieser Befragung ist es, die am meisten für Naherholung benutzte Gewässerstrecken **in der Umgebung der Stadt Aarau** zu bestimmen. Für diese Befragung sind die folgenden Erholungsaktivitäten am Fluss entlang zu berücksichtigen:

- Spazieren
- Radfahren
- Inlineskaten
- Baden
- Spielen (auf Spielplätzen)
- Sich entspannen

Bei dieser Befragung geht es um **kurze Naherholung (tägliche Erholungsaktivitäten**, die **weniger als** 1½ Stunden dauern). Nur **Arbeitstage** (Montag – Freitag) sind zu berücksichtigen.

Zu berücksichtigen sind nicht nur die von den Einwohnern der Gemeinde **Aarau** genutzten Erholungsgebiete, sondern auch jene, die von den Einwohnern der Gemeinden **Küttigen**, **Suhr** und **Buchs** genutzt werden.

Hinweise zum Ausfüllen des Fragebogens:

Bitte füllen Sie den Fragebogen:

- Möglichst **alleine** aus.
- Möglichst **spontan** aus.

1. Frage zur Gewässer Benutzung

Auf der 3. Seite sehen Sie einen Kartenabschnitt, wo die wichtigsten Gewässer der Stadt Aarau und ihrer Umgebung darstellt sind. Jeder Gewässerabschnitt ist auf ein 500 x 500 m Quadrat begrenzt.

Wo sind gemäss Ihrer Abschätzung die Gewässerstrecken, die für Naherholung an Arbeitstagen in der Umgebung der Stadt Aarau am meisten genutzt werden?

!!! Das Ziel ist nicht, die Strecken, die Sie persönlich am meisten nutzen, zu benennen, sondern jene Strecken, die – gemäss Ihrer Einschätzung – durch die ganze Bevölkerung am meistens genutzt werden !!!

Kreuzen Sie bitte auf der nächsten Seite mit einem Stift die Quadrate an, die Ihrer Meinung nach die am meisten genutzten Gewässer-Strecken sind. Sie dürfen **bis zu zehn** verschiedene Quadrate ankreuzen.

Beispiel:

2. Angaben zu Ihrer Person:

1. Was ist Ihr Geschlecht? ☐ weiblich ☐ männlich

2. Welche Postleitzahl hat Ihr Wohnort? ____________________

3. Haben Sie mit den Gewässern der Stadt Aarau beruflich zu tun? ____________________

Herzlichen Dank für Ihre Mitarbeit!

Haben Sie noch Fragen, Anregungen oder Kommentare?

Bitte senden Sie den Fragebogen so bald wie möglich an mich zurück.

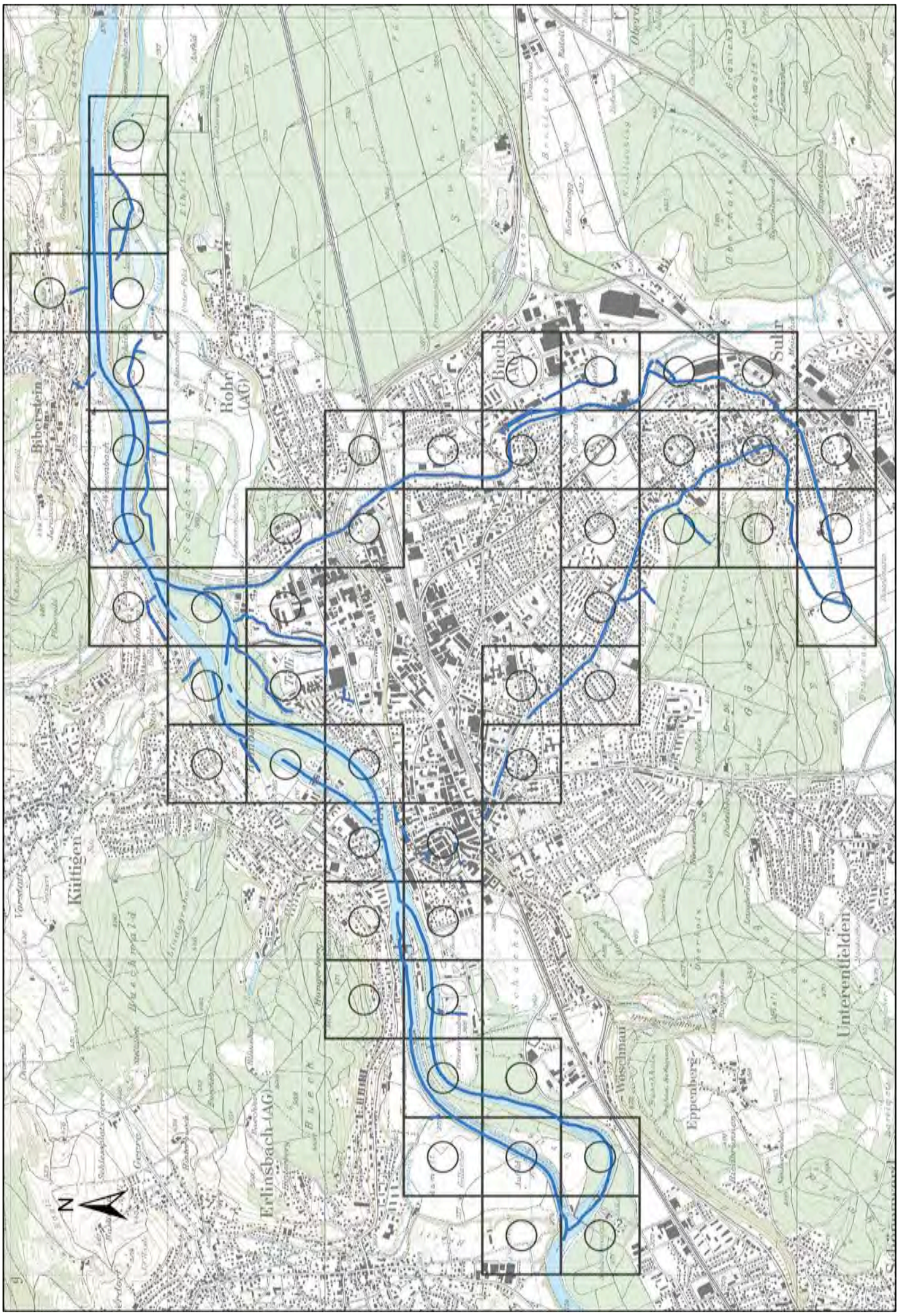
Rückfragen beantworte ich Ihnen gerne:

Sophie Rudolf

Masterstudentin der ETH Zürich

E-Mail: sophie.rudolf@wsl.ch

Eidg. Forschungsanstalt für Wald, Schnee und Landschaft WSL
Zürcherstrasse 111, 8903 Birmensdorf



Biberstein
Rohr (AG)
Buchs (AG)
Suhr
Küttigen
Erlinsbach (AG)
Wöschnau
Eppenberg
Unterentfelden
N

C 1: Main Swiss roads and their description

Road type	Remarks
Highway	Have divided lanes. Pedestrians and cyclists have no access to them.
2nd class Highway	Have undivided lanes. Pedestrians and cyclists have no access to them.
1st class road	Have a minimal width of 6 m. Are often equipped with cycling tracks and pavements.
2nd class road	Have a minimal width of 4 m. Are usually secondary roads.
Suburban roads	Have a minimal width of 4 m. Serve residential estates. Might be restricted by traffic limitations.
3rd class road	Have a minimal width of 2,80 m. Serve villages and hamlets. Usually have a hard surface.
4th class road	Have a minimal width of 1,80 m. Might be banned from traffic.
5th class road	Cycling tracks, paths, and trails. Banned from traffic.
6th class road	Footpath. Banned from traffic.
Park footpath	Footpath situated in official parks. Banned from traffic, strictly limited to pedestrians.
Isolated bridge	Usually accessible to pedestrians and cyclists.
Isolated footbridge	Usually accessible to pedestrians and cyclists.
Hiking trail	Strictly limited to pedestrians.

Source: Swisstopo, 2011.

C 2: CORE QUESTIONS ASKED DURING THE SEMI-STRUCTURED INTERVIEW

The following questions provided the basis for the semi-interview conducted with Mr. Rolf Strebel, project manager of the division “Roads and Water bodies” in the city of Aarau’s administration:

1. What exactly is your function as project manager for the division of “Roads and Water bodies”?

2. Are you responsible only for the rivers situated within the city, or do you collaborate with other communities to manage trans-boundary watercourses?

3. To which extent are the Aare, the Suhre and the Stadtbach managed differently?

4. Does a cantonal program for river restoration exist in the Canton of Aargau?

5. What are the main goals of river restoration projects in Aarau?

6. Is nearby recreation taken into account when planning for restoration projects?

7. According to you, is it important to include nearby recreation to urban planning?

8. What are the criteria used to select which river stretches are suitable for restoration?

9. Which river stretches have already been restored in Aarau? For what purpose?

10. Is there still an improvement potential concerning new river restoration projects in Aarau?

11. Does the Stadtbach have a particular socio-cultural value for inhabitants of Aarau?

12. Why do you still clean the Stadtbach once a year? Who is responsible for this (city of Aarau, community of Suhr…)?

13. Concerning the Stadtbach, does a trade-off exist between its ecological function and its historical value?

14. What is the importance and the significance of the Aare for the population of Aarau?

15. Concerning nearby recreation, do you think that a trade-off exists between the accessibility and the quality of the recreational area?

D 1: Pedestrians – Classification of sampling points according to their category of modelled recreational use

Group 1		Group 2		Group 3		Group 4		Group 5	
Sample	Score	Sample	Score	Sample	Score	Sample	Score	Sample	Score
A 1	0	A 9	6	A 8	2	B 5	0	A 24	18
A 2	1	A 10	5	A 15	0	B 6	1	A 26	118
A 3	1	A 12	1	A 19	2	B 12	3	A 27	11
A 4	0	A 13	1	A 20	5	B 13	2	A 29	10
A 5	1	A 16	4	A 21	4	C 1	7	A 30	30
A 6	2	A 17	4	A 28	12	C 2	19	B 1	12
A 7	0	A 18	3	B 3	5	C 4	16	B 2	4
A 11	6	A 22	2	B 7	6	C 5	1	B 4	3
A 14	3	A 23	4	B 8	2	C 6	3	B 9	6
B 14	2	A 25	3	B 16	0	C 21	4	C 3	17
B 19	3	B 10	1	C 7	0	C 23	0	C 28	1
B 20	8	B 11	1	C 8	1	C 24	0		
B 21	3	B 15	1	C 9	4	C 25	4		
B 22	0	B 17	0	C 10	3	C 26	0		
B 23	2	B 18	4	C 14	1	C 27	12		
B 24	0	B 25	1			C 29	0		
B 26	0	C 11	1			C 30	0		
B 27	3	C 12	2			C 31	0		
		C 13	4						
		C 15	4						
		C 16	0						
		C 17	3						
		C 18	6						
		C 19	3						
		C 20	0						
		C 22	0						

D 2: Cyclists – Classification of sampling points according to their category of modelled recreational use

Group 3		Group 4		Group 5	
Sample	Score	Sample	Score	Sample	Score
A 1	1	A 3	0	A 15	0
A 2	0	A 5	0	A 19	15
A 4	0	A 6	4	A 20	0
A 9	14	A 7	0	A 21	16
A 11	7	A 8	6	A 24	28
A 14	2	A 10	5	A 25	1
A 16	2	A 12	0	A 26	13
A 17	10	A 13	0	A 29	19
A 23	7	A 18	0	A 30	22
A 28	17	A 22	0	B 1	9
B 3	10	A 27	9	B 2	17
B 10	0	B 7	6	B 4	7
B 20	14	B 8	2	B 5	0
B 21	11	B 11	5	B 6	2
B 26	0	B 13	15	B 9	0
B 27	0	B 14	7	B 12	5
C 1	21	B 15	7	B 22	2
C 2	22	B 16	4	C 21	1
C 4	23	B 17	2	C 25	5
C 5	19	B 18	9	C 26	2
C 7	46	B 19	2	C 27	12
C 8	44	B 23	0	C 28	14
C 9	40	B 24	1	C 29	0
C 10	22	B 25	5	C 30	0
C 12	0	C 3	42	C 31	0
C 13	4	C 6	61		
C 14	7	C 11	2		
C 15	0	C 16	1		
C 22	1	C 17	0		
		C 18	0		
		C 19	3		
		C 20	1		
		C 23	14		
		C 24	10		

E: Preliminary analyses

Several authors have previously examined factors affecting the suitability of rivers to provide recreational opportunities to people. Benkler (2011) assessed them in his study on the recreational value of the Sense (Canton of Fribourg) using questionnaires, while Huber (2012) and Spiess et al. (2008) included some landscape features in their modelling of the recreational potential of rivers.

In the present study, the inputs of these previous assessments were used to define appropriate factors. Data from Benkler (2011) were first assessed to check whether they could be used to perform a Primary Component Analysis (PCA), following the method developed by Kliskey (2000) in his "*recreation terrain suitability mapping*". The idea was to use a PCA to determine which landscape attributes could best explain people's preferences for different river environments, and to which extent. Benkler's dataset consisted of people's declared preference for diverse landscape proxies specific to rivers, assessed on a 4-point Likert scale, with a sample size restricted to n=110 observations. After analysing his data, it was concluded that they were not suitable to perform this kind of statistical analysis for the following reasons:

- The data were classified on an ordinal scale representing pseudo-quantitative data, while quantitative data are theoretically required to perform a PCA (Baccini, 2010, p.5).
- The dataset contained many NoData entries, reducing the total sample size to an insufficient number of observations (n=60) compared to the number of variables included (27).

In a second attempt, parameters suggested by Huber (2012), Spiess et al. (2008) and Benkler (2011) as being important to river landscapes' suitability for providing recreational opportunities were listed and classified according to their positive or negative influence (Table F 1). They were then submitted to experts in order to define the extent to which each of them could explain people's preferences in the context of river landscapes.

Table F 1. Parameters suggested by Benkler (2011), Huber (2012), and Spiess et al. (2008) as being good predictors of landscapes' suitability to provide recreational opportunities. They are classified according to their positive or negative influence.

Positive influence	Negative influence
River naturalness (presence of gravel banks, islands…)	Visual or physicl limitations (phone lines, highways…)
River banks covered with forest or shrubs	Path situated on noisy and traffic intense roads
Good visibility on the surroundings	High people density
Landscape diversity	Wastewater treatment plants
Hedges	
Solitary trees	
High amount of sunshine	

The experts consisted of three men and three women, each having already worked in the field of river restoration and/or nearby recreation (F 2).

Table F 2. Experts selected for the assessment of river landscapes' features, together with a selection of their research relating to the fields of river restoration and/or nearby recreation.

Expert	Field of research
Matthias Buchecker	Took part in the development of a GIS-based predictive model of nearby recreation on the Swiss Plateau
Barbara Degenhardt	Took part in the development of a GIS-based predictive model of nearby recreation on the Swiss Plateau
Berit Junker	Studied the social aspects of rivers' restoration projects
Felix Kienast	Took part in the development of a GIS-based predictive model of nearby recreation on the Swiss Plateau
Sigrun Rohde	Studied the potentials and limitations of re-establishing fluvial ecosystems in Switzerland
Harry Spiess	Took part to the development of a GIS-based model of rivers' recreational potential in the Canton of Zürich

Experts were asked to attribute a score to each listed landscape feature on a 6-point Likert scale. The goal was to assess the importance of the given parameters for river attractiveness or repulsion in the context of short nearby recreation (1=hardly important, 6=very important).

Out of the six experts, three completed the questionnaire, two did not answer the questions and one never returned the questionnaire. The experts who did not complete the questionnaire justified their omission by the difficulty of assessing with precision the importance of the different parameters for river recreation and the absence of any objective data allowing them to perform such an assessment. In parallel, the results obtained through the evaluation of the three fully completed questionnaires did not provide much conclusive information. Only two parameters were assessed in a similar way by the three experts: they qualified "paths situated on noisy and traffic intense roads" as being very important (score of 6) for the aversion of river stretches, while they assessed a "high amount of sunshine" as being of rather little importance for their attractiveness (score of 3).

According to these rather vague conclusions, it appeared that many uncertainties still remained in the assessment of parameters driving river attraction or repulsion. Several parameters are ambiguous and can be interpreted as having both a positive and a negative impact on it. For example, a "high amount of sunshine" can be positive because it provides light and warmth, but can also be a limiting factor in summer if it gets too hot. Likewise, a "high people density" can be attractive for individuals who seek social contacts, while repelling people who seek a quiet atmosphere.

Moreover, even experts from the field of river restoration or nearby recreation could not give an objective assessment of the relative importance of the different parameters for river attractiveness because their judgment was often influenced by their personal experiences, preferences and values.

Under these conditions, it was concluded that more research is needed to define precisely which parameters have a significant impact on river attractiveness. It was therefore decided to restrict the model to only a few easily measurable parameters and adapted to a GIS assessment.

F: Enclosed CD

The enclosed CD contains the followings:

- Aml codes used for the accessibility calculations
- R codes used for the determination of the visitation level and for the evaluation of the GIS-based model
- ModelBuilders used for the development of the GIS-based model
- Complete datasets of the recorded recreational infrastructures
- Excel tables used for the distribution of users of public transport among alternative bus stops