Changes Over Time in Remnant Rural Vegetation within Built-up Areas

Recreational use, Vegetation dynamics and Conservation assessment

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Abstract

This dissertation focuses on changes over time within patches of remnant rural vegetation after their inclusion in built-up settings. The dissertation is a compilation of four papers preceded by a summary part. The basis for the study is a unique data set collected over a 30 year period at Järvafältet, in the north western part of Stockholm. Empirical contributions are made in three principal areas: recreational use of remnant vegetation, dynamics of remnant vegetation and conservation assessment of urban properties.

In paper I the recreational use of areas with remnant vegetation close to and within built-up areas was found to increase between the two studied time periods, 1978–1982 and 2002–2004 with children being the largest user group.

The dynamics of remnant vegetation studied in papers II and III were found to vary greatly depending on the specific vegetation's properties. Abandoned pastures were, apparently, not impacted at all. The forest field layer showed a modest and gradual composition change. Bryophytes experienced a curvilinear decrease in cover. Fruticose lichens growing on bedrock was rapidly and fully exchanged by crustose lichens and worn out ground was substantially formed on heavily worn areas. Wear and tear was assessed to be the major driver of the observed vegetation changes.

In paper IV the development of a novel tool for the assessment of the biodiversity depletion state at the urban property-level, 'EcoEffect Outdoors – habitat depletion', is described.

The dissertation's summary part provides a background to the study, a synthesis of the papers and an account of the author's part in the work presented. A short exposition of the research field including the most important associated research areas and a condensed review of the benefits of and the threats to remnant vegetation is also forwarded. The summary part also contains a general scheme for possible outcomes of wear and tear in patches of remnant vegetation. The scheme suggests a promising approach to the further development of our understanding of the importance of different vegetation processes in connection with wear and tear.

Keywords: recreation ecology, outdoor recreation, user counts, urban woodlands, green spaces, city planning, trampling tolerance, wear resilience, vegetation succession, assessment of urban biodiversity, decision tool development

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Contents

List of Publications

This thesis is based on the work contained in the following papers, referred to by Roman numerals in the text:

I Clas Florgård and Oskar Forsberg (2006) Residents' use of remnant natural vegetation in the residential area of Järvafältet, Stockholm. *Urban Forestry & Urban Greening* 5, 83-92.

II Oskar Forsberg (2010) Vegetation development patterns in remnant forest patches within a built-up area. (Manuscript)

III Clas Florgård and Oskar Forsberg (2008) Vegetation changes 1954 - 2006 in pastures preserved as parts of the urban green infrastructure at Vällingby and Järvafältet, Stockholm – Case study. *Salzburger Geographische Arbeiten*, Band 42, 9-24: Ecological perspectives of urban green and open space.

IV Oskar Forsberg and Ulla Myhr (2010) EcoEffect Outdoors – Habitat Depletion: A novel tool for the assessment of locally inflicted strain on biodiversity in urban properties. (Manuscript)

Papers I and III are reproduced with the permission of the publishers.

The contribution of Oskar Forsberg to the papers included in this thesis was as follows (see also chapter 4):

I Forsberg was responsible for the data processing and the writing of the paper was made in collaboration with Florgård.

II Forsberg participated in data collection and was entirely responsible for the processing of data and for the writing of the paper.

III Forsberg was responsible for the processing of vegetation data and belonging writing. Conclusions and final preparations were made in collaboration with Florgård.

IV Forsberg and Myhr share, equally in merit, the responsibility for the development of the HD-tool and for the writing of the paper.

1 Introduction

The focus of this thesis is *remnant rural vegetation within built-up areas*, hereafter referred to as *remnant vegetation*. It involves patches of natural or semi-natural vegetation incorporated into extensively developed and densely populated settlements. Patches of remnant vegetation may differ in size from a few square metres to several square kilometres but have in common the fact that the vegetation is more or less retained from the time before urban development begun in the surrounding areas.

Patches of remnant vegetation have many values (see section 2.1). However, as a consequence of being located within built-up areas these patches also face many threats (see section 2.2). The creation of a better knowledge base is thus desirable with a view to improving our understanding of both of their general aspects and the deeper processes involved such that the values they represent can be better safeguarded, utilised and managed and the threats they face eliminated or rendered less harmful.

The issues addressed in this thesis originate in the discipline of ecology but are operationalised here in a local planning context while, given the multidisciplinary character of the subject, seeping also into other contiguous research areas. It is important to recognise the complexity of urban ecosystems (Pickett *et al.* 2005). While it is increasingly clear that the biophysical and human social systems are highly interrelated scientific society nevertheless continues to struggle in terms of truly integrating this insight into research (Steward *et al.* 2008).

The complexity engendered by the wide array of influencing factors (*cf.* chapter 3) implies constraints on the geographical applicability of many research results. Consequently the work presented here including studies located in the north-western suburbs of Stockholm, addresses the conditions faced more broadly across the Nordic countries (Denmark, Finland, Norway and Sweden) all of which share much in the way of common conditions; history, traits of society, social habits, biophysical conditions, urban design etc. Thus these countries are where most of the generated results are likely to be most applicable. Many of the results obtained here do, potentially, however have wider applicability but great care is required in respect of dealing with condition discrepancies.

1.1 Research questions and study approach

The main aim of the present work is to contribute to the creation of a better knowledge base regarding changes over time within remnant rural vegetation after their inclusion in built-up settings. This knowledge base is of importance as a foundation for the design of management and management tools with implications for remnant vegetation and its associated values. The knowledge base is also useful for the positioning of built up elements in relation to preserved patches of remnant vegetation.

The contribution to a more profound knowledge base is made in three principal areas: (1) Recreational use of remnant vegetation, (2) Dynamics of remnant vegetation and (3) Conservation assessment of urban properties. For detailed method descriptions see respective paper.

Recreational use of remnant vegetation (Paper I)

Recreational use is arguably the most important reason to preserve remnant vegetation. Urban residents in the Nordic countries greatly value recreation in patches of remnant vegetation (Berglund 1996, 2010, Hörnsten and Fredman 2000, Lindhagen and Hörnsten 2000, Schipperijn 2010) but recreation also poses a threat to the survival of the vegetation through wear and tear (Liddle 1997). This wear and tear is considered to be a major driver of change in remnant vegetation (Florgård 2000, Hamberg 2009, Malmivaara-Lämsä 2008). Accessible knowledge in respect of recreational use is therefore of the highest relevance in order to better understand the dynamics of remnant vegetation. With a view to increasing this knowledge base the focus of paper I is on the following research question:

- How does the amount and mode of recreational use of remnant vegetation change over time?

This research question is also relevant in the valuation of remnant vegetation in urban planning and design as well as in open space management.

In paper I the recreational use of remnant vegetation is studied by observations over the periods 1978–1982 and 2002–2004. The number of people, sex, age, type of activity, and place of that activity were investigated in permanent investigation plots in a residential area at Järvafältet, Stockholm, Sweden (see section 4.1).

Dynamics of remnant vegetation (Papers II and III)

Planners have expressed doubt over the survivability of rural vegetation encapsulated by built-up areas and, consequently also over the durability of such vegetation's inherent value (Florgård *et al.* 1984). As the allotted value depends on the persistence of the remnant vegetation it is interesting to chart the degree and character of change in the vegetation over time. Papers II and III address this research question:

- How does remnant vegetation change over time?

While paper II concerns the understorey vegetation of forest patches paper III address vegetation development in abandoned pastures. Both studies make use of a vegetation data set collected yearly using the same investigation plots as in paper I (see section 4.1). This data set enables analysis to begin from the period before construction begun through more than thirty years of residential usage. In addition, paper III makes use of comparisons of photographs taken in different years as well as of numerous on-site observations.

Conservation assessment of urban properties (Paper IV)

In urban landscapes patches of remnant vegetation are local biodiversity key areas for indigenous flora and fauna (Croci *et al.* 2008, Hahs *et al.* 2009). As such, on an increasingly urbanised planet with expanding urban areas, from an ecological point of view they are of considerable conservation value (Czech *et al.* 2000, McKinney 2002). With regard to the assessment of biodiversity issues in urban settings however there is a shortage of suitable tools (Yli-Pelkonen and Niemelä 2005). The construction sector needs operational tools to direct and assess their work with regard to biodiversity conservation (Myhr 2008). Paper IV is an attempt to put theory into practice by means of the development of such a tool within the framework of the comprehensive building environmental assessment system, EcoEffect (Myhr 2008). The novel tool presented in paper IV is intended for use in rapid assessments of locally inflicted strain on biodiversity and is an answer to the question:

- How can site conditions for the conservation of biodiversity in urban properties be assessed?

The tool sets remnant vegetation in relation to other urban habitats and elucidates the importance of remnant vegetation in urban environments in a biodiversity conservation perspective.

2 Remnant vegetation

Urban development pressures increase as more and more people choose to live in cities. Today more than 50% of the world's residents live in urban areas, and by 2050 the urban population is expected to almost double (United Nations 2008). The geographical extent of urban areas is already considerable and will continue to grow resulting in extensive and lasting loss of natural habitats. Indeed, urbanisation is a significant and persistent threat to the conservation of biodiversity (Czech *et al.* 2000, Hahs *et al.* 2009, McInney 2002).

The amount and distribution of remnant vegetation in cities and towns varies greatly. No comprehensive assessment of the urban world's remnant vegetation exists but settlements in the Nordic countries are estimated to have relatively extensive areas of land preserved. A study of 100 Swedish towns with more than 10 000 inhabitants showed that on average 20% of the average town consists of natural woodlands, varying from 1% to 40%, the median patch being 4 hectares (Hedblom and Söderström 2008).

Remnant patches are in many cases leftover areas from developments undertaken though they can also be the result of deliberate planning. In recent decades the level of awareness in respect of remnant vegetation has increased in all parts of the world (Florgård 2007).

2.1 Benefits of remnant vegetation

In increasingly crowded cities patches of remnant vegetation constitute a valuable recourse as potential areas for new development. Indeed, the preservation of remnant vegetation can also provide many additional benefits to urban society. The urban environment can benefit from noise reduction, air pollution reduction and wind speed reduction, mitigation of the urban heat island effect and provision of shade and screening (Bolund and

Hunhammar 1999). Areas of remnant vegetation can also relieve pressure from the sewage system by taking care of rainwater drainage. Compared to designed and planted vegetation, remnant vegetation has the advantage of being in place and fully functional from the beginning unlike planted vegetation which normally needs time to grow.

The existence of remnant natural vegetation can often provide outcomes of a kind that can be difficult or even impossible to achieve through ordinary planting (Berglund 1998, Howell and Benson 2000). It can aid in giving identity to urban districts by providing a certain character, being a heritage carrier or by being a divider between city districts. For some citizens such patches might be their only close contact with the natural environment that they depend on and that form a part of their city and/or national identity (Konijnendijk 2008, Ignatieva and Stewart 2009). Remnant patches also provide pedagogic excursion destinations for day nurseries and schools (Titman 1994). This pedagogic function is a condition for the completion of several school subjects in Sweden related to teaching in natural science. Remnant vegetation can also provide exciting playing areas for children, as a complement to designed playgrounds (Berglund 1996, Lindholm 1995). Indeed, in a comparison between two day nurseries, one traditional with a typical built playground and one where the children spend a lot of time outdoors in greener and more natural surroundings, the children in the day nursery with the 'nature-based' playground did better at both motor function and power of concentration tests (Grahn *et al.* 1997).

It has also been found that natural vegetation and green surroundings can be important for public health in general and that they can have a specific importance in recovery from stress (Hartig *et al.* 1991, Grahn and Stigsdotter 2003, Kaplan & Kaplan 1989, Kaplan 1995, Maas *et al.* 2009, Ulrich *et al.* 1991). As people in the world's wealthier regions lead increasingly sedentary and stressed lives their need for exercise and recreation increase from a public health perspective. The recreational aspect, with possibilities for play, exercise and rest may indeed be the most highly appreciated value of remnant vegetation. The attractiveness of remnant vegetation is, for example, reflected in housing prices (Tyrväinen and Miettinen 2000). The importance of access to urban green space for public health has also been reiterated at the highest political level in Sweden (Miljödepartementet 2010).

Patches of remnant vegetation can be cheap to manage considering that they generally manage themselves. Furthermore, if urban city dwellers' desire for green places can be provided within built-up areas, their commuting for recreational purposes to non-urban and rural areas can be decreased, thus reducing the demands on transportation.

Remnant vegetation is also of both biological and ecological importance (Gilbert 1989, Miller and Hobbs 2002, Werquin *et al.* 2005). Primarily by maintaining viable populations in functional habitat networks within the urban matrix but also by supporting rural core areas by buffering and facilitating connectivity between them. In recent years the issue of biodiversity conservation within built-up areas has received increasing attention (McDonnell *et al.* 2009, Müller *et al.* 2010) not least because of increasing urbanisation. Urban areas also often coincide with environmentally sensitive areas with rich flora and fauna (Rickets and Imhoff 2003).

2.2 Threats to remnant vegetation

Williams *et al.* (2009) set up a conceptual framework for predicting the effects of urban environments on the flora that can also be used to systematise the threats to remnant vegetation and consequently also to its inherent values. The framework identifies four filters affecting the persistence of remnant vegetation: habitat transformation, fragmentation, urban environment, and human preference. A fifth threat has been identified here - ignorant governance and management.

Habitat transformation

During urban development rural areas are to a large extent transformed implying massive loss of original habitat. The losses however vary depending on the building conditions, land use patterns and human preferences (Stehlik *et al.* 2007). Different habitats and species also have different abilities to tolerate gentler habitat modifications.

Fragmentation

The less remnant vegetation retained the more important becomes the issues of patch allocation, connectivity and continuity to maintain vital populations (Bastin and Thomas 1999, Collinge 2009, Lindborg and Eriksson 2004). Theory predicts that the survival of individual populations is more likely in large and well connected habitat patches than in small and isolated patches. Species that can persist despite small population size, have good dispersal ability or those that can use habitats other than the remnant patches have a greater chance of survival than those that cannot. In conclusion, it is predicted that remnant vegetation will lose species resulting in a more simplified community structure with a suite of narrower species traits.

Urban environment

The urban setting involves changed abiotic conditions. These include air, water and soil pollution, littering, elevated temperatures due to the 'urban heat island' effect and increased water stress (Gilbert 1989). Altered disturbance regimes are also probable.

The influence of a changing environment on remnant patches is further increased by what are termed 'edge effects'. Edge effects are a mixture of properties from adjacent habitats occurring on the edge, or border, between them. These edge effects may stretch more than 50 metres into remnant forest patches. As remnant patches are often small in size and in many cases occur in narrow strips, remnant vegetation not affected by edge effects only exists in the interior of larger patches (Hamberg 2009).

Human preference

Human preference is decisive for the introduction and management of species present in urban settings. Alien species are commonly used in, and spread from, horticultural plantings and may also come along as stowaways making urban floras look more and more alike in all urban parts of the world, causing biotic homogenisation (McKinney 2006). Invasive exotic species can pose a significant threat to remnant vegetation due to their ability to 'out compete' and displace the original vegetation (Van Driesche and Van Driesche 2000).

As remnant vegetation is often a preferred environment for recreation the vegetation is usually threatened by 'wear and tear', mainly by trampling (Florgård 2000, Lehvävirta and Rita 2002). Conflicting preferences and interests coupled with one-sided ignorance can lead to detrimental tending. e.g. the same shrubbery can both be appreciated as a great place for building a children's 'den' (Kylin 2003) and evoke fear as a potential hiding place for a rapist (Koskela and Pain 2000).

Remnant vegetation can also be a source of dislike (Bixler and Floyd 1997). Patches perceived as unmanaged can give rise to anxiety caused by fear of crime and wild animals (Jorgensen *et al.* 2007, Kuo and Sullivan 1998). The seclusion facilitated by remnant vegetation and appreciated by recreationists is also attractive for numerous extra-legal or otherwise frowned upon activities.

Governance and management

In the end the decisive question is to what extent the values and threats are taken in consideration when governance of the area in question is undertaken. Mistakes in the long chain from planning through design and construction to management and maintenance can be fatal as lost remnant vegetation cannot easily be restored. In that respect ignorant governance in respect of remnant vegetation can be seen as a major threat.

Regarding the special values of remnant vegetation, such areas ought to be considered as a principal element in urban planning but this is not always the case. Decision-makers and planners with little knowledge of the benefits of natural vegetation often simply do not often take such factors into consideration. For example, Nyhuus and Halvorsen Thorén (1996) found that several small green areas in Norwegian cities were developed by means of infill during the period 1965-1995, and that remnants of natural vegetation ("natural areas") were more threatened than areas with planted vegetation. The prospects for remnant patches are, moreover, likely to be worse if they are not included in planning at all as such areas might effectively become a "tragedy of the commons" (Hardin 1968) and because some 'management' is usually preferable, notwithstanding the unintended consequences, to no intervention at all.

There is also often a discernable lack of planning resources, e.g. competence (Sandström *et al.* 2006), suitable tools in respect of the assessment of urban biodiversity issues (Yli-Pelkonen and Niemelä 2005) or tools for the communication of ecological information and knowledge to urban planners and decision makers (Norton 1998). This shortage is likely, at several levels, to have consequences for decision making influencing remnant vegetation.

3 Research on remnant vegetation

All of the values and threats outlined above, their interconnections and how they are or can be handled, are the subjects of research concerning remnant rural vegetation within built-up areas. The actual volume of research explicitly addressing remnant vegetation is however not large. Moreover, due to the multidisciplinary and complex character of the subjects concerned, many studies that are relevant to the issues surrounding remnant vegetation research do not actually focus on remnant vegetation, but rather on general knowledge developments in the associated research areas brought up in section 3.1.1. Almost any urban study can in some way contribute to the better understanding, and subsequently also the better handling, of the urbanised human–environment relations. This is because the life conditions for flora and fauna in urban settings are principally defined by the built-up environment and the activities and behaviour of the urban population (cf. section 2.2).

The wide array of contributing disciplines however brings its own specific challenges. Authors often lack the required insights in more than one discipline. Poorly described study conditions hamper progress in that comparative work is made difficult or even unfeasible (Lehvävirta and Kotze 2009). In part a common terminology is lacking, as well as definitions, knowledge of significant factors and standards for how to appropriately describe and measure them (Florgård 2007, McIntyre *et al.* 2008).

To further complicate matters cause-and-effect relationships are not seldom poorly appreciated and hugely complex including, as they do, a large number of possible factors. These factors can also seem to vary greatly in importance from site to site for little discernable reason if no specific site information is available.

The research field has, moreover, undergone a significant expansion since the turn of the millennium as urban ecology in general has become the object of significantly more attention in the academic realm. It is a challenging but important task to try to bridge and indeed to tie together the different research areas. In what follows a short exposition of the research field and the most important associated research areas is forwarded.

3.1 Research field

Research explicitly addressing remnant vegetation exists around the world (Florgård 2007). Researchers in the Nordic countries, the USA and Australia have played important roles in the development of the research area, and research has been ongoing at least since the late 1960s. The perspective has been broad and a large variety of academic disciplines as well as non-academic practitioners have helped to promote knowledge development in this field (Florgård 2007, Konijnendijk *et al.* 2007, Young and Wolf 2006). Municipalities have played the role of lead funding agencies ensuring that the research is often applied and policy-relevant. This is also the main reason why much of the research undertaken in this area is published in national languages. On the one hand this has helped to ensure that the results produced quickly reach local authorities and influence the management of the remnant vegetation issue. On the other hand this same practical focus designed to service local level actors hampers international research communication and knowledge development more generally.

According to Florgård's research which maps studies focusing on remnant vegetation up to 2004 (Florgård 2007) one of the main focus points has been the human-caused impact on preserved vegetation. Importance, function, concepts and definitions have to a limited extent been taken into consideration, as have planning, design, construction and utilisation. Care and maintenance have also been studied to some extent, including methods for the rehabilitation of damaged natural vegetation. One particularly successful method used in a number of studies has been the urban-rural gradient approach introduced in the early 1990s (McDonnell and Pickett 1990).

References from Nordic research to Australian or American papers and *vice versa* were almost totally absent however before 2004 (Florgård 2007). The two groups seem to have studied the same field of research without communication. Lack of generally accepted keywords has been a particular obstacle here. Contact has recently increased among others stemming from the holding of an international symposium in Uppsala in 2002 that I helped organise (Indigenous vegetation within urban development – Ecology and management of natural vegetation preserved in urban areas).

3.1.1 Associated research areas

Research concerning urban green space in general is often applicable to remnant vegetation e.g. urban ecology, urban forestry, landscape planning, and urban planning. However, differences between different types of green spaces especially between designed plantings and remnant vegetation i.e. biologically and ecologically, and in how they are used, perceived, managed and maintained have to be observed and considered. Knowledge originating in rural and pristine settings can also be transferable to the urban setting of remnant vegetation. This pertains specially to ecology theory.

Ecology: Knowledge development in such areas as meta population theory (Hanski 1999), vegetation succession (Connell 1977) and species coexistence (Roxburgh *et al.* 2004) are fundamental for the understanding of the vegetation processes observed in remnant vegetation. Traditionally ecology has been biased against habitats dominated by man resulting in a paucity of research in urban settings (Young and Wolf 2006). The intense human influence on urban landscapes makes it inevitable to take human aspects into consideration to a greater extent (Niemelä 1999). On the other hand the urban setting presents a special opportunity to advance ecology research in that theories can be tested and refined in new contexts (McDonnell and Pickett 1990).

Urban ecology includes both traditional ecology work performed in urban environments and work that considers human systems and their associated characteristics as part of a broader system of ecology (Gaston 2010, Niemelä 1999). There are, in addition to vegetation studies, fauna studies, not less on birds to be taken into consideration. Urban Ecology is also a term used by sociologists and anthropologists to frame a sub-field of human ecology (Grineski 2003) but here, and henceforth, usage relates to natural systems.

Recreation ecology is another sub-field of ecology of special interest in respect of remnant vegetation. Recreation ecology addresses the impacts of recreationists and tourists on natural and semi-natural land and the management to mitigate the impacts (Liddle 1997, Monz *et al.* 2010). Experimental trampling studies in particular generate a knowledge-base that is of fundamental importance to our understanding of vegetation development in sites exposed to heavy wear and tear. It should however be acknowledged that the wear of remnant patches has an additional dimension - in terms of how such wear is distributed - while in trampling experiments all vegetation is subjected to wear. The distribution pattern of wear in small remnant patches compared to large wilderness recreation areas (cf. Hammett and Cole 1998) is also likely to differ in both time and space due to the existence of differing user groups with different motives and expectations.

Urban forestry refers to the art, science and technology of managing all trees and forest resources in and near urban areas to provide multiple benefits (Konijnendijk *et al.* 2006). The concept has the longest history in the United States (first mentioned in 1894) mainly building on street and shade tree management while in Europe it has had a town-forest emphasis (Konijnendijk *et al.* 2006).

Urban planning and design, including **landscape architecture** concerns the planning and layout of the total built environment (Spirn 1984). The importance of urban planning for remnant vegetation cannot be underestimated as it is what defines what ends up as remnant, its amount and allocation. Tightly coupled with questions in respect of the planning field is the issue of decision making (Healey 2010, Nilsson and Florgård 2009) which can be a delicate business regarding remnant vegetation as conflicts of interests are common, e.g. development interests versus local remnant vegetation users (Berglund 2010).

Environmental economics and ecological economics are fields of academic research that can also contribute to the research field particularly in respect of the assessment of the economic value of preserved remnant vegetation (Hanley *et al.* 2003, Tyrväinen 2001, Tyrväinen and Miettinen 2000).

Environmental psychology (Bell *et al.* 2001) is also an important field. It renders possible a deeper understanding of the recreational conditions and benefits supplied by remnant vegetation while also explaining and predicting human behaviour in and around remnant vegetation. An accumulating set of studies provide evidence, for example, of the positive relationship between health, well-being and green space (Tzoulas *et al.* 2007).

4 Background to the thesis

The postgraduate project reported on here began with the intention of producing new knowledge about the development of remnant vegetation after incorporation in an urban setting. The starting point was a data set collected over a 30 year period at Järvafältet, in the north western part of Stockholm. The long time series made the data set unique and the challenge was to make the best use of it. Throughout the period of postgraduate work reported here this data set has functioned as the core focus of study. As such, papers I, II and III all make use of data from the Järvafältet studies.

In this chapter the background of the thesis and its papers is described and the author's part in the presented work is noted. The chapter is, in part written in a more personal manner. This allows for an understanding of the sociological background of the work undertaken. This sociological approach to the practise of science (cf. Barnes *et al.* 1996) is common in the social sciences but normally not presented in natural science. Here it helps to elucidate what would otherwise likely remain a concealed understanding of why the thesis turned out to be what it is and why it came to contain the papers it does.

4.1 The Järvafältet studies - pioneer remnant vegetation research

The Järvafältet studies on remnant vegetation started in response to a practical planning problem. At the beginning of the 1970s the rural area at Järvafältet was being planned for development. The planners involved had the idea of using remnant vegetation but had misgivings about the capacity of the vegetation to survive the urbanisation process (Florgård 1981). The Järvafältet research project started in 1972 with a focus on vegetation changes but also included studies focussing on changes in local climate, air pollution, hydrology, soil conditions, recreational use, building and planning processes and experimental treatments to increase vegetation durability (Florgård *et al.* 1984, Florgård 2000). The latest outcomes of the project are this thesis and papers I, II and III included herein.

4.1.1 Study site

The study site, Järvafältet (59°N, 18°E, figure 1), is located 15 km north west of Stockholm city centre in Sweden. Before the 1970s when residential development took place the entire area was rural, with managed forests, meadows, pastures and arable land, and was also used for military training. Hill tops, reaching 25-50 m above sea level, with very shallow soil on bedrock are dominated by Scots Pine (*Pinus sylvestris*) forests, while Norway Spruce (*Picea abies*) mixed with deciduous trees dominate the slopes, and meadows and arable land the valley floors. The typical forest ground cover vegetation is dominated by bilberry (*Vaccinium myrtillus*) but vegetation rich in grasses and herbs also exists and lichens dominate on outcrops.

The studied districts, Kista, Husby and Akalla, host a population of about 30 000 inhabitants. During construction only small patches of natural vegetation were left. The area is typical of the many large scale neighbourhoods that were built in Sweden at that time. Development was mainly carried out in the mid 1970s and not substantially thereafter. The main building type is the 5-6 storey building, but in some parts there are two-storey terraced houses and in others 14-storey buildings. The reference area is a nature conservation area of some 25 km^2 in size located just north of the built-up area.

4.1.2 The vegetation inventory

In 1972, twenty-eight fixed investigation plots were chosen in the remaining natural vegetation at different distances from where construction sites were to be established (Florgård 1984, figure 1). Seven of them were placed in patches of remnant vegetation surrounded by residential housing ("the built-up area"), and seven just outside the built-up area (within 100 m of the buildings, "the border area"). Seven plots were placed in a green area with a distance to the nearest residential building of between 200 and 400 m ("the green area"), and seven in the nature conservation area at a distance of 1.5-3 km from the nearest built-up area ("the nature conservation area" or "the reference area").

As this was originally a study of the impact on and changes in vegetation, the plots were placed so as to represent different vegetation types. The plots in the built-up area and the border area were chosen first. All remnant patches of natural vegetation within the residential area were covered. The plots were placed at the centres of the patches scheduled for preservation to avoid destruction by unplanned building activities and to mitigate the influence of edge effects. The investigation plots in the green area and the nature conservation area were then located so as to resemble the built-up area plots and the border area plots in respect of vegetation type.

From the beginning the built-up area and the border area were not recognised as two separate areas. It was discovered during the work on paper I that the recreational use of the areas differed. After a closer inspection this is quite evident bearing in mind that the remnant islands in the built-up area are accessible from all directions. Therefore they are more easily available to more people than the border areas that are accessible from more or less one direction only and hence likely to receive less use.

Within each quadratic investigation plot (10x10m or 20x20m depending on patch size and local site conditions) five fixed and not overlapping 1 m2 squares were randomly laid out in a grid. Five investigation plots were designed as 1 m wide long strips to enable observations of gradients due to hill slopes and distance from old forest edges possible. Along the strips 3-5 fixed 1 m^2 squares were randomly laid out, though this was subsequently found to be too few to provide any real chance of proving any gradients. A few plots and 1 m^2 squares were lost due to construction in the first few years but most of them still remain (table 1).

The squares have been surveyed with regard to the percentage cover of present vegetation species during the summers 1972-2006. Until 1982 most plots were surveyed every year and after that only a selected number of plots were investigated yearly (see table 1). The reduction in surveyed plots was due to a lack of funding and only the most interesting plots were thus kept on (plots with the greatest vegetation changes and belonging reference plots). In 2003 and 2004 all plots were however once again surveyed by me.

The locations of the investigation plots were also used as observation points for the study of recreational use presented in paper I.

4.1.3 The compilation of the vegetation inventory data into a database

The postgraduate work begun with the considerable task of compiling the nearly 50 000 recordings of observed species into a uniform workable database and then clean it from errors. Data then stored in different software and storage mediums had to be compiled into a joint database. Then typing errors and other anomalies had to be corrected while the scientific names of species that had been altered over the years had to be updated. To make the inventory compatible across the entire study period certain records had to be lumped together in groups e.g. species that one year were recorded with their full scientific name and other years only recorded by family. Those were grouped together to avoid false species turnovers. It took nearly two years before the database was ready for use.

Table 1. *Number of squares surveyed each year in the vegetation investigation plots. Plots used in paper II are marked with bold numbers. One square in plot 3 was not used in paper II due to its location at the forest edge. All plots are used in paper I and plot 12 used in paper III. The plot numbers in the first column are according to the original numbering.*

Built-up area	1972								1980					1985					1990					1995					2000						2006
2 bilberry spruce forest	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
3 bilberry spruce forest	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
8 flat rock pine forest	5	5	5		4	4	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		
9 flat rock pine forest	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
11 flat rock pine forest	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
13 bilberry spruce forest	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
14 dry mixed conif forest	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Border araea																																			
1 dry mixed conif forest	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
4 wet alder forest	5	5	5		5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
5 dry mixed conif forest	5	5	5	5	5	5	5	5	5	5	5					5																5	5		
6 dry mixed conif forest	5	5	5	5	5	5	5	5	5	5	5					5																5	5		
7 grassland		5	5	5	5	5	5	5	5	5	5					5																5	5		
10 wet coniferous forest	5	5	2	2		5	5	5	5	6	6	2	2	2	2	6	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2		2
12 grassland (*used in paper III*)		4	4	4	4	4	4	4	4	4																						4	4		

Green area	1972								1980					1985					1990					1995					2000						2006
41 dry mixed conif forest	5	5	5	5	5	5	5	5	5	5	5					5																5	5		
42 bilberry spruce forest	3	3	3	3	3	3	3	3	3	3	3					3																3	3		
43 bilberry spruce forest	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
44 bilberry spruce forest	5	5	4	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
45 mixed conif. forest		5	5	5	5	5	5	5	5	5	5					5																5	5		
46 grassland		3	3	3	3	3	3	3	3	3	3					3																3	3		
81 dry mixed conif forest	5	5	5	5	5	5	5	5	5	5	5					5																5	5		
Reference area																																			
47 br. leaved decid. forest		5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
82 dry mixed conif forest	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
83 bilberry spruce forest	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
84 grassland		5	5	5	5	5	5	5	5	5	5	5		5	5	5																5	5		
85 flat rock pine forest	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
86 bilberry spruce forest	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
87 wet mixed conif forest	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5

5 Number of squares surveyed

Building period

Squares covered by gravel to facilitate walking paths (field layer eradicated)

One square moved (the change assessed to be of no significance)

All squares moved

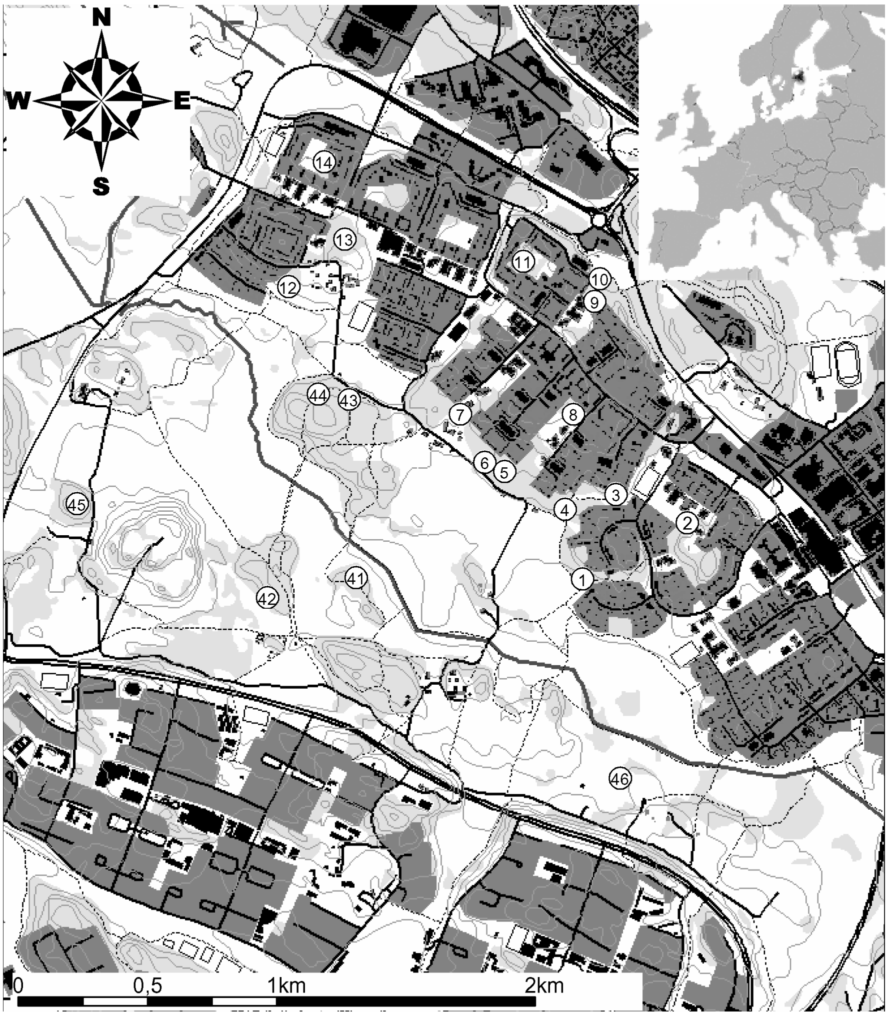

Figure 1. The location of the investigation plots in the built-up area, the border area and the green area at Järvafältet. The nature conservation area is situated approximately 2 km outside the map to the northwest. The plot numbers are according to the original plot numbering.

4.2 Paper I

During the work with the compilation and cleaning of the database another opportunity presented itself. My supervisor, Clas Florgård, needed help with the statistical analyses for a conference paper and we decided to write the paper together. The study site and plots were the same as those that I had already worked on for paper II but the study was about residents´ use of the same vegetation in which I intended to study vegetation dynamics. The aim was to use the results to explain variation in vegetation response between investigation plots. However, the observed users were too few per plot to allow for that.

We divided the work so that I made the statistical analyses and wrote drafts for the belonging sections, the second part of the method section and the results section. I also prepared the figures. The discussion and conclusion sections were carried out together. For design of the statistical analysis we relied upon the advice of a statistical expert. The paper was presented at the conference "Urban Woods for People", 24 May 2004 in Stockholm, and later published together with other papers from the conference in a special issue of "Urban Forestry and Urban Greening".

4.3 Paper II and the data set challenge

Paper II is based on the vegetation data set that provided the main impetus for starting this postgraduate project. The most important asset of the data set is the long time series that begun before construction started. Analyses are however constrained by the limited number of plots investigated at different and changing time intervals and located in different vegetation types. The configuration of the data set has notability restricted analyses both regarding available methods and the ability of such methods to detect meaningful results.

To make the most of the opportunity presented by the time series the work was concentrated on the period after development dependent patterns. In consequence the analyses were focused on the plots that had been investigated every year, see table 1. The study was further focused to plots within the built-up area where the vegetation changes were most pronounced and where a majority of plots in this case were located. Forest understorey vegetation was the prime vegetation studied as it was well represented in all plots and judged to be the most fruitful to investigate in respect of earlier research.

In addition to a contribution to the remnant vegetation research field, paper II is, in a way, an answer to the challenge posed in respect of making the best use of the Järvafältet vegetation data set. The paper in its entirety is the work of the current author.

4.4 Paper III

The work on paper III started and progressed similar to that of paper I. Florgård had made a conference presentation at a workshop at a research congress in 2007 about the development of pastures abandoned when included in built-up settings ~~(Florgård 2007)~~ and was asked to make a full paper out of it. As one of the pastures was represented by a plot in the data set I was working with it was natural that I did the vegetation analyses for that plot and the 'belonging' writing. We made the final preparations in collaboration. The paper was peer reviewed and then published together with other papers from the workshop in a special band of "Salzburger Geographische Arbeiten".

4.5 Paper IV

Ulla Myhr, a fellow PhD student at the department, was considering entering into the design of the part of the EcoEffect system concerned with biodiversity and proposed that we do it together. EcoEffect is a comprehensive framework for the environmental assessment of urban properties (Myhr 2008). We both thought it would be rewarding and fruitful to do the work together and as she was expert on assessment tools, particularly EcoEffect and I knew the biodiversity issue quite well I thought we could finish it within a month of intensive work. This proved to be wildly optimistic and in the end, undoubtedly, a substantial miscalculation. It took us almost a year to design the tool. I gravely underestimated the challenges in developing such an assessment tool but the process was notwithstanding this nevertheless highly rewarding. Tool design after tool design was rejected and along the way our insight grew. The biggest challenge was to find a scientific foundation that could take into account all the aspects present in built-up settings and all their variations and still allow for transparency and ease of use.

The paper has a wider perspective than remnant vegetation. It is a way of putting knowledge on remnant vegetation into practice such that the threat posed by lack of suitable tools and ignorance is decreased. The entire work process was undertaken from start to finish in true collaboration.

5 Main results

5.1 Recreational use of remnant vegetation – paper I

The recreational use of remnant vegetation was studied in paper I. Residents' use of areas with remnant natural vegetation in cities shows that these areas have a recreational value along with other values. It was found that areas of remnant vegetation were used by day nurseries, schools and people in general, for educational purposes, for recreational purposes, for pet walking, and so forth. The amount of use varied greatly between individual plots. Overall, there was a significant increase in the amount of use between the two studied time periods, 1978–1982 and 2002–2004. On the one hand use by organised groups, as well as by adult people out walking, runners and cyclists, had increased over time. While on the other, individual children's play had decreased. Almost every other child observed was found to be partaking in organised school or day nursery group activities. Children belonging to organised groups were seen as frequently in areas at a distance of less than 100 m from the houses as between 200 and 400 m from the built-up area, while children not participating in group activities were seen much more frequently within 100 m from the residential houses.

The areas of remnant vegetation were used more by children and young people than by adults. This implies the likelihood that the use of these areas for recreation is underestimated in outdoor recreation inquiries and interview studies, where children and organised child activities usually are not included. Children were found to use very small areas with remnants of natural vegetation, even when the remaining vegetation was trivial, and subject to severe wear and tear. This means that even small areas of remnant vegetation can be important to preserve, and that proximity to day nurseries, schools and residential houses is more important than uniqueness or other vegetation qualities in these small remnant areas.

5.2 Dynamics of remnant vegetation – papers II and III

The development of the forest understorey vegetation was studied in paper II from the time before urban constructions commenced through 27 years of residential usage. Distinct successions among lichens and bryophytes and a considerable increase in bare worn ground was observed (figure 2-4). Annual species turnover among field layer species was found to be higher in the built-up area than in the reference area. However, the long term rate of change in the field layer was equal between the two areas. The development direction differed between the two areas in that the composition of the vegetation in the residential area moved more towards ruderality than in the reference area. The movement towards ruderality was mainly due to redistribution among species present before residents moved in. Results show that urban use, in this case mainly trampling, affected plant composition. The deterioration of the field layer was however slow and after 30 years still progressing. Regarding remnant vegetation observed long term changes emphasise the importance of taking the temporal situation into consideration. Where people choose to stay the wear seems to be so severe that not much can grow there. Therefore the visitors' impacts are the primary objective for management. Therefore are the same visitor impact management tools that are used in nature preservation areas with high visitor numbers of interest here (cf. Hammet and Cole 1998).

Two pastures preserved in built-up areas were studied in paper III. Wear by the residents was found to be much less than that formerly caused by cattle. Decrease of impact has resulted in overgrowing by bushes and trees similar to the overgrowing seen in abandoned pastures in rural areas. The desired functions of the pastures; high biodiversity, great beauty and great attractiveness for recreation, were found to be on the way to being lost.

5.3 Conservation assessment of urban properties – paper IV

Paper IV describes an effort to design a tool for the assessment of the biodiversity depletion state at the property-level within built-up areas and for the EcoEffect system. The tool EcoEffect Outdoors – habitat depletion, henceforth referred to as the HD-tool (HD as in Habitat Depletion), was developed for use in rapid assessments of the locally inflicted strain on biodiversity. The tool is intended to function as an aid to enable the construction sector to assess and compare development plans and alternatives or to compare various properties to each other. The aim of the tool is to facilitate the enhancement of the urban matrix in order to reduce the strain on biodiversity. The tool uses the vegetation to represent biodiversity and is based on four factors; composition, structure, processes and abiotic conditions. The factors are assessed and quantified at the site. The scores are subsequently aggregated into an HD-index which represents the state of habitat depletion from non-depletion to full depletion in accordance with the vegetation, assets, states and transitions (VAST) framework (figure 5) developed by Thackway and Lesslie (2006). The HD-tool focuses on the often trivial biotopes of the common surroundings in built-up areas.

Patches of remnant vegetation are hotspots for conservation in the urban landscape. Intact remnant vegetation is also the base from which habitat depletion is assessed in the HD-tool. The degree of habitat depletion is composed of the size of vegetation loss and composition change (*cf.* figure 6). In the HD-tool bare ground corresponds to a removed vegetation state while composition change corresponds to a modified, transformed or replaced vegetation state depending on the degree and character of species turnover.

In figures 2-4 the development of the HD-scores for the remnant vegetation studied in paper II are shown for the field layer, bryophyte and lichen communities separately. These scores put together with the assessment of the tree and bush vegetation give the overall HD development shown in figure 5 where also the factor scores are shown. This way of dividing an assessment complements the spatial delimitation of homogenous units to facilitate otherwise hard-to-grasp assessment tasks.

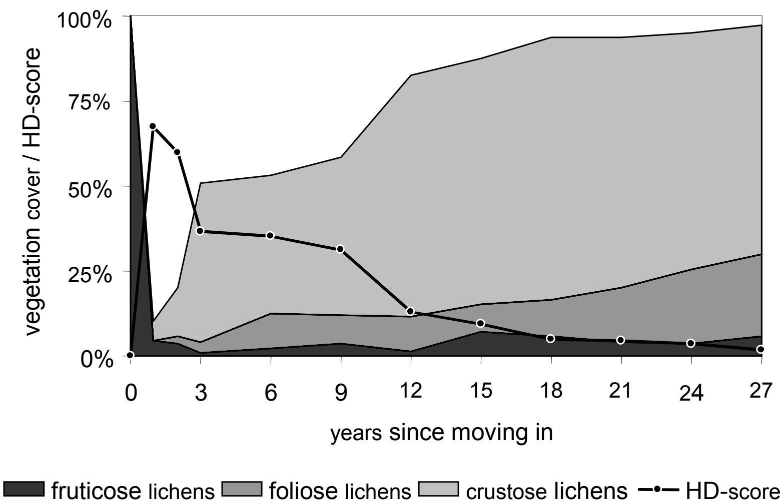

Figure 2. The remnant vegetation development on bedrock covered by fruticose lichens before settlement (data from paper II) and the corresponding HD-score.

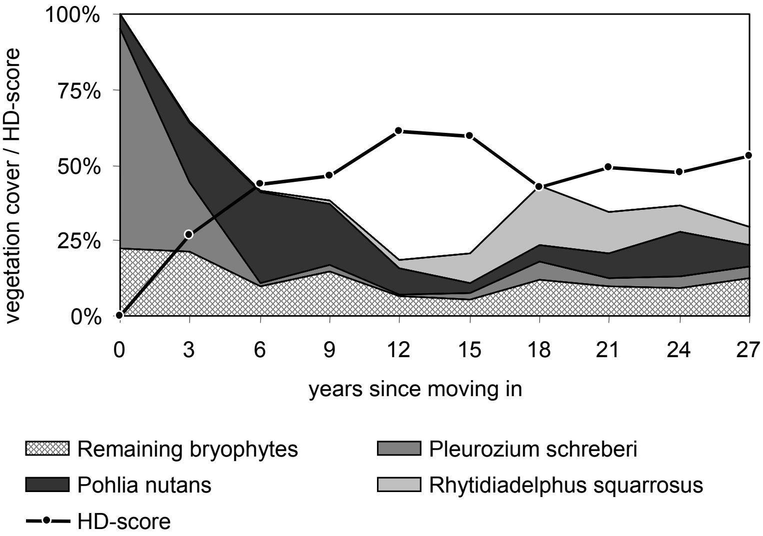

Figure 3. The bryophyte development in the remnant forest patches studied in paper II and corresponding HD-score, i.e. the habitat depletion development within the bryophyte community.

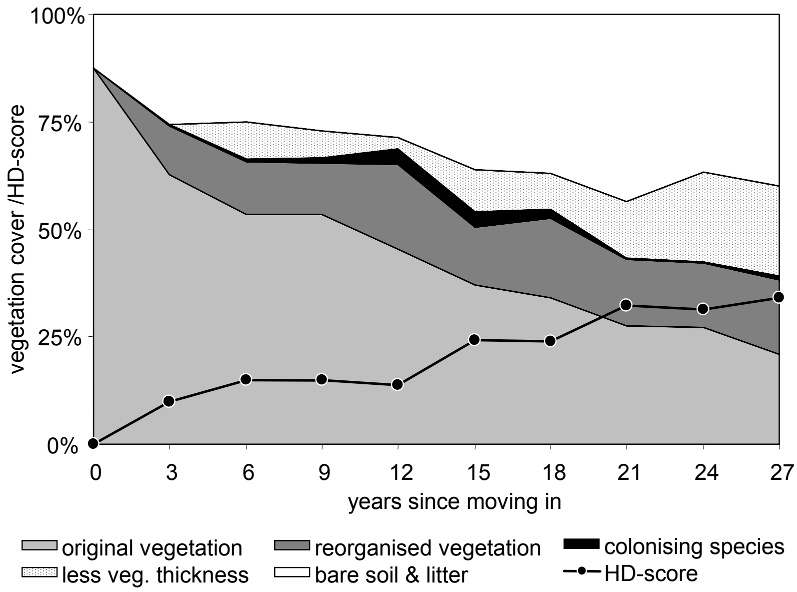

Figure 4. The development of the remnant forest field layer and corresponding HD-score, i.e. the habitat depletion development. Loss of vegetation cover is greater than the increase of bare ground due to less overlaps caused by vegetation in several layers. The share of reorganised vegetation corresponds to the percentage dissimilarity compared with that before moving in took place.

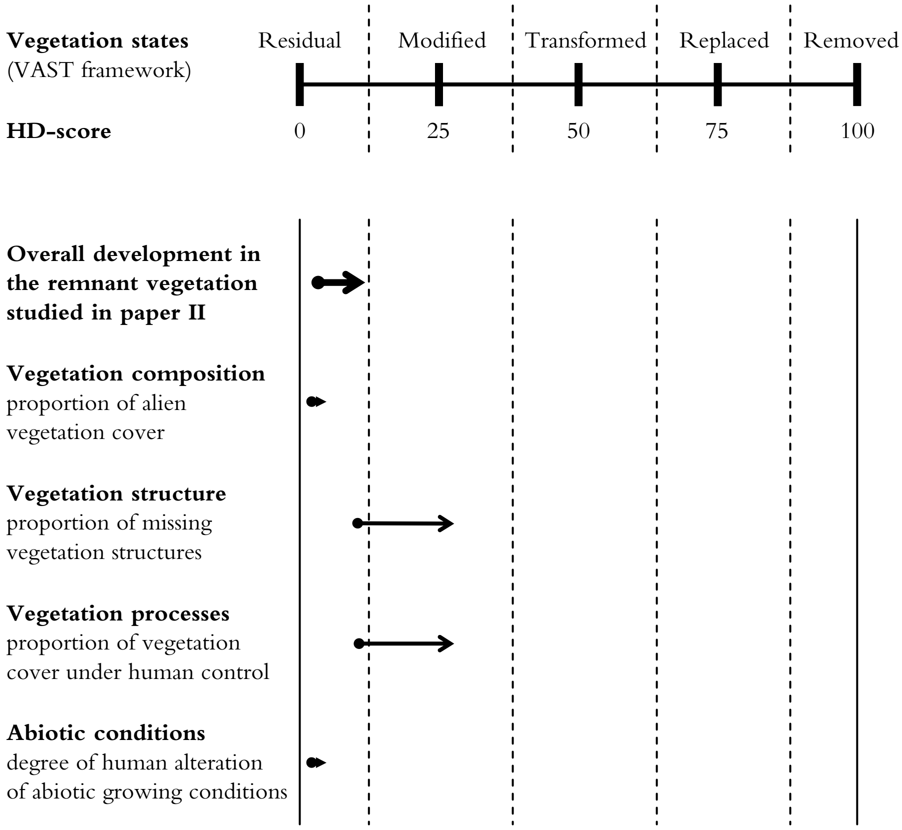

Figure 5. The interrelation of the HD-scale to the VAST framework and the four factors with their respective indicator. The VAST framework (Thackway and Lesslie 2006) anchors assessments and is also used to interpret results. The degree of human alteration increases from left to right. The arrows show the HD-score development for the remnant vegetation studied in paper II from before moving in to 27 years after settlement. The development is shown for the overall development and the development for each indicator.

6 Discussion

6.1 Recreational use

Remnant vegetation like green areas in general is a greatly sought-after environment for recreation primarily because of its restorative and physical activity-promoting influence but also on account of numerous pedagogic and other values. Taken together green space can be important in supporting public health. We have, nevertheless, seen growing concern that people, especially children, spend less time outdoors in green areas (Kardell 2003, 2008, Louv 2008). This concern is not supported by the findings presented in Paper I regarding remnant vegetation very close to where people live. However, the observed increase in recreational use in remnant vegetation close to and within built-up areas reported in paper I does not have to contradict an overall decrease in outdoor recreation. The situation may be different for other types of neighbourhoods and for larger open-air activity areas located further away from where people live. Outdoor recreation in urban remnants can be expected to differ in character from that of larger nature areas. While visits to large nature areas are in the main made with the single purpose of recreation in that environment, the main reason for visits to small remnant nature areas may often be something else, such as taking a journey shortcut. This does not however necessarily diminish the value of the 'recreation' received. On the contrary it could be considered as an advantage because you get the recreation "for free" while doing something else. Furthermore, if it is true that less time is spent on outdoor recreation the value of the "for free" recreation received in small remnant patches would thus seem to increase as would the relative importance of green areas in urban settings.

It is made clear in paper I that children's use of the studied remnant areas has changed becoming more closely tied to organised group activities (cf. Sandberg 2009). This has resulted in that the fact that children, guided by school and day nursery staff, more often use areas farther from the built-up area than they would otherwise do by themselves. In relation to management issues this development is advantageous in two respects. First, the substantial wear caused by the children should be quite easy to control through good communication between managers and school and day nursery staff. Second, the wear can be allocated over a larger area.

Recreational use might affect the remnant vegetation negatively and is, as such, in conflict with the conservation of the vegetation. Conserved vegetation is normally a condition for maintained recreational values. However, some wear and tear is probably mostly positive for the plot's recreational prospects (cf. Farrell 2001). Worn out ground is beneficial for play and walking as it is dryer. It also presents easier walking and helps path finding that in turn can mediate a feeling of security. At Järvafältet the recreational value in respect of the number of users seems not to have decreased in spite of a substantial increase of worn out ground. Contributory here might be the fact that people are there for other than recreational reasons. The tolerance of worn out ground is likely to be higher in small remnant patches than in large nature reserves as the sought-after experience and the expectations are likely to differ.

6.2 Vegetation dynamics

Papers II and III demonstrate that changes in remnant vegetation caused by the imposed built-up surroundings can vary greatly depending on vegetation properties from 'apparently not impacted at all' to 'fully replaced or worn out'. The speed and magnitude of vegetation change also depends on the intensity and type of the change's driving forces. In paper II the course of events span the period from the fast and total transformation of the lichen community (figure 2) via the curvilinear decrease of bryophytes (figure 3) to the modest, gradual and long time composition change taking place in the field layer (figure 4). Place that against the pastures studied in paper III which seem to be unaffected by the new urban surroundings. Vegetation change in the form of overgrowing is certainly taking place in the pastures but this is part of a natural succession caused by ceased grazing and not urban influence. It cannot however be ruled out that urban influence has either accelerated or delayed the succession. It is likely that tending dependent vegetation as grazed pastures will be as tending dependent after inclusion in an urban setting as they were in the rural setting. It is probably very rare that the equivalent role of a former management regime can be taken over by the strain imposed by the urban setting. To maintain the remnant vegetation in the same state tending has to be enforced in the same way as if the settings were rural.

During the first thirty years after urban inclusion wear and tear, edge effects and the existence of a changed management regime can be expected to be the most important drivers of change (cf. Florgård 2000, Hamberg 2009, Malmivaara-Lämsä 2008). In the longer run other drivers such as fragmentation effects, changed local climatic conditions and pollution levels might also become important. Based on the significant part of the ground that was worn out at Järvafältet wear and tear can be assumed to be the major driver of change there. Figure 6 exhibits the general influence scheme of wear and tear on remnant vegetation. The scheme is developed to demonstrate alternative outcomes of wear but can be transferred to pertain to any changed condition affecting any vegetation. The interaction process is divided into three stages corresponding to the *alpha, beta* and *gamma* processes of animal/plant interactions described by Liddle (1984). The process can stop at any stage and the earlier it stops the less the impact of wear. The three outcomes resulting in a preserved vegetation state; no contact, resistance and recovery, can be considered as three different strategies for plants to cope with wear.

The first stage, 'contact/no contact' is hardly studied. The attractiveness and repellence of different vegetation types and plants matters (Bjerke *et al.* 2006, Dumont *et al.* 2005, Roovers *et al.* 2006) but the importance of this factor in terms of wear is unknown. Growth place is also likely to matter. It has been shown that structural elements can act as barriers against wear creating less worn pockets of vegetation (Lehvävirta 1999).

The complete wearing out of fruticose lichens on bedrock within the first year of wear at Järvafältet (figure 2) supports a conclusion implying an all-covering wear but it is likely that rock outcrops receive another amount and/or kind of wear, e.g. the climbing and sliding opportunities offered by rock outcrops is likely to attract children's play more than level ground. It might even be possible that it was the play with the fruticose lichens that was attractive and when there was no lichens left the wear was reduced. The geographical situation of the remnant patch, i.e. surrounding districts, neighbouring attractions, communication routes, visitor entrances etc. and their relations is otherwise decisive for the amount and distribution of wear.

The second stage, the resistance during contact, is quite well studied in trampling experiments (Liddle 1997). Damage can be lethal or imply the loss of tissue, changed form or changed growth rate and fitness. It has been suggested that grasses will replace species more intolerant to trampling in worn areas because of high wear resistance among grasses (Kellomäki and Saastamoinen 1975) but such a general effect has not been found in the studied vegetation and neither in the remnant vegetation in the greater Helsinki area in Finland (Hamberg *et al.* 2008, Malmivaara *et al.* 2002). It has been found though on very thin soils on bedrock and along path edges (Florgård 2000, Hamberg *et al.* 2008).

Recovery through re-growth has been suggested as being more important for vegetation resilience than resistance particularly in respect of long term trampling disturbances (Cole 1995, Malmivaara-Lämsä *et al.* 2008b). This is supported by the findings of paper II. Damage can nevertheless facilitate colonisation, (cf. the intermediate disturbance hypothesis in Roxburgh *et al.* 2004). The lichen succession taking place on bedrock involving an almost full replacement of the vegetation demonstrates the potential for colonisation if the conditions are right. On the other hand colonisation can be seen as playing only a minor role in the field layer at Järvafältet because the share of new species in the investigation plots was low and true ruderal species, the real specialists on colonisation, were scarce. This condition contributes to modest composition changes in the field layer along with the formation of bare ground. A prerequisite for recovery and colonisation to take place is that there is enough time between the disturbances. If the disturbance frequency is high the only available vegetation strategy will be resistance otherwise the result will be bare ground. The wear and tear leading to bare ground is also the most important consequence of the urbanisation of the remnant vegetation studied.

The formation of bare ground and changes in vegetation composition has repercussions on the allocation of future wear and tear, e.g. the formation of paths has a guiding effect on future wear (Dumont *et al.* 2005). The importance of this effect for the overall vegetation development is however poorly known.

The scheme in figure 6 addresses damage caused by direct contact but wear can influence vegetation in two additional ways. Firstly by causing changed abiotic conditions e.g. path edge effects and soil conditions (Hamberg *et al.* 2008 and 2009a, Malmivaara-Lämsä and Fritze 2003, Malmivaara-Lämsä *et al.* 2003), and secondly by facilitating the dispersal of vegetation (Benninger-Truax *et al.*1992, Hamberg *et al.* 2010). The effect of direct damage and dispersal depends to a large extent on the distribution of the wear in time and space. This distribution might go through drastic changes and depend on random events such as the opening or closing of a day nursery or to where the day nursery chose to make a day trip. On the contrary, changed abiotic conditions or for that matter most other urbanisation effects apart from those connected to the wear can be seen to be quite constant or to show only slow change rates, e.g. the heat island effect. The different characters of the change drivers will thus have different effects on the vegetation dynamics. The partly episodic character of wear can give vegetation the time and opportunity to recover unlike the more constant and lasting effect of e.g. a new forest edge, although edge effects may also vary with edge properties (Hamberg *et al.* 2009b).

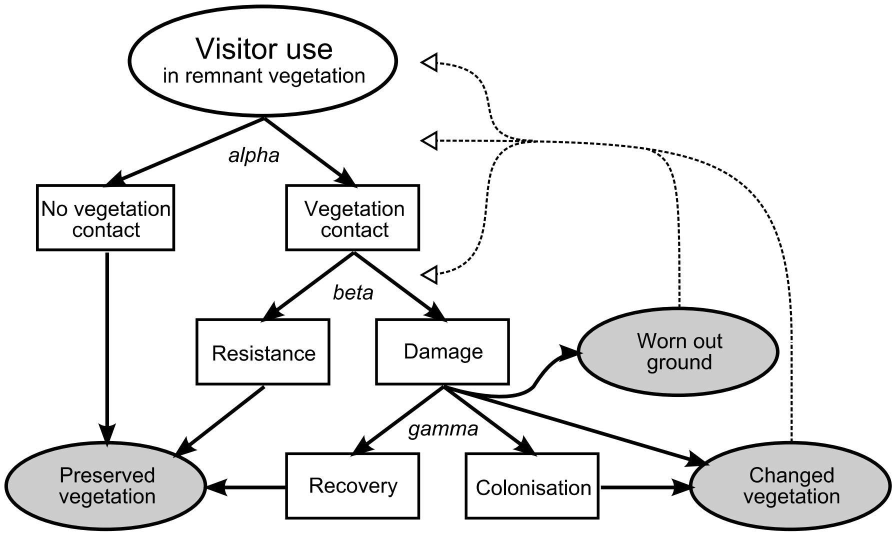

Figure 6. A general scheme for the direct vegetation outcome of visitor use in patches of remnant vegetation. The three stages of interaction correspond to the *alpha*, *beta* and *gamma* processes of animal/plant interactions described by Liddle (1984). Ends implying worn out ground or vegetation change will have repercussions (dashed lines) on future wear and tear and can also indirectly affect preserved vegetation through e.g. changed micro climate and changed soil conditions.

6.3 Conservation assessment

The most important feat during the development of the HD-tool presented in paper IV was the incorporation of the common scale based on the VAST framework developed by Thackway and Lesslie (2006). It made the tool design transparent and together with the use of the four factors, three representing the primal attributes of biodiversity given by Noss (1990) and one constituting the basic prerequisite for biodiversity; the abiotic conditions, it makes up the gist of the HD-tool. While the VAST-based scale greatly helps facilitate communication the use of the four factors helps facilitate another important aspect of this kind of tool; the educational aspect. An effect which includes raising the level of knowledge among designers and managers coupled with the instructiveness of the indicators greatly enhances the chance of the tool having an increased impact on everyday activities. If a tool is to make any real difference it has to be widely used. Therefore user-friendliness is in many cases more important than absolute accuracy in these kinds of tools.

The generally applicable design of the HD-tool makes assessments in different environments, scales and situations possible. Although the HD-tool is primarily designed to be able to distinguish between the broad spanning environments present in urban situations it well also depicts the overall depletion development taking place in the remnant vegetation studied in paper II. Figures 2-5 show that the loss of vegetation due to wear and tear is much decisive for the depletion occurring in the remnant vegetation studied. The influence of the compositional changes on the HD-score is low because the share of immigrating species is low and due to the fact that the reorganisation of naturally present species does not affect the HD-score. The part of the ground that is worn out on the other hand is assessed to be completely depleted except for the abiotic condition factor that is only slightly modified. To sum up, although the significant increase of worn out ground the overall habitat depletion is within limits as displayed in figure 5.

The HD-tool focuses on environmental loadings as it assesses the locally inflicted strain on biodiversity but remnant vegetation can also have special conservation qualities. The greater share of deciduous trees especially *Sorbus aucuparia* (Hamberg *et al.* 2009c, Lehvaävirta and Rita 2002) and more open forests, are examples of general qualities provided in the remnant forests that in the Nordic countries have decreased to alarmingly low levels in rural boreal forests due to commercial forestry. Qualities are however best assessed on the basis of larger contexts. Therefore, and because spatial relations in scales larger than normal property sizes are of fundamental importance, complementary tools taking larger scale considerations are needed as well.

6.4 Future perspectives

The research presented and referred to renders possible reasonable predictions of the patterns of vegetation development in studied vegetation types for the first thirty years after urbanisation. Ideas about the driving forces behind predicted changes also exist but the knowledge and understanding of underlying vegetation processes remains at an insufficient level. A promising prospect would be to try to quantify the relative importance of the processes and strategies represented by the boxes in figure 6. In order to do so however a better understanding of recreational use is needed, above all the within patch distribution of wear in both time and space. The importance of observed vegetation changes for different remnant vegetation values is another area in need of further investigation. For any of these study areas to be meaningful however the implications need to reach city planners and remnant vegetation managers, and preferably in a way that sees them built into deployable and easy-to-use tools such as the HD-tool discussed in the context of paper IV.

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